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Contents

Editorial

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The next few months are going to be a busy time for GLOBEC, with the Coping with Global Change and Eastern Boundary Upwelling Ecosystems symposia being held in the summer, and the GLOBEC SSC meeting at the IGBP Congress in May. Thank you for all of you who have submitted abstracts to the symposia, we have received a tremendous response to both events and are very much looking forward to what promises to be two very exciting meetings. I am also pleased to announce that dates have been set for the 3rd GLOBEC Open Science meeting, which will be held at the Victoria Conference Centre, British Columbia, Canada on 22-26 June 2009. For those of you who were at the ESSAS symposium, you will remember that this is a superb venue and I hope that many of you will be able to attend.

It's all change again in the GLOBEC IPO, we would like to wish Lotty Dunbar well for her maternity leave. Lotty will be away from the IPO for a year from the beginning of April but will be back with us again in time for the OSM next year. We have been very lucky to find Alice Archer and would like to welcome her to the GLOBEC IPO in Lotty's abscence.

I look forward to seeing many of you at the forthcoming GLOBEC meetings and hope you enjoy the latest issue of the GLOBEC International Newsletter.

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

IMBER-GLOBEC establish Transition Task Team

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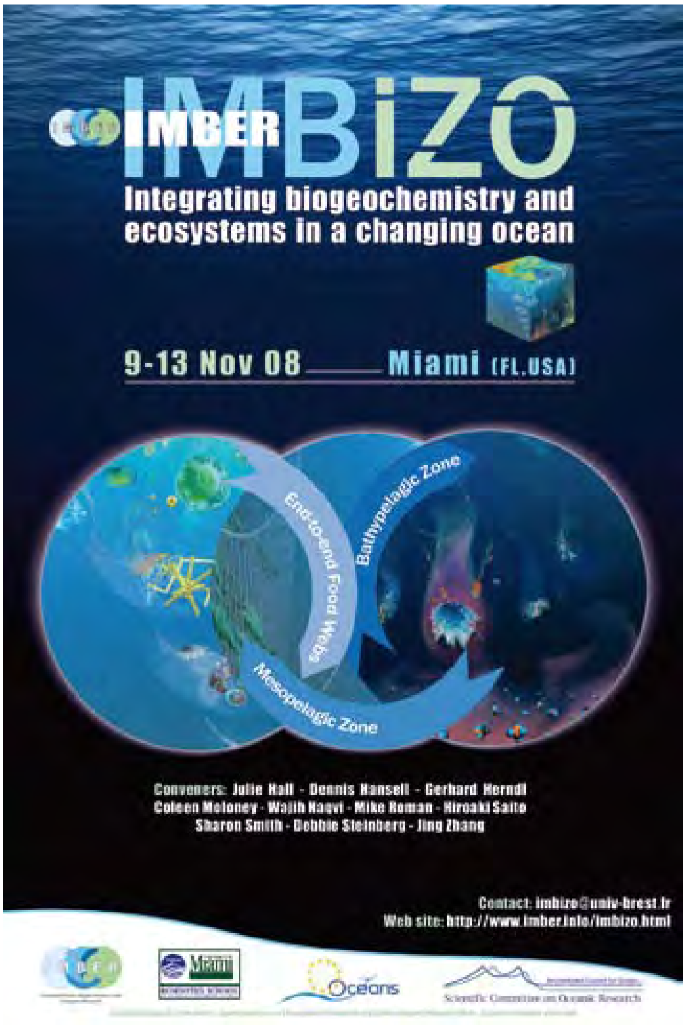
The two ocean projects of IGBP/SCOR (GLOBEC and IMBER) each have full 10 year lifetimes. The second 5 years of GLOBEC overlap IMBER's initial 5 years. As such they are complementary, enabling continued, internationally coordinated studies of oceanic and marine systems for 15 years. The Global Ocean Ecosystem Dynamics (GLOBEC) programme (1999-2009) focuses on physical-biological interactions in the ocean, particularly for upper trophic levels. The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) programme, which focuses on the integration of biogeochemical cycles and ecosystems, began in 2004 and will run to 2014.

The sponsors of both GLOBEC and IMBER (IGBP and SCOR) have agreed that preparations should be made for a single ocean research project in the IGBP structure after 2009. The IMBER Science Plan and Implementation Strategy was written with a 10 year lifetime and may need amplification in response to new scientific developments. Therefore, the programmes and their sponsors agreed that a Transition Task Team (TTT) should prepare a supplement to the IMBER Science Plan and Implementation Strategy, to define the additional science to be tackled by IMBER beyond the conclusion of GLOBEC.



There will be an increasing emphasis on integrating activities starting in 2008. The IGBP-SCOR Ocean Vision (Lochte *et al.*, 2003; http://www.igbp.net/obe/FW-Final-2002.pdf) will serve as a scientific guide to help facilitate the evolution of GLOBEC and IMBER towards a single integrated project, and to identify important scientific interactions between IMBER, GLOBEC, and the interface projects SOLAS and LOICZ. This will help place all IGBP-SCOR ocean projects in the new IGBP Earth System Science context.

In preparing this supplement to the IMBER Science Plan and Implementation Strategy the Transition Task Team will consider:

- New developments in marine ecosystem science,
- Key new scientific questions arising from GLOBEC,
- Scientific results of IMBER to date,
- Projects currently within GLOBEC that are planned to continue after 2009.

The Transition Task Team may include recommendations for mechanisms to facilitate the transition, including representation in programmatic structures.

The timetable for this activity is:

30 July - 1 August 2008:	First meeting of the TTT
September 2008:	Report on activities to IGBP and SCOR Officers
October/ November 2008:	Second meeting of the TTT with input from the Executive Committees
January/ February 2009:	Posting of a draft on the programme's websites and broad invitation for public comment
May 2009:	Presentation and discussion at the GLOBEC 3rd Open Science Meeting
October 2009:	Discussion/approval by the IGBP and SCOR Officers

The IMBER/GLOBEC Transition Task Team was appointed jointly by SCOR and IGBP, and its membership based on scientific and programmatic representation is:

John Field (Chair)	Food web dynamics
Eileen Hofmann	Modelling
Kathleen Miller	Human dimensions
Olivier Maury	Upper trophic levels
Roger Harris	Middle trophic levels
Mike Roman	Lower trophic levels
Hugh Ducklow	Biogeochemistry
Ken Drinkwater	Climate dynamics
Qisheng Tang	Marine resources

Reference

Lochte K., W. Broadgate and E. Urban. 2003. Ocean biogeochemistry and biology: a vision for the next decade of global change research. Global Change Newsletter 56: 19-23.

Reconciling concepts in biological oceanography

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The inherent complexities in the structure and dynamics of marine food webs has led to two major simplifying concepts – *species centric*, focusing on physical processes affecting particular pelagic species, including the early life stages of fish – and *trophic-centric*, emphasising energy flow through broad functional groups, from nutrient input to fish production. These two concepts are complementary. Together they embrace most food web processes and answer different questions. They can describe features of spatial distribution of individual species, and of food web structure, especially those relevant to fish communities. But they cannot provide general explanations for the factors determining changes in abundance of individual marine species. Nor can they resolve the practical problems in managing fish stocks in an ecosystem-based context. These issues remain central theoretical and practical challenges for biological oceanography and for the GLOBEC syntheses.

Introduction

The close linkage between physical and biological processes is a major factor and a dominant theme in the GLOBEC programme. These interactions depend on a wide range of physical dynamics and biological responses but we can categorise them by assuming that the physical processes operate in two different ways – directly on individual organisms, and indirectly through food-chain interactions at the community scale. Analysis of the former has been very successful in providing detailed illustrations of spatial dynamics of plankton and fish larvae. However the use of detailed simulations of the spatial dynamics requires some limitation on the biology and leads de Young *et al.* (2004) to say that "rather than model the entire ecosystem we should focus on key target species and develop species-centric models". The power of this approach is apparent in recent GLOBEC publications dealing with physically complex shelf ecosystems (Wiebe *et al.*, 2001). The constraints follow from the focus on spatially detailed models for individual species.

The overall productivity of marine populations results from physical processes that determine nutrient fluxes and primary production. These processes determine yields of fish and other predators that depend on benthic as well as pelagic sources of food. The problems in developing an end-to-end trophically vertical approach lie with the large range in time scales as well as in the complicated food web interactions. Usually the upper and lower trophic levels are treated separately. The microbial web in the open ocean has been studied intensively in the JGOFS programme (Buesseler, 2001) where export is defined as downwards transport out of the euphotic zone or trophic transport upwards. For the upper trophic levels, emphasis is on predatory and competitive interactions (Christensen and Pauly, 1993; Heath, 2005). To encompass these complicated interactions, linear, steady-state, food web models have been used. This trophic-centric approach does not deal with the dynamics of individual species.

The former "horizontal" approach emphasises the processes that link individual species or single trophic guilds directly to their physical environment, and benefits from advances in modelling the physical dynamics of shelf regions with complex topography – such as Georges Bank and the North Sea. The latter "vertical" method focuses on the flux of nutrients from inorganic states to the upper levels in the food web and uses complicated optimisations with large matrix inversions to resolve fluxes in linear steady state systems (Vezina and Platt, 1988). The issue here is how far these methods, jointly, can illuminate some of the central problems in marine ecosystems. Each approach involves trade-offs. The former has complex physical processes and relatively simple population dynamics; the latter combines complicated food webs with linear steady state descriptions of processes. We argue that there are no contradictions between these two sets of simplifying assumptions. They are complementary or "orthogonal", and answer different questions. The problem is whether, together, they encompass the major issues and problems in biological oceanography.

As a case study of these issues we review briefly recent GLOBEC work on Georges Bank based on these alternative approaches; we consider the available theoretical concepts to unite them; and we relate the results to issues in climate change and fisheries management.

Georges Bank: a case study

Recent GLOBEC work on the Georges Bank ecosystem has focused on the growth and survival of larval cod and haddock in relation to the circulation around the Bank (Werner *et al.*, 1996), and to the supply of calanoid copepods as food (Lynch *et al.*, 2001). The circulation takes the larvae from spawning sites to potentially rich food on the southern flank of the Bank (Fig. 1).

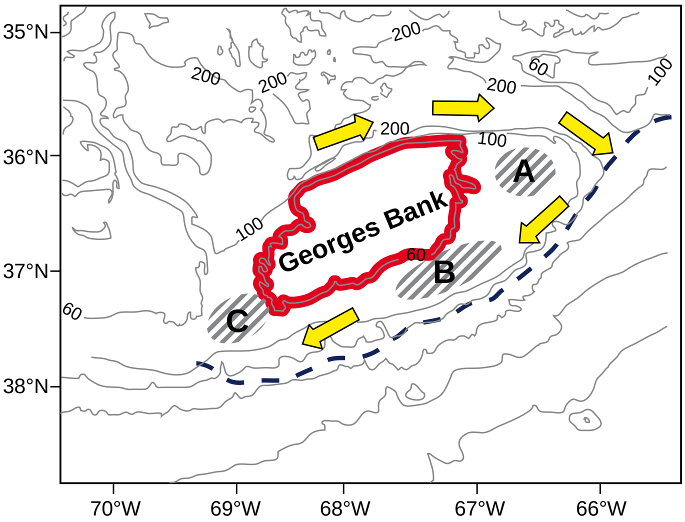

Figure 1. Georges Bank in the northwest Atlantic showing the approximate location of A, eggs; B, larvae; and C, pelagic juveniles of cod and haddock in response to circulation between the tidal (red line) and shelf edge (dashed line) fronts. Adapted from Lough and Manning (2001).

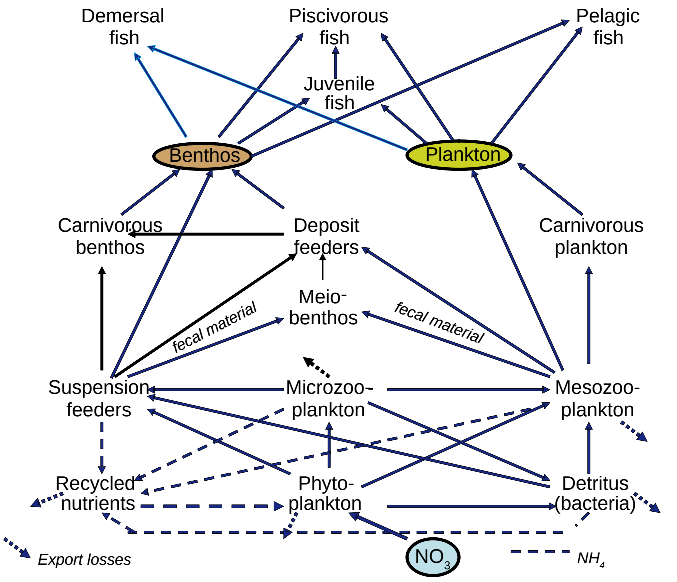

Figure 2. Georges Bank food web showing the components used in Steele et al (2007). Solid arrows represent fluxes. The input NO_3 drives the microbial food web including recycling of nitrogen as NH_4 (dashed lines). Dotted lines are physical losses. Benthos and plankton ovals are the integrated outputs to the fish community.

Larval growth rates are correlated with copepod abundance, particularly *Pseudocalanus* spp. (Buckley and Durbin, 2006) for the years 1995-1999, but not with successful recruitment to the adult stocks of cod or haddock. These studies demonstrate the way that larval marine organisms depend on and adapt to the regularities in their physical environment, but the complexities in such processes and their probable inter-annual variability explains why very few environment–recruitment correlations survive re-examination (Myers, 1998). The only exceptions are for populations at the latitudinal extremes of their range (Drinkwater, 2005).

The alternative approach quantifies fluxes of energy, nutrients or carbon through the whole of the food web. For Georges Bank there were seminal studies by Sissenwine and colleagues (Cohen *et al.*, 1982; Sissenwine *et al.*, 1984). More recently Steele *et al.*, (2007) combined detailed analyses of the microbial food web with data on the fish community and their diet. The starting point (Fig. 2) was provided by data on new production, estimated from the uptake of NO_3 (Bisagni, 2003) that led to estimates of planktonic and benthic production based on GLOBEC data for the years 1995-1999 (Wiebe *et al.*, 2001). The fish and fish diet data (Garrison and Link, 2000) were used to estimate food requirements in terms of plankton and benthos consumption, assuming that the piscivores ate juvenile fish that are predominantly plankton eaters (Steele *et al.*, 2007). A reasonable match with the output from the microbial web was obtained for the corresponding decade 1993-2002, and for the preceding two decades 1973-1992. But for the first decade of available fish abundance data, 1963-1972, estimates of benthos and plankton production from the later decades were approximately twice the requirements of the fish community. This is explained (Steele *et al.*, 2007) by a greatly reduced flux of nutrients onto the Bank, evident in the decreased NO_3 concentration of the Labrador Sea source water during this decade (Petrie and Yeats, 2000). Thus a critical physical constraint on new primary production determines the total abundance of the adult fish stocks but does not define the species composition.

The problems in reconciling these two approaches are illustrated with data on the abundance and food consumption of the fish community. There are marked changes in the structure of this community over four decades (Steele *et al.*, 2007) with a succession of dominant species (Fig. 3a). Aggregation into feeding guilds (Garrison and Link, 2000) shows major shifts in these categories (Fig. 3b), but further analysis in terms of plankton and benthos consumption (Fig. 3c) gives a simpler representation of the overall food web relations. The changes in species abundance can also be presented as diversity indices; specifically as evenness (Fig. 4a), or as percent that the dominant species contributes to the total biomass (Fig. 4b). The decade of decreased dominance, 1966-1975, corresponds to the period of extreme over-fishing (Fig. 4c) before the extension of US national jurisdiction in 1976. This decade overlaps a period of low fish production, 1963-1972 (Fig. 3c) due to decreased nutrient supply (Steele *et al.*, 2007). Thus two very different factors, over-fishing and environmental change, contributed to the excess of catch over production for the fish community on Georges Bank (Fig. 4c). At the same time, however, there was a gradual decrease (Fig. 4d) in the benthic fraction of the total food consumption (plankton plus benthos, see Fig. 3c) by the fish community. This can be attributed to destruction of benthic habitat by excessive trawling and dredging (Hermsen *et al.*, 2003; NRC, 2002) but might also be linked to the changes in productivity.

These time series (Figs. 3 and 4) demonstrate links between the external stresses on the whole system - nutrient supply and fishery removal; and internal features of the ecosystem - changes in plankton and benthos production and in fish diversity. Studies

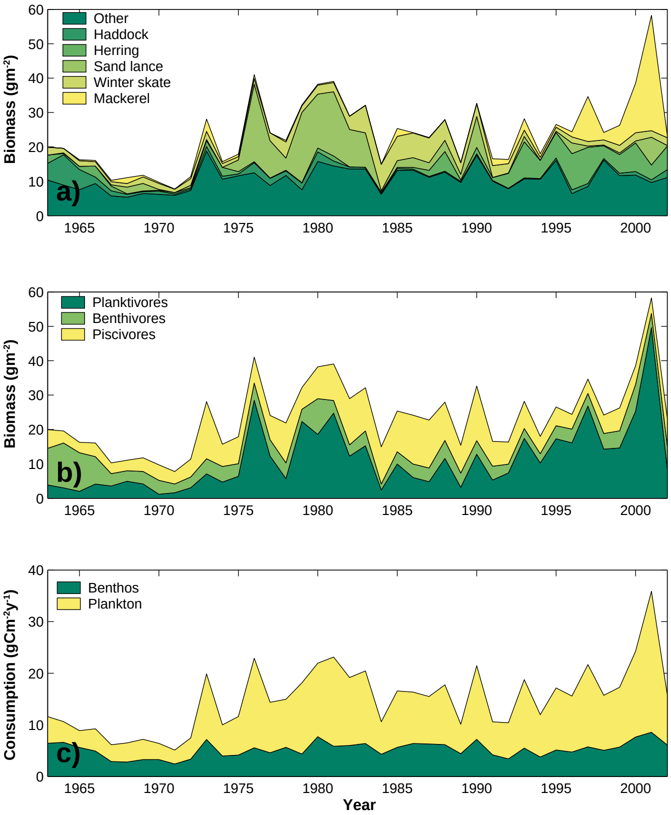

Figure 3. (a) Cumulative biomass of fish community on Georges Bank giving the 5 species with highest biomass. (b) Biomass contributed by three feeding guilds. (c) Calculated total food requirement of fish on Georges Bank supplied by plankton and benthos.

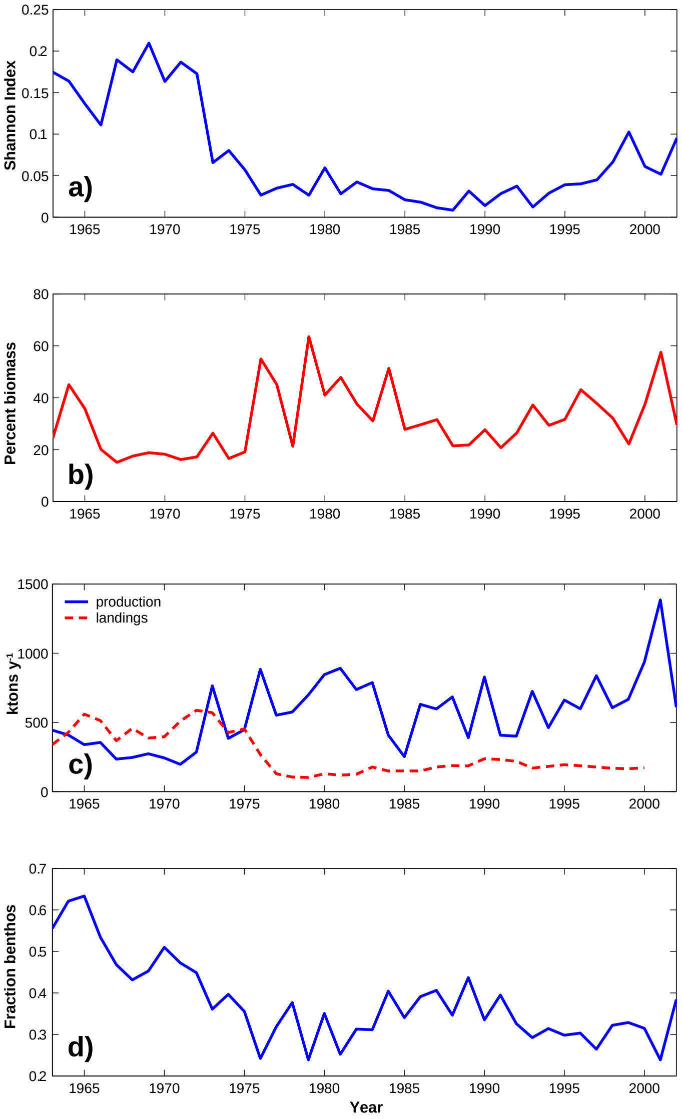

Figure 4. (a) The Shannon evenness index (Magurran, 1988), (b) percentage of total biomass contributed by the dominant species, and (c) calculated total food requirement of fish on Georges Bank compared with commercial fish catch (Hennemuth and Rockwell, 1987; M. Fogarty pers.comm.). (d) Food intake from benthos as fraction of total (benthos plus plankton).

of larval cod and haddock dynamics, combined with budgets for energy flow through the food web, can illuminate the general processes underlying these patterns but are not able to explain the particular sequence of dominants in Figure 3a, nor the changes in proportion of benthos in Figure 4d.

Analysis

In principle, the "vertical" and "horizontal" approaches can be combined in comprehensive ecosystem models (e.g. ERSEM, Baretta *et al.*, 1995). However, very large simulation models combining complex physical processes with a large number of interacting populations, are not useful (de Young *et al.*, 2004), even when technically possible. We need to simplify some component of these coupled physical-biological systems. The Georges Bank studies epitomise general distinctions between approaches with different simplifying assumptions and trade-offs that can be categorised as species-centric and trophic-centric (Table 1).

Table 1. Species-centric vs. trophic-centric approach

Species-centric approach	Trophic-centric approach
Assumptions	
Critical physics: direct action on planktonic individuals such as copepods or fish larvae	*Critical physics:* indirect effects through processes of nutrient supply for new production
Critical ecology: population dynamics at critical life stages such as copepod diapause	*Critical ecology:* energetics of trophic groups and fluxes between groups
Trade-offs	
Physical complexity: detailed dynamics for regions with complex topography	*Trophic complexity:* food webs containing many groups from microbes to fish
Trophic simplicity: spatial demography of one species or one life stage	*Physical simplicity:* linear steady states averaged over time and space

These two approaches make different judgments about the underlying interest or significance of certain aspects of marine systems. The former focuses on individual species, especially at higher trophic levels (de Young *et al.*, 2004). For fish species there is the general assumption that "recruitment" processes in the larval phase determine year class strength (Rothschild, 1986). Whereas the latter approach emphasises the constraints imposed on large trophic groups of species by overall food supply and, implicitly, assumes that the abundance of adults is the significant component.

The two approaches are not unconnected. For Georges Bank a critical factor for individual fish larvae is the residence time of upper layers of water on the bank (Werner *et al.*, 1996). This residence time determines, in turn, the influx of deeper nutrient rich water that fuels the overall production (Steele *et al.*, 2007). For fish population dynamics, a major unknown factor is the mortality pattern of juveniles (Houde, 1996). This is a problem both for the links between larval and adult numbers for individual species (Rothschild, 1986); and for the calculation of total food requirement of fish communities (Sissenwine *et al.*, 1984; Steele *et al.*, 2007; Heath, 2007).

These approaches are sufficiently distinct to be regarded as two separate hypotheses about critical factors for marine communities – one related to their species composition; the other to their abundance. The former focuses on inter-annual variability of larval survival as the critical population factor; the latter considers the adult food requirements of communities as the main constraint. One approach attempts to determine the causes of inter-annual variability of individual species; the other stresses the probable causes of decadal changes in production and diversity. There is no reason why both may not operate together as constraints on individual populations and on communities. Our interest, as consumers, is in the maintenance of individual species at some appropriate level of abundance; and as ecologists in the sustainability of communities. How far can these two sets of assumptions and methodologies (Table 1) meet these interests?

Discussion

The species-centric and trophic-centric dichotomy depends more on our analytic capabilities than on the actual complexity of organism responses to the physical environment. These concepts can be linked together in certain general measures of ecosystem structure. Abundance can be expressed as function of trophic structure (Pauly *et al.*, 1998); or of organism size (Jennings *et al.*, 2002); or in theories of diversity (Hubbell, 1997). These measures may be valuable indices of stress on the food web but they do not describe effects on individual species. The indices in Figure 4 indicate the resilience of the fish community to the removal of stress from excessive fishing and low productivity. They do not prescribe which species benefit.

The horizontal approach tackles the problem of identifying those factors that are responsible for the great inter-annual variability observed in particular fish stocks such as cod or haddock. When we look at time series of species dominance from the vertical perspective, we assume that species diversity ensures that the available productivity is fully utilised. Then the species that compose these functions may be assigned by "lottery" events (Sale, 1977), arising from inter-annual physical variability in the processes described by the GLOBEC studies (Wiebe *et al.*, 2001). In this approach, species diversity is insurance against stochastic processes that redistribute species randomly (Yachi and Loreau, 1999). Lehman and Tilman (2000) attempted to resolve the long-standing diversity/stability debate by proposing that "diversity increases (temporal) stability at the community level but decreases stability at the population level". The Tilman concept (Tilman, 1999) supports the minimalist theory of biodiversity, that "the inter-specific dynamics of ecological communities is a stochastic zero-sum game" Hubbell (1997). In our case, for Georges Bank, the zero-sum is determined by the plankton-plus-benthos food supply.

This resolution of certain concepts inherent in the diversity/productivity/stability debate (Ives and Carpenter, 2007) does not attempt to answer questions about changes in abundance of individual species, questions that are central to the management of commercial fish stocks. As an example, the decrease in fishing effort and increase in productivity on Georges Bank around 1975, was followed by an outburst of the small planktivore sand lance, and then by a marked increase in the piscivore winter skate (Fig. 3a). These events are linked by evidence that the former was a major component in the food of the latter, forming 47% to 66% of the diet (Link, 2007). In contrast, sand lance was 5% in the diet of cod in the same period (Link and Garrison, 2002) and negligible in other non-commercial piscivores (Link, 2007). This congruence strongly suggests that the dominance of winter skate for the decade 1981-1990 depended on adult feeding behaviour as well as larval survival. It is *a priori* reasonable to expect that independent processes in the larval, juvenile, and adult phase together determine success at the population level. To this extent the divergence in our methods of data gathering, and of model building, between the early physically dominated pelagic life and the later community based phase, may reflect distinct ecological options at different parts of the life cycle of individual species (Houde, 1996.).

Thus, the species-centric approach can explain some of the factors determining inter-annual variability in recruitment of individual species (Lynch *et al.*, 2001). The trophic-centric analysis can determine abundance of, say, piscivores under steady state scenarios. But we cannot predict the processes necessary and sufficient for a transition from present conditions to scenarios with adequate quantities of desirable fish species. These questions fall between the two simplifying concepts, horizontal complexity and vertical complication, in the sense that answers to them would require integration of species interactions and community dynamics. We need to search for such syntheses, but, in the meantime, we need to accept the limitations on any comprehensive description of marine ecosystems, their complicated structure, and complex dynamics.

Implications for ecosystem-based management (EBM)

At present the main thrust in management is towards an ecosystem approach to conservation and to fisheries. The former is concerned with broad community measures such as diversity and resilience (Levin and Lubchenko, 2008); the latter with a "commercial" subset of fish stocks. A central problem is how to put the fisheries interests in particular species within an ecosystem context. This is comparable with and related to the species-centric and tropho-centric dichotomy

The former approach appears to provide "a necessary but not a sufficient condition for production of a strong year class" (Buckley and Durbin, 2006). A review by Heath (1992) states that "taking the wide range of published data on larval dispersal, growth and mortality as a whole, it is hard to accept that the spatial integrity of populations dominates over food chain processes, or vice versa". Myers (1998) considers that "the proportion of environment-recruitment correlations that have been verified upon re-test is low". The exceptions tend to be "those populations at the limit of the species' geographic range". Thus fisheries managers still rely on pre-recruit surveys of juveniles or average stock-recruit relations for short- term predictions of individual stocks.

Indices of ecosystem structure are generally based on some integrating measure; diversity (Hubbell 1997), mean trophic level (Pauly *et al.*, 1998), size distribution (Jennings and Dulvy, 2005). The general conclusion is that "while community metrics do provide good long term indicators of changes in fish community structure, they are unlikely to provide an appropriate tool to support short term management decisions" (Nicholson and Jennings, 2004).

These conclusions match the distinctions made between the species- and trophic-centric concepts. The two management aims, optimal yields from individual stocks and stability or resilience of communities, are complementary rather than conflicting. For a range of management options, the former can provide short-term forecasts for specific stocks; the latter can give projections of longer term community structure and overall production.

Proponents of EBM stress that "at the core of EBM is the fundamental importance of factors that drive human behaviour" (Ruckelhaus *et al.*, 2008). The same theme dominates fisheries management; expressed as the "failure to enforce unpalatable but necessary reductions in fishing effort on fishing fleets and communities" (Beddington *et al.*, 2007). Such necessary management measures are likely to benefit both the commercial stocks as well as their ecosystems.

Acknowledgements

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The beginning of a new trans-Arctic interchange?

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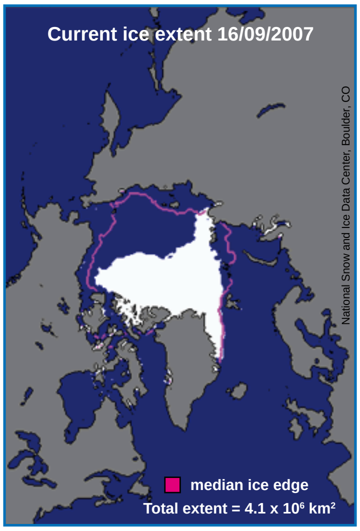

Figure 1. Record minimum Arctic ice extent reached on 16 September 2007 at 4.13 square kilometres. See http://nsidc.org/news/press/2007_seaiceminimum/20070810_index.html. Figure courtesy of the National Snow and Ice Data Center.

The thickness and areal coverage of ice in the Arctic have been melting at an increasingly rapid rate over the last two decades to reach the lowest ever recorded extent in September 2007 (Fig. 1). In this month, between the Bering Strait and the Labrador Sea, immediately to the north of Alaska and Canada, ice was virtually completely absent. A similar extensive area of clear water between the two oceans first occurred in 1998, possibly for the first time in thousands of years. Following this event the Northwest Passage closed up again until last summer. In the spring following the ice free period in 1988 large numbers of a Pacific diatom *Neodenticula seminae* were found in samples taken by the Continuous Plankton Recorder (CPR) in the Northwest North Atlantic. The first identifications were made in samples from the central Irminger Sea to the south of Greenland, but their significance was initially not recognised. The uniqueness of the event became apparent when the samples were compared to others taken over the last 40 years in the same area by the CPR team and when colleagues in Canada noted its presence in large numbers in the Gulf of St Lawrence in 2001. The realisation dawned that this was the first time in 800,000 years that the diatom had occurred in the North Atlantic. The discovery was reported in the September edition of Global Change Biology (Reid *et al.*, 2007) and was followed by a commentary in Nature Reports: Climate Change, volume 6, November 2007 (www.nature.com/reports/climatechange).

Neodenticula is an abundant member of the phytoplankton in the subpolar North Pacific where it is important in the ocean cycling of carbon. Because it grows in long chains it is well sampled by the CPR. In 1999 it was already familiar to the analysts who identify and count the plankton on the CPR sampling silks as a pilot tow for a survey in the North Pacific had been analysed in 1997. The results from the CPR were backed up by independent observations from international colleagues from the Institut Maurice-Lamontagne, Canada (M. Starr), the Canadian Museum of Nature (M. Poulin) and Uppsala University, Sweden (P Snoeijs). Since 1999 the species has remained common in the western basin of the subpolar gyre with outliers ranging further afield and extending down to off New York in 2007 (Fig. 2).

How had the species suddenly appeared and where had it come from? Because of the open ocean location of the first records ballast water exchange was discounted as a source. Instead it was hypothesized that this new species had been introduced as a consequence of the first recorded major melting and retreat of sea ice from the whole coast of Alaska and Canada. This left a large area free of ice during the summer for the dominant easterly wind to move water through from the Pacific to the Atlantic. The long summer days would also have ensured that the diatom cells continued to grow during transit. The hypothesis is backed up by modelling results and by evidence from hydrographic measurements in 1998/9 that confirmed the largest volume of Pacific water on record in the northwest Atlantic at that time.

Based on records from deep sea cores *N. seminae* has a well defined palaeo history. In the Pacific the species has been common since it first appeared ~3 Ma years ago showing maximum numbers in core sections laid down in interglacial periods. Evidence for the frequency and intensity of glacial/interglacial periods in the cores is based on measurements of the ratio of two different oxygen isotopes in the calcareous 'skeleton' of single celled planktonic foraminifera. In the northern North Atlantic the species is also characteristic of interglacial periods and had a wide distribution first appearing in cores at ~1.2 Ma and becoming locally extinct at ~0.8 Ma. This extinction occurred just after the first major glaciation in the northern hemisphere, around 0.9 Ma (the early-middle Pleistocene transition) when ice sheets spread beyond the Arctic and outside mountains. At this time in history intensified and continued cooling took place, sea levels lowered and ice extended to cover the whole of the Arctic Ocean throughout the year cutting any surface link between the Pacific and North Atlantic. The disappearance of *N. seminae* coincided with many other similar events in the terrestrial and marine realm (Head and Gibbard, 2005).

Flow of water between the Pacific and North Atlantic is also dependent on sea level. The land bridge that connected Asia and North America across what is now the Bering Strait was first breached by the sea in the late Miocene to early Pliocene (circa 4.8 to 7.4 Ma), but it was not until later in the Pliocene at ~3.5 Ma that Pacific organisms first invaded the North

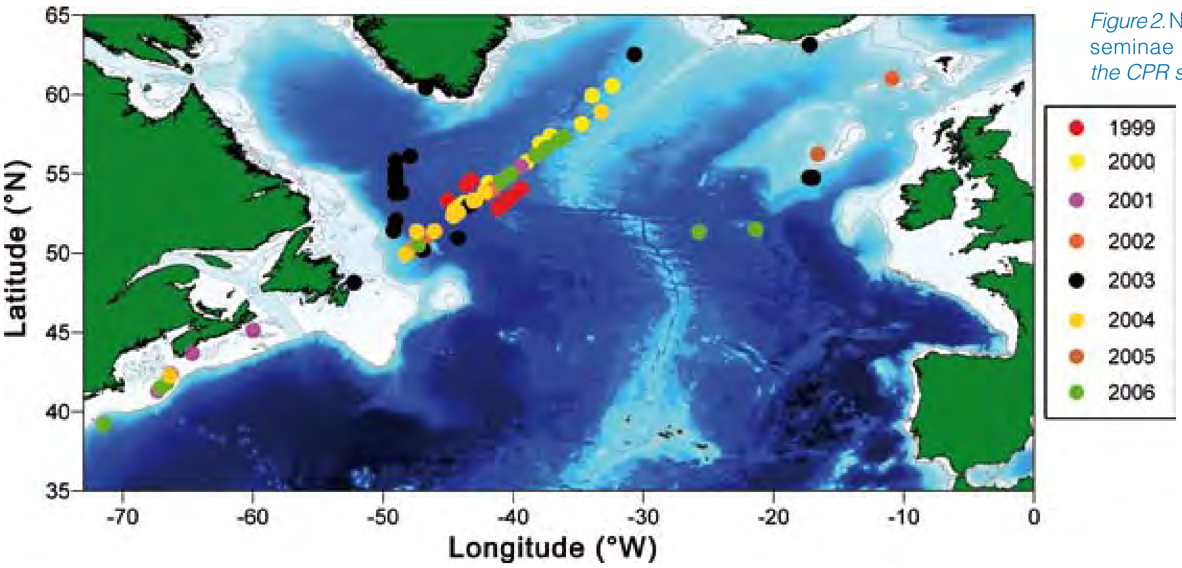

Figure 2. Neodenticula seminae *records in the CPR survey*

Atlantic in what is known as the trans-Arctic interchange. The Strait was closed again for a long period in the later Pliocene and early Pleistocene. This pattern fits well with the first appearance of *N. seminae* in Atlantic deep sea cores at ~1.2 Ma, but does not explain why it was not found in sediments from the last interglacial, the Eemian, when conditions were thought to be as warm at least as at present.

The reappearance of *N seminae* in the North Atlantic after such a long gap is an indicator of the scale and speed of changes that are taking place in the Arctic and North Atlantic oceans as a consequence of global warming. Because of the unusual nature of the event it most likely indicates that a threshold has been passed, marking a change in the circulation between the North Pacific and North Atlantic Oceans via the Arctic. It is likely a forewarning of other likely introductions from the Pacific into the Atlantic as Arctic ice continues to melt, with potentially large impacts on Atlantic biodiversity. Such changes in plankton diversity are likely to impact the process by which carbon is taken to the deep ocean by sinking biological debris, known as the biological pump, with resulting feedbacks to the carbon cycle and likely changes in the extent to which the ocean can take up atmospheric carbon dioxide (CO_2). In September 2007 Arctic sea ice reduced in area at a rate that was 25% more than previously. Does this mean that additional Pacific species will enter the North Atlantic in the spring and summer of 2008?

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Salvador wins natural sciences prize

GLOBEC SSC member, Salvador Lluch-Cota has been awarded the prize for contributions to research by a young scientist in the area of natural sciences from the Academia Mexicana de Ciencias (the Mexican Academy of Sciences).

Every year since 1961, The Mexican Academy of Sciences (Academia Mexicana de Ciencias) grants the AMC-Research Prize, which is the most important award from the academy, and one of the most prestigious in Mexico, to early career scientists (younger than 40) making relevant contributions and state of the art research in the fields of Formal, Natural, and Social Sciences, Humanities, and Engineering and Technology.

For further details see the Academia Mexicana de Ciencias's website: http://www.amc.unam.mx/modules.php?name=Content&pa=showpage&pid=94

2007 Annual Norway GLOBEC Meeting

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On 20-22 November 2007 a meeting of three Norway GLOBEC projects funded by the Research Council of Norway was held in the Rica Brakanes Hotel in picturesque Ulvik in western Norway. Nestled amongst snow topped mountains and with a view of the Ulvik Fjord near the head of the Hardanger Fjord, twenty-three scientists met to present their results and exchange scientific ideas (Fig. 1). Two of the projects are associated with the regional GLOBEC programme ESSAS (Ecosystem Studies of Sub-Arctic Seas).

Figure 1. Participants of the Norway GLOBEC meeting at Ulvik in western Norway.

The first is the Norwegian national ESSAS project (NESSAS) that began in 2005 and runs until the end of 2008. Its objective is to quantify and predict the impact of climate variability on the Barents Sea marine ecosystem. The research within NESSAS has five major tasks: to better understand the climate forcing of the physical oceanography of the Barents Sea; to quantify the biological response of the ecosystem to climate variability; to predict the ecosystem response to future climate change; to investigate the possible economic impacts of future changes in fish stocks; and to compare the Barents Sea ecosystem responses to climate variability and change with the responses in other sub-arctic seas. The research is being carried out through retrospective analyses and modelling.

The second project associated with ESSAS is the IPY project NESSAR (Norwegian component of the Ecosystem Studies of Subarctic and Arctic Regions) that began in 2007 and will run to the end of 2010. NESSAR is investigating the physical and biological dynamics at the front separating the cold waters originating from the Arctic from the warmer Atlantic waters in both the Norwegian Sea and the Barents Sea. This is primarily a field programme with three cruises conducted in 2007 and three more planned for 2008. Dr. Ólafur Pálsson who leads Iceland's IPY initiative, the Iceland Sea Ecosystem (ISE) project, was in attendance on the invitation of the NESSAR project.

The third project participating in the meeting was the INFERNO project (Effects of Interactions between Fish Populations on Ecosystem Dynamics and Fish Recruitment in the Norwegian Sea), which focuses on the potential interaction between planktivorous fish in the Norwegian Sea. This area harbours some of the largest fish stocks in the world, including Norwegian spring spawning herring, blue whiting and mackerel. These planktivorous stocks have substantial spatial and diet overlap, and by virtue of their high abundances, potentially have a strong ecological impact on the ecosystem and each other. The main goal of the project is to quantify the interactions between herring, blue whiting and mackerel in the Norwegian Sea through a combined effort involving stomach analyses, historic data analyses and modelling. The project integrates data on physics, plankton and fish distribution from collaborating Norwegian, Russian, Icelandic and Faeroese marine institutions and one scientist involved in the project from each of these latter three countries was in attendance. An individual based modelling approach will be used to generate data driven 3-D distributions of the key fish stocks and to quantify their overlap and interactions over the life cycle. The project runs from 2006-2009 and the joint meeting provided an update of the activities within the project over the last year.

The meeting began with the IPY presentations. The first main talk was given by Dr. Pálsson on the ISE project, whose objectives are to explore the ecosystem structure and function of the Iceland Sea and adjacent waters with special emphasis on the life history of the Iceland–East Greenland–Jan Mayen capelin stock and the role of the environment in causing observed changes in this stock. Of particular interest were distributional shifts in recent years with older capelin (age 1+) having moved away from their usual habitat in the Iceland Sea north of Iceland seemingly towards colder waters along the East Greenland continental shelf. The project is looking at possible reasons for such a geographic shift including changes in the physical environment and/or lower trophic levels. Initial results from three cruises in each of the past two years were described, one in each of the late winter, early spring and summer. While there has been an increased amount of Atlantic water along the north coast of Iceland and warming in the Iceland Sea, it is not yet clear why the changes in the capelin distributions have occurred.

Dr. Palsson's presentation was followed by five talks on the results from the NESSAR cruise to the Norwegian Sea to examine the physical structure and ecological significance of the Jan Mayen front south of the island of Jan Mayen on the research vessel *G.O. Sars* from the Institute of Marine Research. The first talk described the current meter moorings that were deployed on the Jan Mayen ridge to monitor the inflow of Atlantic water into the Iceland Sea. These will be the first direct current measurements in this area and are scheduled to be recovered in May 2008. The other four presentations focused upon the front which lies immediately to the east of the ridge and separates the warm, salty Atlantic water from the cold, fresh Arctic waters with their subsequent different biota. Talks focused on the front's hydrographic structure, turbulence measurements in the front, the zooplankton community structure and abundance, and the distribution and diet of herring in the vicinity of the front. Details on the results of the cruise to the Norwegian Sea are presented on page 50 of this newsletter.

Figure 2. The chart of the Barents Sea. The box indicates the study area during the Jan Mayen cruise in August 2007. The line shows the location of the cross-front transect shown in Figure 3.

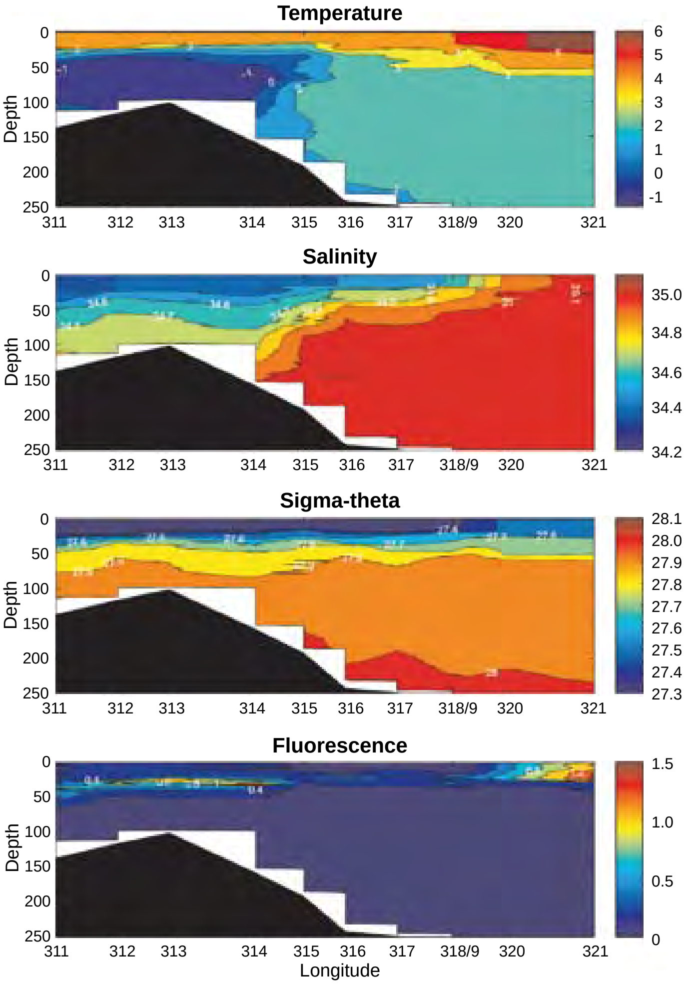

Figure 3. The temperature, salinity, sigma-theta and fluorescence on an across-front transect on Storbanken. Note the shallow near surface, low salinity layer extending towards the Atlantic water on the right. The deeper temperature-salinity front lies over the slope of the bank but there is no strong density front due to density compensation.

Later in the meeting results from the two NESSAR cruises to the western Barents Sea were also presented. The first talk showed the location and physical characteristics of the Polar front from a hydrographic survey during May 2007 on the research vessel *Lance* out of the Norwegian Polar Institute. The work focused upon Bear Island, Spitzbergen and Hopen Banks where the front tends to be tied to the topography hugging the southern sides of these banks. The second cruise was during August 2007 on the research vessel *Jan Mayen* out of the University of Tromsø to undertake detailed ecosystem measurements at the front, initially to the east of the island of Hopen and later on Storbanken (Fig. 2). Talks based on the results from this cruise included ones on the physical features of the front, across and along-front variability in zooplankton and benthic sampling. The sampling near Hopen showed a rather confused picture of the front, which on closer inspection of the charts raised the possibility of topographically generated eddies due to a prominent ridge upstream of our sampling area. Because it may prove difficult to separate out frontal processes from those related to such eddies, the sampling was moved to Storbanken slightly to the east. The frontal structure there consisted of a surface salinity front extending to 30-50 m deep and approximately 10-20 km seaward of the southwestern side of the bank and a deeper front in both temperature and salinity that lay over the bank slope (Fig. 3).

The fluorescence measurements indicated a minimum in phytoplankton biomass in the frontal region, a subsurface maximum along the pycnocline over the bank in the Arctic waters and the highest values in the surface mixed layer in the Atlantic waters farther offshore of the bank (Fig. 3). The presentation on the towed optical plankton counter indicated that the zooplankton structure in the top 100 m was defined by the hydrography with the smallest plankton in the shallow front and larger plankton away from the front. Consistent with this, the capelin data from the trawl surveys showed that the smallest and youngest fish (age 0-1) were located in the vicinity of the front while the larger and older capelin were located away from the front, primarily on the bank. A presentation on benthos emphasised the collection of clams, from which growth rings will be determined and used to estimate the possible variability in the frontal location.

Nine presentations were given from NESSAS. Following an introduction to the project, work on the general circulation of the Barents was presented based upon both observations and models. The currents are generally weak but of particular note was the identification from modelling studies of a new northern pathway for Atlantic waters to reach the eastern opening of the Barents Sea between Nova Zemlya and Franz Joseph Land. The current flows between Central Bank and Storbanken, transports approximately half of the water of the southern branch south of Central Bank but reaches the eastern entrance in approximately two-thirds the time taken by the southern branch. In another talk, model studies of the heat budget for the Barents Sea suggest that atmospheric heat fluxes tend to dominate in the autumn but that advection dominates in the winter especially. Both are important in determining the interannual variability in heat content within the Barents Sea although for the pentad beginning in 1997 advection was the principal cause of the observed warming.

Investigations on the effect of light on phytoplankton have shown that spectral wavelengths must be taken into account rather than the full spectrum if one is to obtain accurate estimates of primary production and that these are somewhat species related. Several papers discussed future climate scenarios and their consequences. Despite predicted increased fresh water to the high northern latitudes and a weakened Atlantic Meridional Overturning, there will be only small changes in the volume flux of Atlantic water into the Nordic Seas (eastern branch may strengthen and the western branch may weaken), the Nordic Seas and the Barents Sea will become warmer, salinity may not change or will weakly increase in the eastern Nordic Seas and in the Barents Sea, and a northeastward shift in storminess may maintain inflow of Atlantic water into the Barents Sea. It was noted however, that current climate GCMs are still not appropriate for direct downscaling of the local Barents Sea climate for ecosystem studies. Modelling of *Calanus finmarchicus* suggested that in the future they will have a wider distribution within the Barents Sea and although more will be transported through Fram Strait into the Arctic Ocean, they will not become established there.

Modelling of capelin suggests that under warming these fish will spread north and eastward in the Barents Sea with the likelihood that they will establish new spawning sites in regions such as Spitzbergen and Nova Zemlya. Based on observed responses to previous warming events it is also expected that other species such as cod and haddock will also spread northward and eastward in the Barents Sea. In addition, growth rates, recruitment and abundance of several species including cod and herring are expected to increase but these will depend upon the fishing intensity in the future. One of the components of NESSAS is comparative studies of the Barents and Norwegian Seas with other sub-arctic seas in order to gain further insights as to what processes are fundamental and what are unique to the region. NESSAS scientists are involved in two major initiatives, one with Canada on comparisons with the Labrador Sea and the Newfoundland-Labrador shelves called NORCAN and the second with the United States on comparisons with the eastern Bering Sea, the Gulf of Alaska and the Georges Bank/Gulf of Maine region. The latter is called MENU (Marine Ecosystem Comparisons of Norway and the United States). A series of comparative papers to appear as special issues in primary publications are in the process of being written within both NORCAN and MENU.

Altogether 9 presentations on the INFERNO project were given at the meeting. After a short introduction by the project leader, there were presentations on the distribution of the target species in the Norwegian Sea during spring and summer. During spring there is typically a considerable overlap between blue whiting and herring, whereas mackerel are not present in the Norwegian Sea. The Norwegian summer surveys, which have the same target species as INFERNO, show that all three species are found over large parts of the Norwegian Sea. A novel result was that mackerel are found in water as cold as 4°C, which is below what is generally assumed. Dr. Jan Arge Jacobson from the Faroese Fisheries Laboratory then presented Faroese data on planktivorous fish in the Norwegian Sea. He also presented interesting ideas about the recruitment dynamics of blue whiting that might explain the leap in recruitment seen in the stock during 1996-2005.

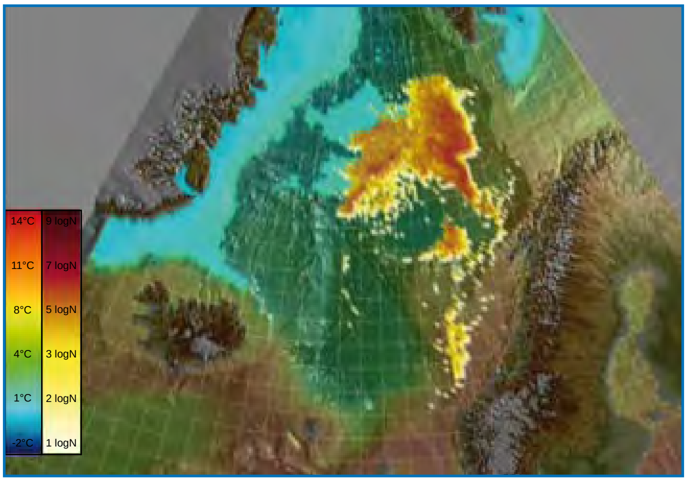

Figure 4. Screenshot from the herring model where the herring distribution in summer is shown in yellow-red and the temperature (only temperatures below 2°C are shown) in light blue. The figure illustrates the predicted distribution of herring during summer under a warm climatic scenario where most of the Norwegian Sea is available to the herring.

Next there was a presentation about the stomach contents of herring, blue whiting and mackerel, showing some spatial and interannual variation in the diets of these species. For herring there also seems to be some seasonal variation in the diet, with a more *Calanus* dominated diet in spring and a more diverse diet in summer. Mackerel mainly eats *Calanus*, while blue whiting has an ontogenetic shift in diet from taking a lot of *Calanus* as 1-2 year olds to taking more euphausiids and amphipods when older. The following talk introduced a temperature atlas for the Norwegian Sea that is based on compiling all available temperature information and interpolating this spatially and temporally to achieve a fully covered atlas with quarterly resolution. Although the frequency of observations varies substantially between seasons, the spring and summer, which are most relevant to the INFERNO project, are fairly well covered in most years. Two presentations focused on individual-based models for *Calanus finmarchicus* and herring (Fig. 4) based on super individuals and simulating the population and spatial dynamics of the entire stocks of these species in the Norwegian Sea. Since *C. finmarchicus* is a key prey of all the target stocks in the INFERNO project, there is special emphasis on the distribution and population dynamics of this species within the project. The session ended with a presentation on transport of overwintering *C. finmarchicus* in the Norwegian Sea studied by RAHFOS floats.

At the end of the presentations on day 2 of the meeting a general discussion was held. There was a consensus of overlapping interest between the different projects and that the meeting was felt to have been useful to all. It was also felt that future meetings of the different projects should be combined and to perhaps include other Norwegian projects. However, given that NESSAS will terminate at the end of 2008 it was unclear whether they would participate as their final results might be presented in a larger forum such as a conference or symposium.

On the final day of the meeting we divided into project working groups. NESSAR scientists discussed plans for the upcoming cruises in 2008 while NESSAS scientists reviewed the deliverables for their project to ensure that all would be covered during the upcoming final year of funding. During the separate INFERNO session, issues related to data formatting, stomach analyses and the status of publications that are under preparation were discussed. There were also discussions about survey activities during the upcoming summer and a presentation of data from Russian aerial surveys using LIDAR, which are particularly useful for studying the distribution of mackerel.

Marine climate change analysis in Irish waters

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Ireland is a key location for investigating the effects of climate variation on marine ecosystems, and on the ocean's biogeochemistry. The island, and in particular the west coast, is under the direct influence of the main climate regulators, such as the North Atlantic climate system and the Gulf Stream current. At the same time, the anthropogenic pressure is extremely low on these coasts.

The Irish Marine Institute has just launched the national Marine Climate Change (MCC) research programme, to investigate the effects of climatic variations on the Irish marine ecosystem. The programme began in December 2007, and will span over seven years.

This study aims to investigate the dynamics of the Irish coastal ecosystem over decadal time spans, and in relation to climate variation. In particular, changes in abundance and geographic distribution of the biological resources – phytoplankton, zooplankton, and fish (salmonids and marine species) will be analysed, together and in relation to the temporal variations of the ocean's physical conditions (temperature, salinity).

A further level of analysis will consider the influence that climate exerts on the trends of the ecosystem's variables. Fluctuations of the principal components of the biological and physical variables will be analysed against the temporal variations of climate indicators such as the North Atlantic Oscillation (NAO) index.

A final level of analysis will consider the interactions among the different trophic levels, and the possible ecosystem modifications in response to climate change scenarios, through an ecosystem-modelling component.

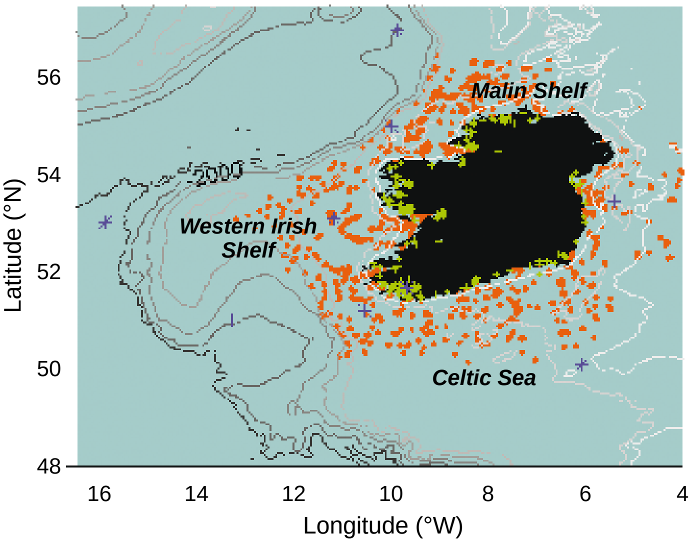

Figure 1 Maps of Ireland showing bathymetric contours, geographical features, and the distribution of some monitoring locations: Phytoplankton National Monitoring Programme stations (in green); Irish Groundfish Survey stations (in orange); National weather-buoys (blue symbols).

The archives of the Irish Marine Institute contain long time series of diverse datasets, from various national monitoring programmes:

- A coastal high-frequency phytoplankton-monitoring programme (Fig. 1) ran year-round in the period 1980-2005. Cell counts and taxonomic analyses are available for 28,000 samples, allowing a retrospective analysis of seasonal/annual abundance of phytoplankton, bloom onset dynamics, and geographic distribution shifts of phytoplankton species.
- Stock assessment data for some commercial fish species go back 35-55 years. Among those, cod and herring could be indicator species of climate change. Their productivity and abundance are likely to change in Irish waters, as a consequence of climate variations, and as the biogeographic distribution of these species finds a natural southern limit in the Celtic Sea.
- In north-west Ireland, considerable datasets have been collected from the Burrishoole-catchment monitoring stations over the last 50 years, encompassing biological and environmental data: salmonid and eel stock abundance, growth, and survival parameters; macro-invertebrate fauna; sea-lice species, abundance, and fecundity; genetics; freshwater and marine temperature, riverine water level and discharge, rainfall and meteorological data.
- The ocean climate essential physical variables, such as air and sea temperature, wind, pressure, and humidity have also been assimilated during the past 12 years (~1994 to the current day), from National Research Vessels, the Irish National Data Buoy Network (INDBN), as well as other short term buoy deployments and the national tide gauge network.

The 'Marine Climate Change' (MCC) team will mine these data sources, and additional datasets available from national and international databases, to perform a new series of analyses, in the climate-change research context. The MCC programme is further allocating a significant amount of resources towards the implementation of new monitoring systems, such as ARGO floats deployment, coastal weather buoys, research cruises on board national research vessels and multiple measuring systems of carbon dioxide partial pressure ($p\text{CO}_2$) in the ocean's surface waters.

From the experience gathered in the bi-annual analytical phase, the Marine Climate Change research group will draw a series of recommendations to address the technological, scientific, and political gaps of climate change research in Ireland. This will take the form of a marine climate change research strategy for the 2009-2013 period, and the production of a bi-annual ocean climate status summary, jointly with other relevant national and international institutions.

US GLOBEC Northwest Atlantic programme: long distance climate connections

US GLOBEC National Coordinating Office

The US GLOBEC Northwest Atlantic programme has conducted intensive field and modelling studies to understand the potential impact of climate change on the Georges Bank ecosystem. The Georges Bank forms the southern boundary of the Gulf of Maine (Fig. 1) and is highly productive and supports many commercially important fisheries. The programme focused on the coupling of physical and biological processes that together control the bank's biological production. On the physics side the programme investigated the processes responsible for the circulation, stratification and exchange of waters on the bank. Biologically the programme focused on the population dynamics of the zooplankton *Calanus finmarchicus* and *Pseudocalanus* spp., and the egg and larval life stages of the cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) stocks on the bank. The targeted zooplankton are important food items for the larval fish. The field studies were conducted from 1995 to 1999 and were concentrated in the January-June period each year when the fish eggs and larvae were in the water column.

The Georges Bank region was selected as the location for study in part because climate models identified it as a region likely to experience large changes in climate (US GLOBEC, 1992). Recently, however, the major focus of climate interests in the media and with the public has been on the large changes observed in the arctic (ACIA, 2005): significant warming, loss sea ice and dire predictions for polar bear and other animal populations in the region. These changes also have been associated with an increased export of fresh water to the North Atlantic, resulting in a lowering of its surface layer salinity and in implications for changes in the meridional overturning circulation (MOC) (Curry and Mauritzen, 2005).

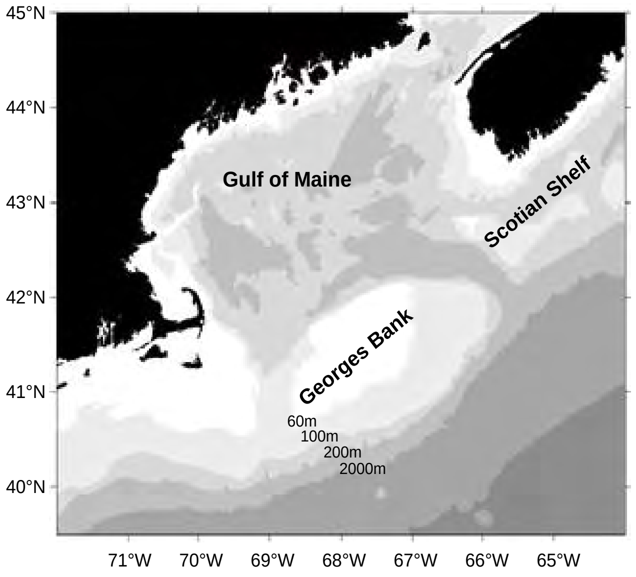

Figure 1. The US GLOBEC Northwest Atlantic programme study region (figure courtesy of J. Manning, NMFS)

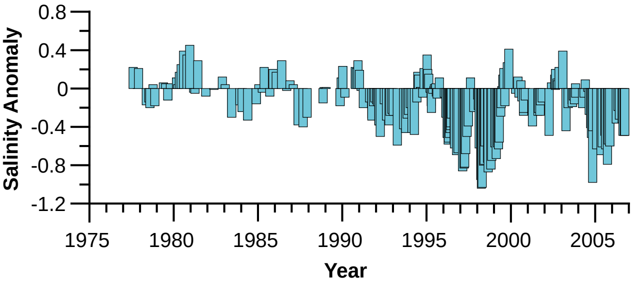

Figure 2. Salinity anomaly for the surface layer waters (0-30m) on Georges Bank (modified from Mountain, 2003). Each bar represents a different survey cruise.

The local atmospheric climate in the Gulf of Maine/Georges Bank region has not experienced comparably large changes (NERA, 2002). However, during the GLOBEC study years, and through much of the 1990s in general, the Georges Bank waters exhibited a large decrease in salinity (~0.4 PSU on average) relative to earlier decades (Smith *et al.*, 2001; Mountain, 2003; Fig. 2). GLOBEC results (Houghton and Fairbanks, 2001) have shown that the major source for the Georges Bank waters, both volumetrically and in freshwater content, was water from the Labrador Sea that travelled to the bank via the Gulf of St. Lawrence, the Scotian Shelf and the Gulf of Maine (Fig. 3). Direct current measurements in the mid-1990s showed that the average transport of low salinity water from the Scotian Shelf into the Gulf of Maine was about twice that measured in the late 1970s (Smith *et al*, 2001). More recently another study (Greene and Pershing, 2007) has indicated that the ultimate source for the decrease in salinity observed on Georges Bank during the 1990s was the increased export of freshwater from the arctic, through both the Fram Strait and the Canadian Archipelago.

A number of GLOBEC analyses have documented biological changes in the Gulf of Maine/Georges Bank system that were associated with the salinity changes. Within the Gulf both the annual phytoplankton abundance and the abundance of small copepods increased during the 1990s as the salinity decreased (Pershing *et al.*, 2005). Both the

Figure 3. Transport pathways from the Labrador Sea to the Gulf of Maine/Georges Bank region (modified from Chapman and Beardsley, 1989).

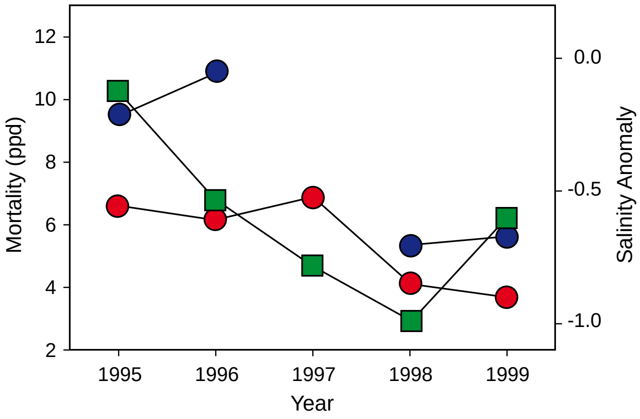

Figure 4. Larval mortality rates (ppd) for the cod (blue circles) and haddock (red circles) populations on Georges Bank, 1995-1999 (left vertical axis). The March-April salinity anomaly (green squares) for the surface layer waters (0-30m) on Georges Bank, 1995-1999 (right vertical axis). (modified from Mountain et al, 2008).

timing and amplitude of the spring phytoplankton bloom on the western Scotian Shelf and in the Gulf of Maine were influenced by the variation in surface layer salinity, likely through its effect on vertical stratification (Ji *et al.*, 2007). An analysis of the zooplankton community structure on Georges Bank showed a similar trend to higher abundance of smaller copepods, particularly *Pseudocalanus* spp., during the 1990s (Kane, 2007). Growth rates for larvae of the cod and haddock fish populations on Georges Bank were higher in years of high *Pseudocalanus* abundance, which were years of lower salinity (Buckley and Durbin, 2007). The mortality rates for the cod and haddock larvae populations were lower in the years of lower salinity, when the small zooplankton prey were more abundant and the larval growth rates were higher (Mountain *et al.*, 2008; Fig. 4).

The mechanistic or process level connections controlling these apparent physical and trophic interactions - from changes in salinity to phytoplankton production, to zooplankton abundance to larval fish growth and survival - are being explored in coupled bio-physical modelling studies as part of the synthesis phase of the US GLOBEC programme. The important message here is that the changes in climate which have the greatest impact on a system may not be local, but originate elsewhere and be carried to the region by the ocean circulation patterns. Our productive coastal ecosystems can be vulnerable to distant climate conditions.

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US GLOBEC Transitions: Towards a fully integrated climate-to-fish model

US GLOBEC National Coordinating Office

One of the primary goals of the US GLOBEC synthesis effort is the development of a modelling framework which can be used to study the interactions between global climate variability and local oceanic ecosystem response. To accomplish this goal, modelling techniques developed within the US GLOBEC regional programmes are being transitioned for use within contemporary climate models. The resulting system of linked models has many practical benefits, including the abilities to simultaneously resolve multiple spatial scales (necessary to link the climate and coastal scales for both physics and biology) and to correct biases in the climate models (e.g. sea surface temperatures in upwelling regions).

An effort of this type is underway to couple the Regional Ocean Modeling System, one of the principal modelling tools in use within US GLOBEC, to the Community Climate System Model (CCSM) developed and maintained at the National Center for Atmospheric Research. In a large measure due to the efforts of GLOBEC investigators, the ROMS system now includes multiple options for ecosystem studies (NPZD-type models, e.g. NEMURO) with a range of complexities, as well as bio-energetic models (e.g. NEMURO.FISH). Individual based models for higher trophic levels are also currently being added to ROMS. The incorporation of ROMS within the CCSM framework thus offers immediate opportunities for regional downscaling of oceanic circulation, and the explicit inclusion of ecosystem dynamics.

All the components of the CCSM communicate with each other through a flux coupler, responsible for mediating fluxes among the components, as well as for re-gridding and time synchronisation of the various components. The coupler is currently based on MCT (the Model Coupling Toolkit) with an ESMF (Earth System Modeling Framework) version under development. As part of the coupling of ROMS to CCSM, a new composite ocean was developed which couples and synchronises the global ocean model (the Parallel Ocean Program) and ROMS. Multiple regional domains can be simultaneously coupled to the global ocean model, and each regional patch can have its own ecosystem model.

Figure 1 shows results utilising the composite ocean where the northeast Pacific is simulated with a high-resolution ROMS nested within a global POP grid. The regional model, on the right, has a more realistic representation of the upwelling physics, both in spatial scale and structure, and upwelling temperature. For this simulation, only one-way coupling was used, with the global ocean and atmosphere driving the regional model. The capability for two-way coupling back to the atmosphere is presently being tested.

Overall, our results show that a hybrid climate/regional model can improve the physical representation in regions of importance to ecosystems. Our approach allows for flexibility in designing a simulation with multiple patches at various resolutions. There are plans for similar coupling of regional atmospheric models using CAM and WRF, thereby enabling simultaneous regional downscaling of atmosphere and ocean.

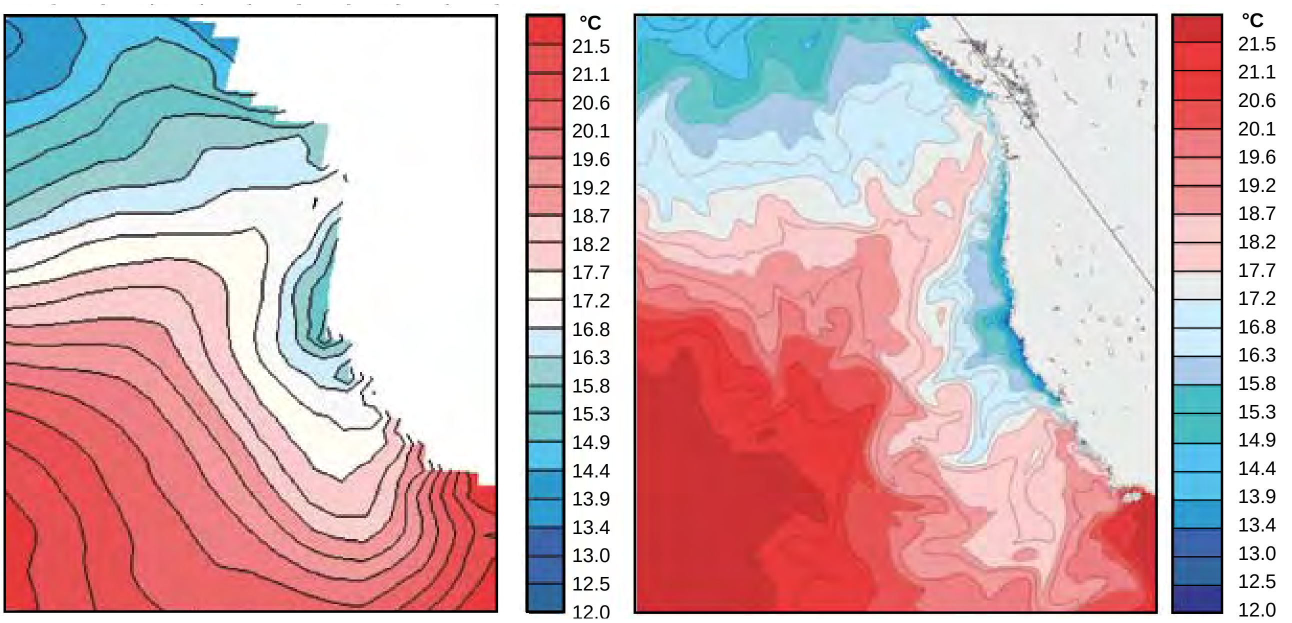


Figure 1. The Northeast Pacific as simulated by the Parallel Ocean Program (left) and by the Regional Ocean Modeling System nested within the global POP grid (right).

High honours for US GLOBEC scientists:

Edmundo Casillas and William T. Peterson

Edmundo Casillas

William T. Peterson

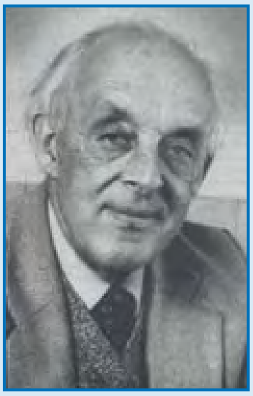
Two US GLOBEC scientists are among the NOAA employees awarded a Bronze Medal for their contributions in 2007. The medal is the highest honorary award granted by the NOAA Administrator. William T. Peterson and Edmundo Casillas, along with two of their colleagues, received the recognition for developing a web-based description of eleven ocean productivity indicators which enables the forecasting of adult salmon returns years sooner than previous techniques.

“We have found that salmon managers like the website,” said Peterson, “because it paints a simple picture of the status of a dozen or so ocean conditions (using the stoplight approach) that influence salmon survival.” He added, “for those wanting more detail, one can click on each indicator which then links one to a more detailed one- or two-page description of how each index was calculated and how it relates to salmon growth and survival” To visit the website, see www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm

A Bronze Medal recognises superior performance characterised by outstanding or significant contributions, which have increased NOAA’s efficiency and effectiveness. Bronze Medals are awarded to individuals, groups (or teams), and organisations. Recipients receive a framed certificate signed by the NOAA Administrator. The Bronze Medal is the highest honour award that can be granted by the Under Secretary of Commerce for Oceans and Atmosphere. Winners are recognised annually at a formal ceremony held in the Washington Metropolitan area.

David Henry Cushing: In memoriam

David Henry Cushing, the great pioneer of marine ecology and fisheries science died on 14 March 2008, on his 88th birthday. He was born in Alnwick, Northumberland, the son of a local schoolmaster and was educated at the Duke’s School Alnwick, and the Newcastle-upon-Tyne Royal Grammar School before going up to Balliol College Oxford where he gained his M.A. and in 1950 his D. Phil on the subject of ‘Vertical migration of the zooplankton’. After service in the Royal Artillery from 1940 to 1945 and in the 1st Bn. Royal Fusiliers from 1945 to 1946 he joined the Fisheries Laboratory, Lowestoft in 1946 to “count plankton on the Flamborough Line”, but eventually becoming Deputy Director from 1974 until his retirement in 1980. The Journal of Plankton Research, which he founded in 1979 and edited until 2001 is acknowledged as one of the leading international marine science journals.



David Henry Cushing

He made ground-breaking advances in at least four areas of marine ecology: fisheries acoustics, plankton production, impacts of climate and fisheries recruitment, with numerous books and papers on all of these. His achievements were recognised through his election as Fellow of the Royal Society in 1977, the Rosenstiel Medal in Oceanographic Science of the University of Miami in 1980, the Medal of Albert ler of Monaco of the Institute d’Oceanographie in Paris in 1984, the Award of Excellence of the American Fisheries Society in 1987 and the German Ecology Prize in 1993.

He was very actively involved in the early stages of GLOBEC and chaired one of the first workshops on population dynamics and physical variability in Cambridge in 1993. GLOBEC could hardly have happened without David Cushing as it was fundamentally based on so much science which he pioneered, particularly on the population dynamics of zooplankton, the trophic relationships between plankton and fish, the influence of climate variability on fisheries and the importance of early life history of fish in governing recruitment. He could be intimidating, but I also remember him as one of the most considerate and tactful of colleagues who at the end of a nerve-wracking seminar early in my career came up afterwards with words of encouragement and one or two perceptive and difficult questions which he did not want to expose me to in public. It is rare to read a paper on marine ecology and fisheries which does not include a reference to some of David’s work and that testimony to the enduring quality of his science is one he would appreciate and which serves as our best tribute to him.

A longer account of David Cushing’s life and work can be found in Fisheries Oceanography 2 (3/4):109-113, 1993.

Keith Brander

Third Japan-China-Korea joint GLOBEC Symposium

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Following on from the success of the first symposium in Ansan (Korea) and the second one in Hangzhou (China), the third Japan-China-Korea joint GLOBEC symposium was held on 13-15 December 2007 in Hakodate, Japan. The symposium was opened with a welcome address from Mr Toshiki Kudo, the Vice Mayor of Hakodate, and Professor Akihiko Hara, Dean of the Faculty of Fisheries Sciences, Hokkaido University, followed by welcoming remarks by Yasunori Sakurai. A total of 92 people from Japan, China, Korea, Germany and Canada attended the symposium, including a number of graduate students.

The first session on the morning of 13 December 2007 included 3 overviews of recent activities of the national GLOBEC programmes, presented by the programme chairs of each nation, Qisheng Tang, Hyung-Ku Kang (on behalf of Im Sang Oh) and Yasunori Sakurai. Subsequently, 45 talks were presented over two days in the following four sessions: “oceanography and ecosystem modelling”, “primary production and zooplankton biology”, “marine biology and biodiversity” and “population dynamics, community structure and climate change”.

Participants of the third Japan-China-Korea joint GLOBEC symposium

The meeting was held in a town hall in Hakodate, Japan

A poster session was also held in the evening of the second day, and 31 posters were presented. Most of the presentations focused on the study of physical/ecological mechanisms of fluctuations in the northwestern Pacific ecosystems and their management. The marginal regions in the northwestern Pacific, such as the Yellow Sea, the East China Sea and the Japan/East Sea, are some of the highest fish production areas in the world, and many Japanese, Chinese and Korean scientists are actively working in these regions. The symposium provided good opportunities to discuss recent progress of these studies and to establish and confirm research links between east-Asian scientists, including young graduate students. Some of the highlights from the meeting are presented in this special section of the GLOBEC International Newsletter. We would like to thank all of the authors for their contributions.

During the symposium, Japan, China and Korea GLOBEC Scientific Steering Committee meetings were held and future activities for the programmes were discussed. There are plans to produce a special issue from the symposium in a peer reviewed marine science journal. Furthermore, it was agreed that the next Korea-China-Japan GLOBEC/IMBER meeting will be held in Cheju Island, Korea, in December 2009. The meeting will be hosted by Dr Sinjae Yoo (Korea Ocean Research and Development Institute: KORDI) who is the new chair of the Korea GLOBEC programme.

The organising committee would like to thank all the participants for making the symposium such a great success. Support for the symposium was provided by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), Hakodate City and the Hakodate Fisheries Committee. In addition, travel costs for a number of Korean scientists were provided by the Fisheries Science Core University Program (FiSCUP), the Japan Society for the Promotion of Science (JSPS) and the Korea Science and Engineering Foundation (KOSEF).

Japan GLOBEC has come into its third phase (2005-2009), which focuses on the biological oceanography of the Oyashio and the Kuroshio regions. The recent achievements of Japan GLOBEC under several funded projects and some ongoing projects were reviewed in a previous special section of the GLOBEC International Newsletter 12(2): 2006.

The recent activities of China GLOBEC

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China GLOBEC has come into its third phase as the combined GLOBEC/IMBER national programme with the title of "Key Processes and Mechanisms of Sustainable Food Production in the Coastal Ocean of China" (2006-2010). The new programme gives priority to the marine biogeochemical cycles and key processes of end-to-end food webs in the China seas. The four major scientific questions to be addressed are the supporting role of the main biogeochemical processes of food production, key physical forcing of biogenic element cycles, primary production coupling with main biogeochemical processes, and food web trophodynamics of the major biological functional groups. The research activities will mainly focus on some unique sub-ecosystems in the Yellow Sea and the East China Sea (ECS) with studies of ecological capacity. The implementation of the programme is expected to make breakthroughs in some of the frontier scientific fields like the key processes of food production in the coastal and shelf ecosystems and sustainable utilisation mechanisms of marine living resources. The programme detailed in the implementation plan has been divided into 8 projects.

Three research foci have also been identified in the China GLOBEC III/IMBER I programme:

Research Focus 1: Diversity of biological functions and trophodynamics of end-to-end food webs in Yellow Sea Cold Water Mass (YSCWM):

a) Basic biology of functional groups and key species at each trophic level, including microbes, phytoplankton, zooplankton, and nekton, and

b) Interactions in two important biological processes:

  i. interactions between blooming phytoplankton and zooplankton, and

  i. the relationship between important zooplankton species and key species at higher trophic levels.

Research Focus 2: Impact of the Kuroshio and land source inputs on the nutrient dynamics and food production in the shelf of the East China Sea.

a) Key processes influencing the supplement dynamics of exogenous nutrients:

  i. impact of matter exchange between the ECS and the Taiwan Strait on the cycling of nutrients and trace elements in the ECS;

  ii. impact of upwelling above the slope from Taiwan to Diaoyu Island on the budget of biogenic elements in the ECS and their annual variation;

  iii. impact of the Kuroshio front eddy and inner tide etc. in the north of Diaoyu Island on biogeochemical cycling above the continental shelf of the ECS.

b) Key processes influencing the supplement dynamics of land source nutrients:

  i. impact of spatial and temporal change of runoffs and atmospheric deposition on the cycling of nutrients and trace elements in the ECS.

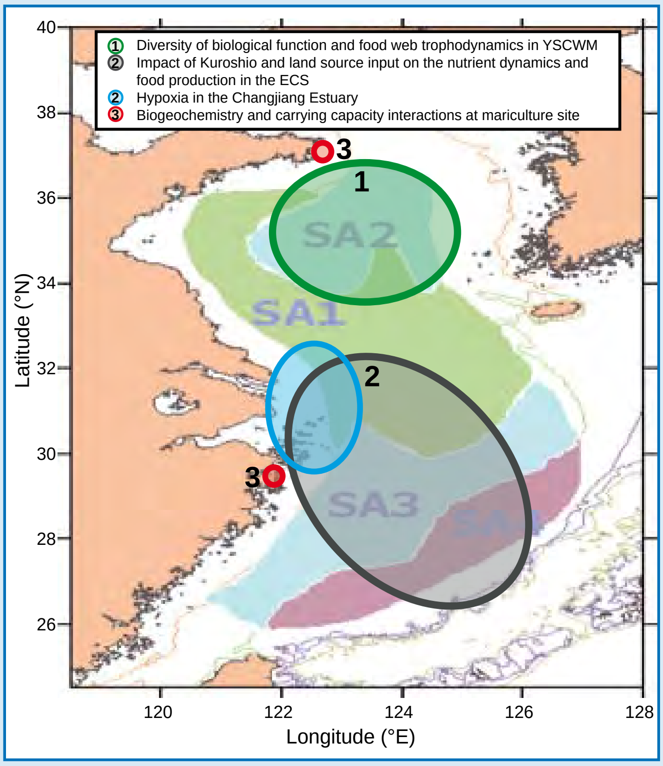

Figure 1. Research foci and main survey areas. The base map is the nekton survey areas in the Yellow Sea and East China Sea, Spring 2001.

Research Focus 3: Biogeochemistry and carrying capacity in typical mariculture areas.

a) The biogeochemical cycling in mariculture of shellfish and algae and polyculture model, and

b) The interactions between mariculture and the environment in fish cage farms and bioremediation.

The programme is currently working on the field-data collected during the implementation phase in 2006-7. Six special activities have been designed to facilitate integrated multidisciplinary research. The activities are as follows:

Action 1: Bloom processes of phytoplankton, with an emphasis on the development of the bloom and its contribution to food production in the ecosystem.

Action 2: The relationship between zooplankton and higher trophic-level living resources, including the determination of key species and major functional groups at various trophic levels and their trophodynamic interactions in the food web.

Action 3: Nutrient supply processes to the East China Sea shelf, with emphasis on the hydrodynamic processes of nutrient supply from the Kuroshio Current and the Taiwan Warm Current.

Action 4. Nutrient supply processes in the coastal spawning ground in the East China Sea, including those due to land sources and to upwelling.

Table 1. Research foci, survey and cruises by *R/V Bei Dou* in the Yellow Sea and East China Sea

Focus and Survey Activity		Cruise	Survey Date	Completed	Days
Focus 1	**Action 1.** Bloom processes of phytoplankton	1	30/03/07-24/04/07	Yes	25
	Action 2.1 Relationship between zooplankton and higher trophic-level living resources (Yellow Sea Cold Water Mass area)	1	10/04/06-29/04/06	Yes	20
		2	16/10/06-03/11/06	Yes	19
	Action 2.2 Relationship between zooplankton and higher trophic-level living resources (Qingdao, China to Chejudao, Korea)	1	18/09/06-27/09/06	Yes	10
		2	25/12/06-02/01/07	Yes	9
		3	14/03/07-23/03/07	Yes	10
		4	17/05/07-27/05/07	Yes	11
		5	*10/06/07-16/06/07*	*No*	
		6	03/08/07-09/08/07	Yes	7
Focus 2	**Action 3.** Nutrient supply processes to the East China Sea shelf	1	19/11/06-23/12/06	Yes	35
		2	22/02/07-11/03/07	Yes	18
	Action 4. Nutrient supply processes in the coastal spawning grounds in the East China Sea	*1*	*25/04/07-06/05/07*	*No*	
		2	05/05/07-15/05/07	Yes	10
		3	*29/05/07-09/06/07*	*No*	
	Action 5. Mechanisms of the formation and the harmfulness of coastal hypoxia off the Changjiang Estuary	1	01/06/06-13/06/06	Yes	13
		2	16/08/06-31/08/06	Yes	16
		3	02/10/06-14/10/06	Yes	13

Table 2. Research foci, surveys and cruises in typical mariculture areas in north and south China

Focus and Survey Activity		Cruise	Survey Date	Completed	Days
Focus 6	**Action 6.1** Biogeochemical cycles and ecological carrying capacity in a typical mariculture area (Sungo Bay of Shandong Province)	1	25/04/06-25/05/06	Yes	30
		2	25/06/06-25/07/06	Yes	30
		3	13/11/06-18/11/06	Yes	6
		4	10/01/07-24/01/07	Yes	15
	Action 6.2 Biogeochemical cycles and ecological carrying capacity in a typical mariculture area (Xiangsham Bay of Zhejiang Province)	1	26/01/07-30/01/07	Yes	5
		2	09/04/07-13/04/07	Yes	5
		3	13/07/07-22/07/07	Yes	10
		4	16/08/07-21/08/07	Yes	6
		5	13/09/07-18/09/07	Yes	6
		6	12/10/07-17/10/07	Yes	6
		7	08/11/07-10/11/07	Yes	3

Action 5. Mechanisms of the formation and the harmfulness of coastal hypoxia off the Changjiang Estuary, including the development of the hypoxia, with emphasis on the role of nutrient over-enrichment on the formation of hypoxia and its negative effect on the structure and function of the coastal ecosystem.

Action 6: Biogeochemical cycles and ecological carrying capacity in typical mariculture areas, including shellfish/algae polyculture and sea-pen fish culture areas.

A total of 216 days survey was carried out on 14 cruises for Focus 1 and Focus 2 on board the *R/V Bei Dou* in 2006-7 in the Yellow Sea and East China Sea (Table 1 and Fig. 1). Table 2 shows 122 days survey for Focus 3 in the Sungou Bay of Shandong Province in North China and the Xiangshan Bay of Zhejiang Province in South China. They are studies of biogeochemical cycles and ecological carrying capacity in shellfish/algae culture and fish cage culture areas.

These studies are very important for understanding the resources and environment of the region. The main new findings from the GLOBEC/IMBER programme in 2006/7 include:

- Spring phytoplankton bloom processes in the absence of vertical water column stratification are found in the cold mass area of the Yellow Sea.
- Advances in knowledge on the mechanisms of formation and development of coastal hypoxia off the Changjiang Estuary.
- Functional group becomes the focus for zooplankton studies in the programme.
- New proof of the impact of climate change on fluctuation cycles of living marine resources in the North China Sea.
- Multiprinciple ecological studies provide basic information on ecoregions in the Yellow Sea and East China Sea.
- New production demonstration on the basis of a polyculture model in the bay area.

The findings above will enable us to consider new management strategies under the application of an ecosystem approach in the Yellow Sea and the East China Sea.

Recent activities of Korea GLOBEC

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The Korea GLOBEC committee was established by the Korean Society of Fisheries Resources and the Korean Society of Oceanography in 1998, chaired by Prof. Suam Kim, Pukyong National University. The objective of Korea GLOBEC was to develop a GLOBEC-like research programme in Korea. In 2004 Prof. Im Sang Oh took over the chair of the programme and now the committee is entering its third phase as the Korea GLOBEC/IMBER committee chaired by Dr. Sinjae Yoo, Korea Ocean Research and Development Institute (KORDI).

In August 2000, the first Korea-Japan Joint GLOBEC Symposium on "Long-tern variations in the northwestern Pacific ecosystem" was organised at Busan, Korea. Selected papers from the symposium were published in a special session of Fisheries Oceanography (see GLOBEC International Newsletter 6(2): 2000). In December 2002, we also organised the first China-Japan-Korea Joint GLOBEC Symposium on "Processes and dynamics in the northwestern Pacific ecosystem" at Ansan, Korea. Selected papers from that symposium were also published in the Journal of Oceanography (see GLOBEC International Newsletter10(2): 2004).

A second phase of Korea GLOBEC began in January 2004, with Prof. Im Sang Oh, Seoul National University elected as chairman. During this phase some of our committee members conducted several key projects in relation to the marine environment, climate change and ecosystem variability.

Dr. Chul-Ho Kim (KORDI) has conducted the northern East China Sea project entitled "Prediction of marine ecosystem variation in the East China Sea due to the long term climate change" since 2003. This project has focused on the monitoring and prediction of marine ecosystem variability due to climate change in the northern East China Sea with key parameters including the physical and chemical factors (nutrients, chlorophyll-*a*, partial pressure of CO_2 in the surface water, etc.), dynamics of lower trophic level community and squid larva population (Fig. 1).

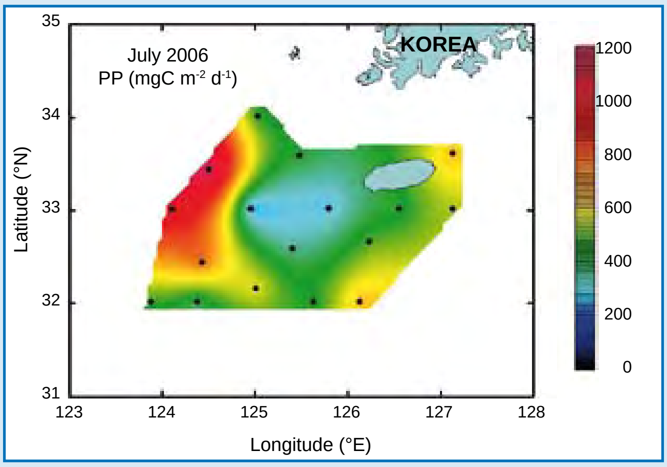

Figure 1. Primary productivity in the northern East China Sea, July 2006.

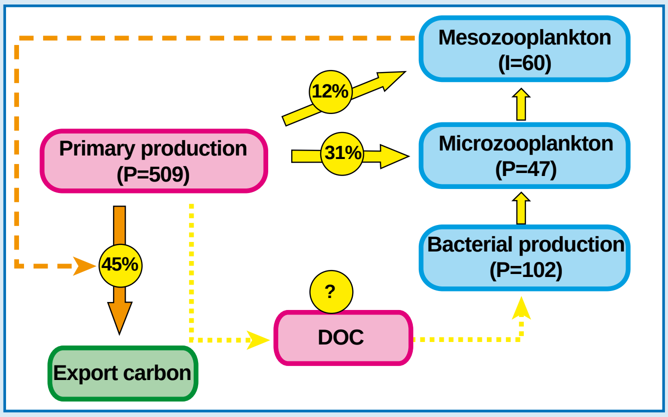

Figure 2. Estimated carbon flow (mgC m^{-2} day^{-1}) in the pelagic food web in the Ulleung Basin in spring 2006 (I: Ingestion, P: production).

The second project entitled "Carbon cycle in the East Sea: The Ulleung Basin" has been conducted by Dr. Sinjae Yoo, KORDI since 2005. This carbon cycle project focused on how the eddies and coastal upwelling shape the lower trophic level and influence the carbon fluxes in the Ulleung Basin. Many parameters were measured including: carbon dioxide exchange between the atmosphere and the upper ocean, biological processes in the upper ocean (including bacteria, protozoa, phytoplankton and zooplankton), organic carbon sinking to the deep ocean, sinking and recycling of organic carbon between the deep ocean and sediments, and finally organic carbon sedimentation (Fig. 2).

In 2006, we started a big project called "POSEIDON (Pacific Ocean Study on Environment and Interactions between Deep Ocean and National seas)" with Dr. Woong-Seo Kim, KORDI, as a principal investigator. The objective of the POSEIDON

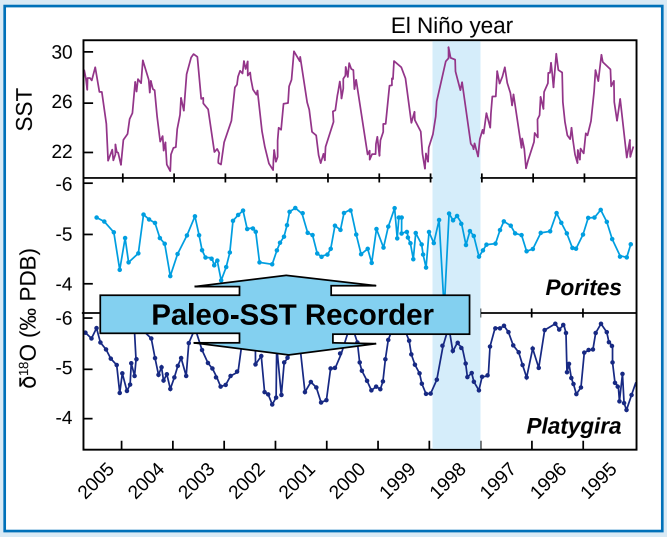

Figure 3. Reconstructed paleo-SST using oxygen isotopic values of $CaCO_3$ in the skeleton of corals.

project is to understand the impact of environmental variation of the northwest Pacific on the seas surrounding Korea (Fig. 3). The research area ranges from Hawaii through Micronesia (Chuuk), Philippine EEZ, Japan EEZ and East China Sea to Korea Strait.

The Korea GLOBEC committee has supported several young Korean scientists who want to present their results at international symposia since 2004 (Table 1). This programme will continue until 2013.

Table 1. Summary of the financial support programme for young Korean scientists

Year	No. of recipients	Symposium
2004	8	PICES (13th), Hawaii
2005	3	GLOBEC Symposium, Victoria
2005	5	PICES (14th), Vladivostok
2006	3	PICES/GLOBEC CCCC Symposium, Hawaii
2006	7	PICES (15th), Yokohama
2007	2	PICES (16th), Victoria
2007	3	China-Japan-Korea GLOBEC Symposium, Hakodate

Recently, the Korea GLOBEC committee was replaced by a new Korea GLOBEC/IMBER committee and chaired by Dr. Sinjae Yoo. The new committee will invite new members and take responsibility for building the new research framework for Korea IMBER activities after 2009.

Figure 4. Some members of Korea GLOBEC committee. Left to right, back row: Hyoung Chul Shin, Chul Ho Kim, Hee Dong Jeong, Suam Kim. Front row: Hyung-Ku Kang, Jin Young Kim, Im Sang Oh.

Ecosystem modelling to evaluate changes in the structure and function of the East China Sea ecosystem around the Three Gorges Dam

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An ecosystem model was used to evaluate changes in the structure and function of the East China Sea ecosystem, which has been influenced by the construction of the Three Gorges Dam in China (Trites *et al*., 1999). The biological organisms in the East China Sea ecosystem were divided into 21 species or groups using a self-organising mapping (SOM), based on the characteristics of the organisms in the study area (Lek and Guegan, 1999). Common squid were separated into an independent group because this species is one of the most important species with the biggest catch in the East China Sea. Ecosystem parameters for each group were estimated before and after the construction of the Three Gorges Dam. Estimated parameters include biomass, P/B ratio, Q/B ratio and diet matrix of each species or group (Christensen *et al*., 2005; MOMAF, 1996-2005; Tamura and Ohsuni, 1999). Biomass and P/B ratios of phytoplankton and zooplankton were estimated from the NEMURO model which can be used to investigate the lower trophic level for each group by analysing food organisms of each group and prey-predator relationships (Pauly *et al*, 1998). It was found that mean trophic levels have declined since construction of the dam.

This study aims to analyse changes in the structure of the East China Sea ecosystem and the fisheries resources (Fig. 1). The species in the ecosystem were divided into 21 species groups (Table 1). The basic input parameters of the species

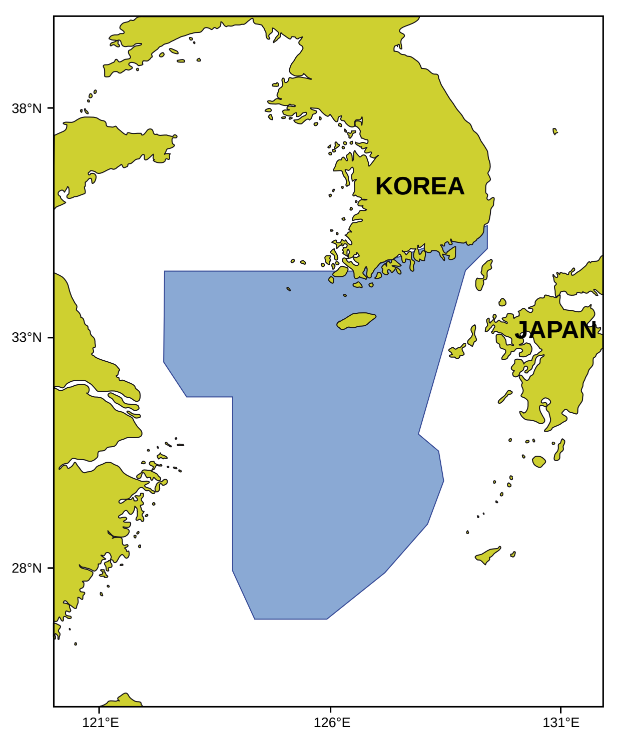
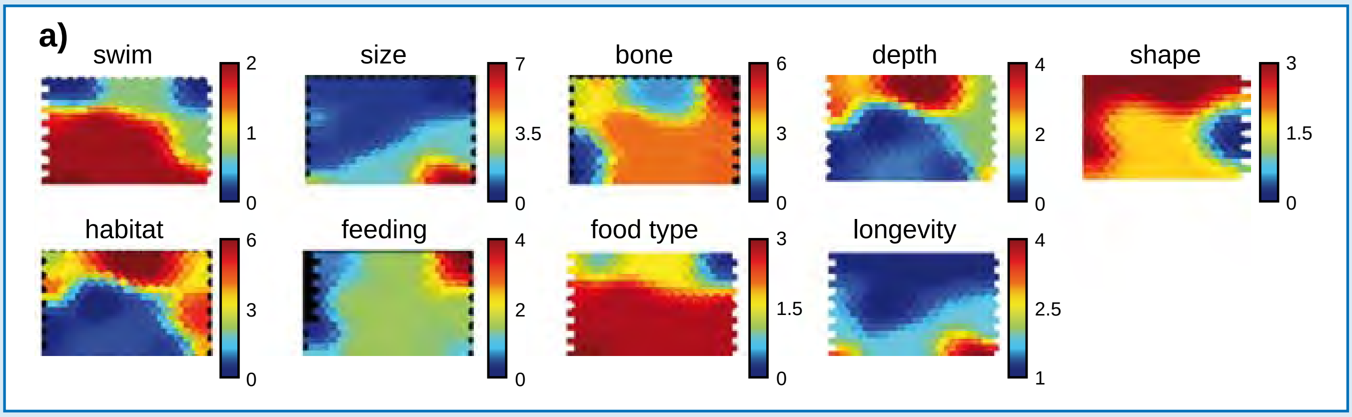


Figure 1. Area defined for the ecosystem model in the East China Sea.



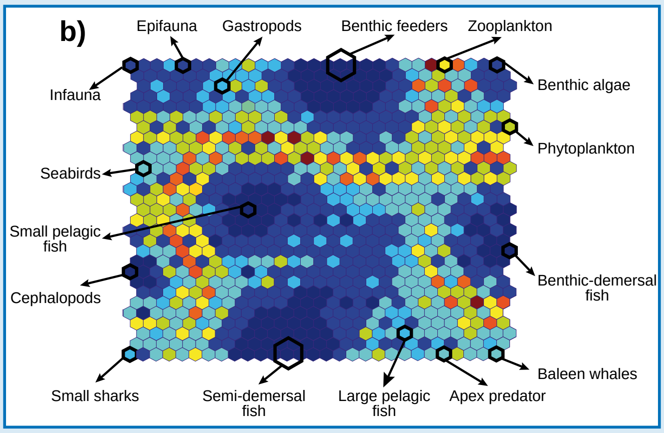


Figure 2. Organisms grouping using self-organising mapping in the East China Sea, (a) 9 ecological characteristics, (b) species name and ecological niche of each species group.

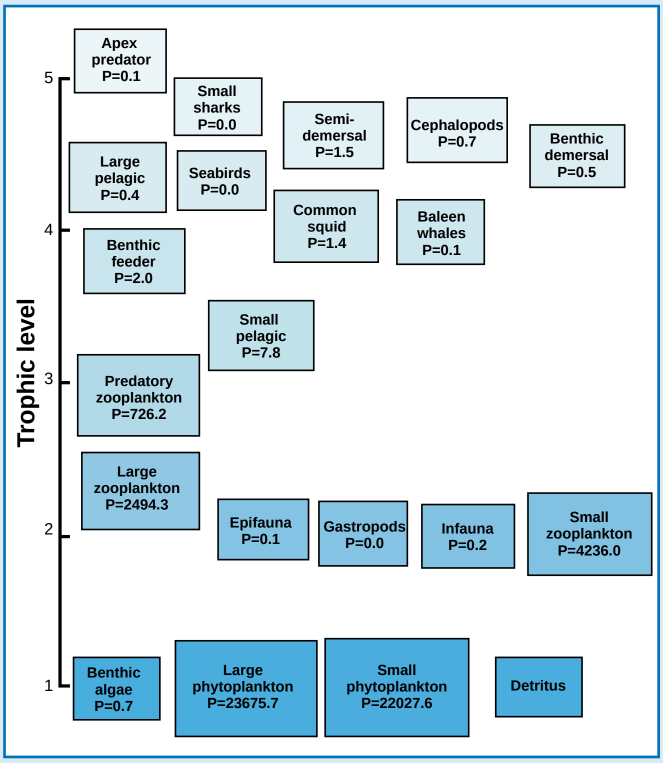


Figure 3. The structure of the East China Sea ecosystem after the Three Gorges Dam (P: Production).

Table 1. Species groups used in the ecosystem model in the East China Sea

Group name	Species name
Apex predator (8)	Great white shark, shortfin mako, scalloped hammerhead, smooth hammerhead, tiger shark, sperm whale, Risso's dolphin, finless porpoise
Baleen whales (6)	Blue whale, fin whale, Sei whale, Bryde's whale, Minke whale, northern right whale
Small sharks (3)	Blue shark, spiny dogfish, broadnose severgill shark
Seabirds (6)	Black-tailed gull, common tern, Sander's gull, slaty-backed gull, black scoter, Temminck's cormorant
Common squid (1)	*Todarodes pacificus*
Small pelagic fish (13)	Pacific sardine, horse mackerel, Pacific saury, common mackerel, anchovy, half beak, sand smelt, puffers, Pacific sand lance, gizzard shad, Pacific herring, Chinese herring, *Setipinna taty*
Large pelagic fish (7)	Tunas, yellowtail, trouts, sea bass, grey mullets, Spanish mackerel, Salmonidae
Semi-demersal fish (37)	Walleye pollock, sandfish, hairtail, javeline goby, brushtooth lizardfish, Indian flathead, Pacific cod, big eyed herring, blenny, brown croaker, blackthroat seaperch, sevenband grouper, pomfrets, sharp toothed eel, common conger, inshore hagfish, black sea bream, red sea bream, red horsehead, corafish, other sea breams, scorpion fish, rock fish, jacopever, bluefin searobin, atka mackerel, file fish, small yellow croaker, white croaker, yellow croaker, bighead croaker, other croakers, Pacific sandeel, spotty belly greenling, shaggy sea raven, grassfish
Benthic demersal fish (6)	Flounders, flatfishes, tonguefishes, skates, skate ray, goosefishes
Cephalopods (6)	Cuttlefishes, octopus, webfoot octopus, small octopus, mimika bobtail, other cephalopods
Benthic feeders (9)	Blue crab, other crabs, Japanese spiny lobster, large shrimp, kuruma prawn, akiami paste shrimp, medium shrimp, southern rough shrimp, other shrimps
Epifauna (5)	Oysters, sea urchin, sea squirts, sea cucumber, other aquatic animals
Gastropods (4)	Baitop shell, top shell, abalones, variously coloured abalone
Infauna (15)	Scallops, venus clam, Chinese mactra, granular arks, surf clam, Gould's jackknife clam, filipino venus, venus clams, Japanese cockle, Japanese geoduck, comb pen shell, Broughton's ribbed ark, hard shelled mussel, purplish Washington clam, other shellfish
Zooplankton (4)	Copepoda, Chaetognatha, Decapoda, Amphipoda
Benthic algae (12)	Laver, sea cabbages, Typicuses, sea duckweed, sea mustard, agar, sea staghorn, Seaweed fusiforme, sea lettuce, sea string, other agar-agar, other seaweeds
Phytoplankton (2)	Diatoms, dinoflagellates

Table 2. Weighted mean trophic levels in terms of biomass and catch in the East China Sea ecosystem

	Mean trophic level	
	Pre-construction	Post-construction
Biomass*	4.52	4.48
Catch	3.91	3.67

*Biomass of species groups: common squid, semi-benthic demersal, benthic demersal, cephalopod and benthic feeders.

groups before and after the Three Gorges Dam construction were estimated (Fig. 2). Based on these data, the structure of the East China Sea ecosystem was constructed (Fig. 3).

Changes in the trophic level and the ecosystem structure caused by the Three Gorges Dam construction were identified. Nine species groups had lower trophic levels after the Three Gorges Dam construction. The mean trophic level in terms of biomass was 4.52 before the construction and was 4.48 after the construction, and that in terms of catch was 3.91 before the construction and was 3.67 after the construction (Table 2).

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Vertical attenuation of PAR in the Yellow Sea

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The Yellow Sea is one of the most turbid coastal oceans. The optical properties and related parameters, including planar Photosynthetically Available Radiation (PAR, 400-700 nm), turbidity and the concentration of chlorophyll *a* ([Chl-*a*]), were measured during a cruise from 19 to 27 March 2005 in the Yellow Sea (the observation stations are shown in Figure 1). Based on these data, this study first analyses the vertical attenuation characteristics of PAR, which are shown as K_d (PAR) and the factors that affect light attenuation in the sea. An aquatic optical radiative transfer model (AOMC) is then used to simulate the light attenuation characteristics in different areas of the Yellow Sea. The relationship between the main light attenuation factors and the apparent optical properties were studied.

The vertical variation of PAR in the whole Yellow Sea can be expressed by exponential functions at different stations. The distribution of turbidity and the concentration of chlorophyll *a* [Chl-*a*] have distinct regional differences in the Yellow Sea. The mean K_d (PAR) is about 0.277±0.07 m^{-1} of the entire area which is considerably higher than other Case 2 seawaters. The clearest and most turbid waters occurred at station G17 (0.206 m^{-1}) and station G23 (0.353 m^{-1}) respectively. The main factors affecting light attenuation are different between stations which show some regional characteristics and complicated situations. At most stations K_d (PAR) has no coherent relationship with [Chl-*a*] but increases with turbidity at some stations implying that it is not the phytoplankton but the non-algal particles that are the primary light attenuation factors (Fig. 2). However, at some near shore stations there is no obvious relationship between K_d (PAR), turbidity and [Chl-*a*], and accordingly the controlling factors are complex in offshore waters (Fig. 2).

The Aquatic Optical Monte Carlo model (AOMC) developed by Manuel Gimond (2004) is used to study the light attenuation characteristics of the Yellow Sea. At most stations, the vertical averaged PAR attenuation coefficient K_{dM}(PAR) computed by the AOMC has a high agreement with K_{dO}(PAR) calculated from the observed data. The relative errors between K_{dM}(PAR) and K_{dO}(PAR) are within the range of 20%. On the basis of the AOMC model results and the observed data in the Yellow Sea, a simple relationship between turbidity and K_d(PAR) has been derived as $K_d(PAR) = 0.0933 * T + 0.122$ (Fig. 3).

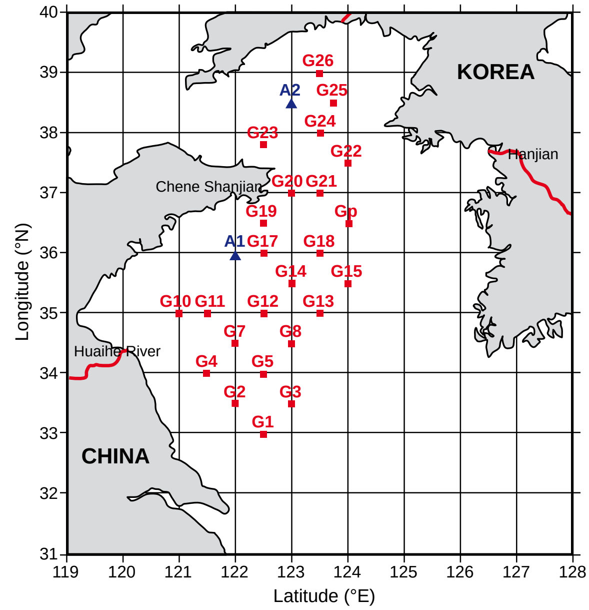

Figure 1. Observation stations in the Yellow Sea.

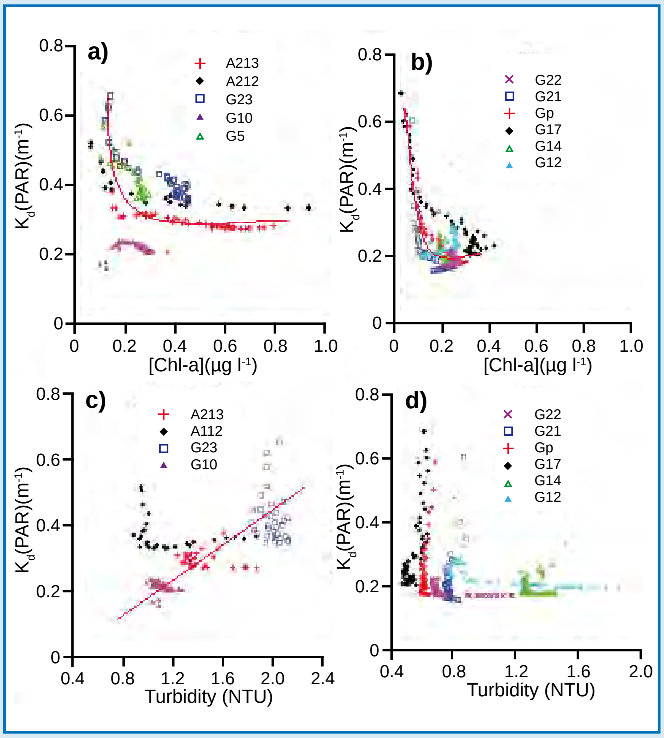

Figure 2. K_d (PAR) with Chl.a and turbidity (a) near shore, (b) off shore.

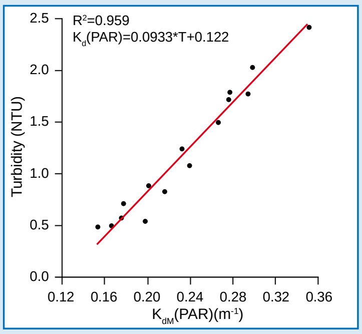

Figure 3. Relationship between K_{dM}(PAR) and turbidity T(NTU)

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Vertical distribution of suspended fecal pellets and potential fecal pellet production of the copepod community in the Ulleung Basin in the East/Japan Sea

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We investigated the vertical distribution of suspended fecal pellets (SFP) in the water column and production of fecal pellets by the copepod community to understand the importance of mesozooplankton fecal pellets in the carbon cycle in the Ulleung Basin, southwestern East/Japan Sea in July 2005. An anticyclonic warm eddy which has been known in the southwestern East/Japan Sea (Chang *et al*., 2004) existed in the centre of the Ulleung Basin. The warm eddy was stratified with a seasonal thermocline and a strong subsurface chlorophyll maximum (SCM) layer in the centre of the eddy developed at 40 m depth. Experiments were carried out at two stations in the Ulleung Basin: D2 (at the periphery of the warm eddy) and D4 (inside the warm eddy).

SFP were collected at depths of 10, 30, 50, 100 and 150 m. Water samples were collected by day and night with two 10 l Niskin bottles. SFP were retained on a 20 μm mesh sieve and were preserved with Lugol's solution. Carbon content of the fecal pellets was estimated assuming a carbon:volume ratio of 0.0694 mgC mm^{-3} (Riebesell *et al*., 1995). Fecal pellet production rates by copepods were measured twice a day (day and night time) at both stations. Six experimental bottles with 6-10 copepods and two control bottles (0.8 l) containing the seawater from 10 m depth and SCM layer were incubated at 23°C for three hours. At the end of the incubation, the contents from the bottles were sieved through a 20 μm mesh sieve and the copepods and fecal pellets were preserved with Lugol's solution for later quantification. The potential fecal pellet production of the copepod community was calculated by multiplying the copepod abundance in the upper 200 m by the average fecal pellet production rate, assuming that fecal pellet volume of copepods was proportional to the copepod body size (Uye and Kaname, 1994).

Small sized copepods such as *Paracalanus* and *Clausocalanus* dominated in abundance in the upper 200 m at both stations. Also there was no significant difference in zooplankton abundance between day and night sampling.

Mean biomass of SFP in the upper 150 m was higher at station D2 than at station D4 and the mean biomass of SFP increased positively with zooplankton biomass in the upper 200 m (Fig. 1). High zooplankton feeding activity around the SCM layer and the strong seasonal stratification of the water column were responsible for this positive relationship between the mean biomass of SFP and the zooplankton biomass. The SFP

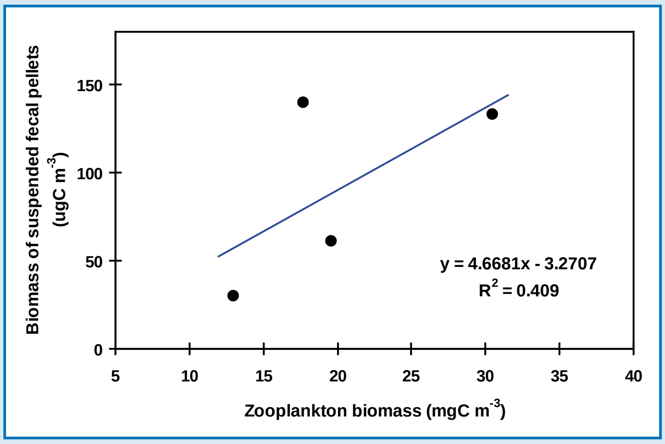

Figure 1. The relationship between biomass of suspended fecal pellets and zooplankton biomass in the Ulleung Basin in July 2005.

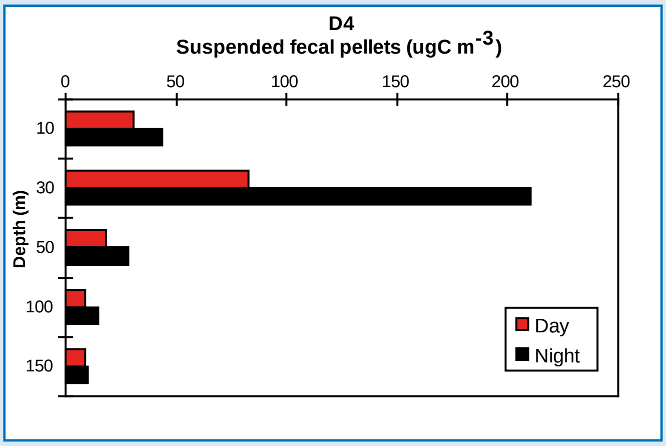

Figure 2. Vertical distribution of suspended fecal pellets in day and night and at inside the eddy (station D4) in the Ulleung Basin in July 2005.

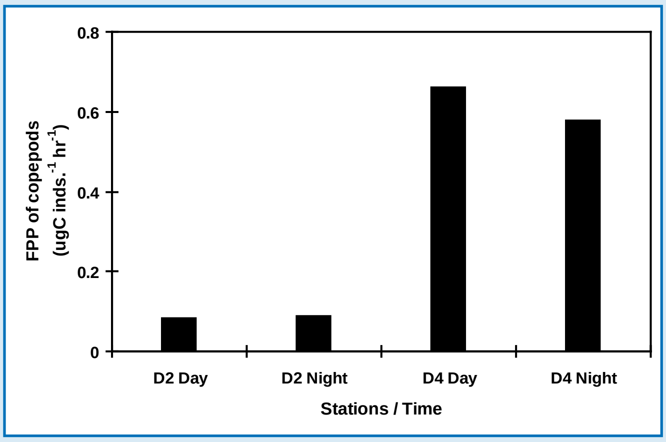

Figure 3. Fecal pellet production (FPP) of individual copepod measured on board in day and night at stations D2 and D4 in the Ulleung Basin in July 2005.

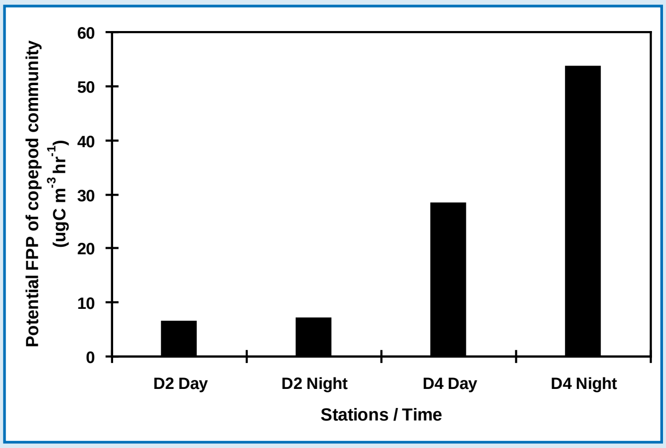

Figure 4. Potential fecal pellet production (FPP) of copepod community in day and night at the periphery of the warm eddy (station D2) and at inside the eddy (station D4) in the Ulleung Basin in July 2005.

varied between from 0.006 to 0.58 mgC m^{-3} at station D2 and from 0.009 to 0.21 mgC m^{-3} at station D4. The SFP peaked at 30 m depth at both stations, corresponding to the seasonal thermocline and the SCM layer, without a clear difference in the vertical distribution pattern of SFP between day and night sampling (Fig. 2). The fecal pellets produced in the upper 40 m were retained at the seasonal thermocline depth or in the SCM layer, and then decomposed and fragmented into small pellets by bacteria and copepod activity including coprophagy or coprorhexy (Viitasalo *et al.*, 1999; Poulsen and Kiørboe, 2005). Therefore, downward flux of the fecal pellets in the upper 40 m to the deep water decreased inside and at the periphery of the warm eddy in Ulleung Basin in summer.

The fecal pellet production of individual copepods measured on board was significantly higher at station D4 than at station D2 (Mann-Whitney U test, $p<0.001$; Fig. 3) due to the higher chlorophyll *a* concentration in the SCM layer at station D4. The potential fecal pellet production rate of the copepod community was 6.36 μgC m^{-3} hr^{-1} by day and 7.12 μgC m^{-3} hr^{-1} at night with a mean of 0.16 mgC m^{-3} day^{-1} at station D2 (Fig. 4). The potential production of fecal pellets by the copepod community at station D4 was 28.32 μgC m^{-3} hr^{-1} during the day and 53.67 μgC m^{-3} hr^{-1} at night and averaged 0.98 mgC m^{-3} day^{-1} (Fig. 4). Therefore, the estimated fecal pellet production of the copepod community in the Ulleung Basin was higher inside the warm eddy than at the periphery of the eddy in summer 2005.

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Dietary shifts and feeding intensity of *Stenobrachius leucopsarus* in the Bering Sea

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Stenobrachius leucopsarus is one of the most abundant fishes in the Bering Sea and it plays an important role in transporting matter from the productive epipelagic zone to the deep sea (Longhurst and Harrison, 1988). Besides being an important prey for higher trophic levels, S. *leucopsarus* is also a potential competitor for zooplanktivorous fish, which utilise the Bering Sea as a nursery area during summer. In the present study, the food habits of *S. leucopsarus* were examined in the central basin of the Bering Sea in relation to oceanographic conditions.

Shipboard sampling was conducted during four cruises of *R/V Kaiyo-Maru* in the Bering Sea; 3-18 September 2002, 30 June - 13 July 2003, 3-12 September 2003 and 2-14 June 2006. During the 2002 and 2003 cruises, micronekton was sampled using a rectangular midwater trawling (RMT) net with a 12 m^2 mouth opening and 6 mm mesh size. During the 2006 cruise, a MOHT net with a 5 m^2 mouth opening and 1.59 mm mesh size (Oozeki *et al*., 2004) was used. These nets were towed obliquely from a depth of either 500 m (RMT) or 300 m (MOHT) to the surface at ship speeds of 2-3 knots (3.7-5.6 km h^{-1}). The nets were deployed one hour after sunset. Hydrographic observations were made at 13 to 27 stations during each cruise using a CTD instrument. An approximate indicator of density of phytoplankton in the central basin was the relative value of fluoresence measured by an Electric Plankton Counter System (EPCS; Thrner Desins, 10-AU-005 fluorometer). We measured and weighed each *S. leucopsarus* collected, and removed the stomachs from up to 30 individuals at each station.

The relative value of fluorescence (EPCS) in June 2006 was much higher than the other cruises. The high fluorescence value indicates a spring bloom during June 2006. We examined the stomach contents of a total of 690 individuals of *S. leucopsarus*, ranging from 17.2 mm to 99.2 mm SL. Of these, 208, 172, 180 and 130 were collected in September 2002, July 2003, September 2003 and June 2006, respectively. The diet of *S. leucopsarus* was generally predominated by copepods, ostracods, euphausiids and amphipods, comprising at least 35 genera and 50 species. *S. leucopsarus* exhibited an ontogenetic and seasonal dietary shift. In spring, small fish (<40 mm) preyed mainly on *Neocalanus flemingeri/plumchrus* whereas large fish fed mainly on *Neocalanus cristatus* (Fig. 1). In summer, small fish preyed mainly on *Metridia pacifica* whereas large fish fed mainly on euphausiids (*Thysanoessa* spp.).

The ontogenetic dietary shift of *S. leucopsarus* caused by gape size limits the ingestion of oversized prey (e.g. *Thysanoessa* spp., *N. cristatus*). Another possible source of ontogenetic difference in the present study is different DVM patterns according to fish size.

Seasonal dietary shift of *S. leucopsarus* reflects the seasonal variation in zooplankton composition. *Neocalanus* spp. performed ontogenetic vertical migration (Mackas and Tsuda, 1999). It is thus concluded that the seasonal difference found in the diets of *S. leucopsarus* reflects seasonally varying abundances of prey species in the feeding layer.

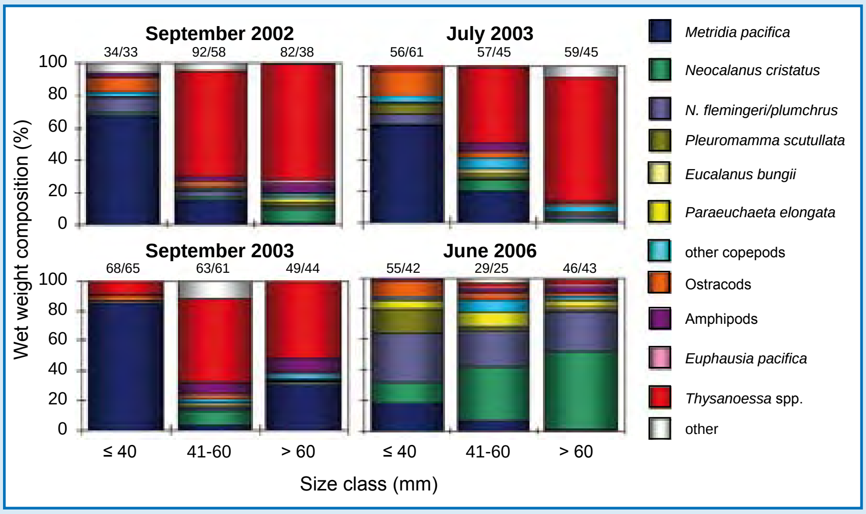

Figure 1. Stenobrachius leucopsarus. *Dietary composition for different periods and size classes in wet weight composition in the Bering Sea basin. Numbers above each bar show number of stomachs examined and containing food, respectively.*

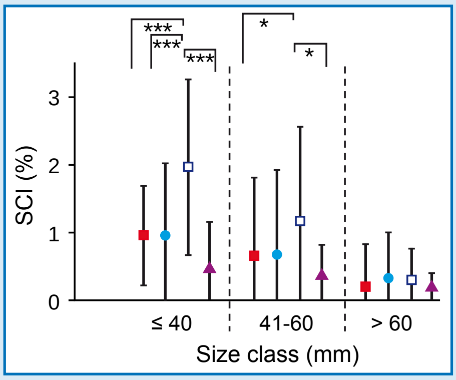

Figure 2. Stenobrachius leucopsarus. *Comparison of stomach contents index (SCI) among different fish size classes and sampling months (closed square: September 2002, closed circle: July 2003, open square: September 2003, closed triangle: June 2006). Error bars indicate +1 standard deviation; *: P < 0.05, ***: P < 0.001 in ANOVA.*

In the summer of 2003, when water temperature in the epipelagic layer (<100 m) was warmer, reflecting the prevalence of the Alaskan Stream, small-sized *S. leucopsarus* showed a higher stomach content index (Fig. 2), perhaps reflecting the greater abundance of *M. pacifica*. Thus, the present study shows that the physical variability in the epipelagic layer affects not only diets but also feeding performance of micronekton.

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Genetic divergence and demographic history of the Pacific herring *Clupea pallasii* in the north Pacific

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Pacific herring *Clupea pallasii* is a commercially important fish species, which is widely distributed throughout much of the North Pacific Rim (Grant and Utter, 1984). In previous research, it was thought that the species was derived from Atlantic herring in the Arctic Ocean which dispersed into Pacific after the Bering Strait opened in the late Pliocene (Grant, 1986). The Quaternary was famous as a series of frequent climate oscillations and large-scale glaciations (Avise, 2000). It indicates that the phylogeographic pattern of the species should be influenced heavily by such environmental changes. The purpose of our study is to ascertain the population genetic structure and demographic history of the species. This information can help to evaluate the genetic consequences to the species of climatic oscillations and glaciation in the north Pacific, and it is also crucial to the success of long-term fisheries conservation because consistent exploitation of mixed populations often leads to the demise of the least productive stocks (Schweigert, 1993).

To assess these objectives, a 479-bp segment of 5' end of mitochondrial DNA control region was sequenced in 319 Pacific herring specimens collected from 9 localities (Fig. 1). Three distinct lineages were detected based on the phylogenetic tree of 143 haplotypes, which indicated two geographic groups, the northwestern Pacific group and the eastern Pacific group (Figs. 1 and 2). Hierarchical molecular variance analysis (AMOVA) and the conventional population F_{ST} comparisons revealed significant genetic divergence between the two groups (Φ_{CT} = 0.423; P = 0.02). In contrast to the northwestern Pacific group, the eastern Pacific group exhibited a higher genetic diversity. The nested clade analysis (NCA) produced a network with four nested levels, which correspond to the phylogenetic tree.

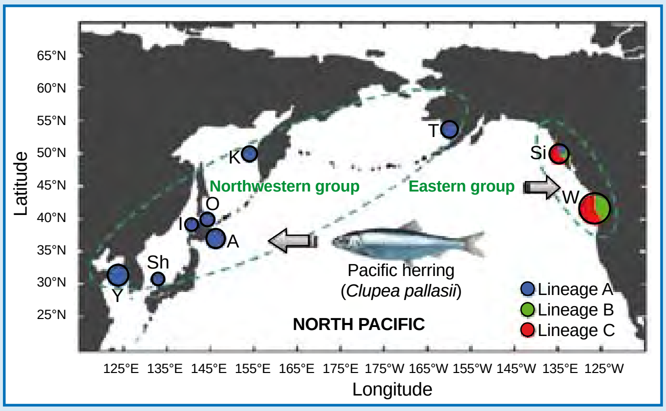

Figure 1. The sampling localities and the frequency of 3 haplotype lineages (A, B and C). Y(39): Yellow Sea, Sh(24): Shimane, I(24): Ishikari Bay, O(26): Okhotsk Sea, A(36): Akkeshi, K(29): Western Kamchatka, T(30): Togiaki, Si(26): Sitka Island and W(84): Washington Inlet.

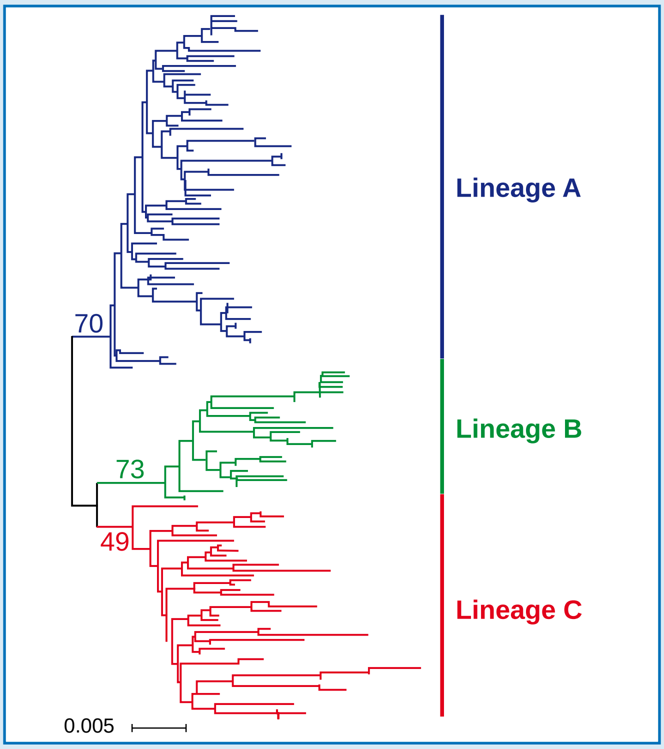

Figure 2. Unrooted neighbour-joining tree constructed using a TrN model for 143 haplotypes. Bootstrap supports for lineage A, B, C in 10000 replicates are shown above branches.

Most clades in the northwestern Pacific group were inferred as a result of contiguous range expansion, while in the eastern Pacific group the demographic events were mostly restricted gene flow with isolation by distance. The neutrality tests and mismatch distribution analysis indicated that Pacific herring experienced a series of range and population expansions. The expansion time of the eastern Pacific group was earlier than the northwestern Pacific group.

From these results, we postulated that the species experienced a long distance colonisation entering the Pacific as a repeated Pleistocene glaciation south of Alaska might have blocked the gene flow and permitted the two geographical groups to diverge. However, the paleogeographic environment in the northwestern Pacific was less stable during the Pleistocene glacial-interglacial changes than the eastern Pacific. The gene flow among the populations of eastern Pacific might reach a dynamic balance earlier than in the northwestern Pacific, which could explain the differences between the two geographic groups.

Acknowledgements

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Comparative phylogeography study of Japanese sand lance *Ammodytes personatus* in northwestern Pacific

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Geographical patterns of genetic variation reflect both historical processes and present gene flow attributable to the biological characteristics of the organism (Imron *et al*., 2007). The Japanese sand lance is a common and commercially important species in the coastal waters of Japan (Inoue, 1949; Okamoto, 1988). To assess the role of historical process and contemporary factors in shaping population structures in the northwestern Pacific, phylogeographic patterns of Japanese sand lance were studied.

The phylogeographic patterns of Japanese sand lance sampled from 17 populations through its entire range were investigated using the mitochondrial DNA control region sequences (Fig. 1). Population genetic structures were detected by AMOVA (analyses of molecular variation) and F_{ST} statistics (Schneider *et al*., 2000). Demographic history was examined using neutrality tests and mismatch distribution analyses.

Two distinct lineages were detected, which might have been diverged in the Sea of Japan and Pacific coastal waters of the Japanese Islands, during low sea level (Fig. 2). Significant genetic structure was revealed as expected between the Kuroshio and Oyashio Currents. However, significant genetic differentiation was also detected in the Sea of Japan, contrasting the expected homogenisation hypothesis in the Tsushima Current (Kitamura

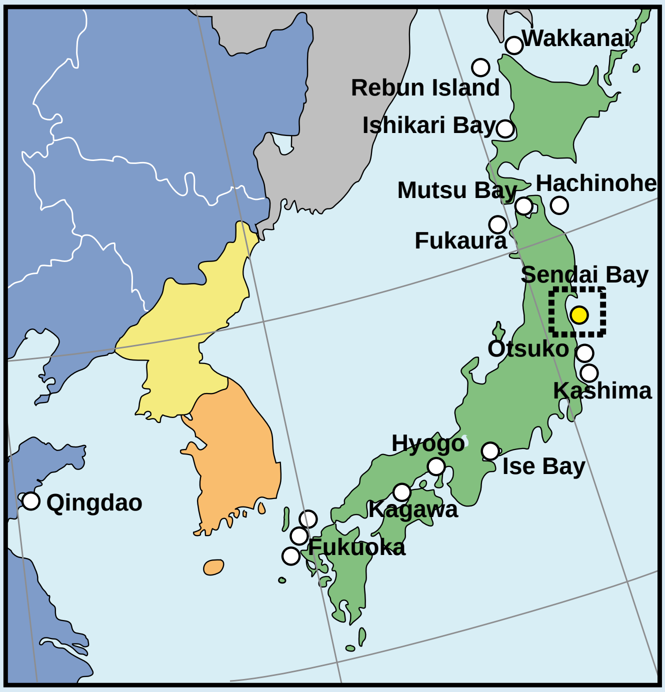

Figure 1. Sample locations

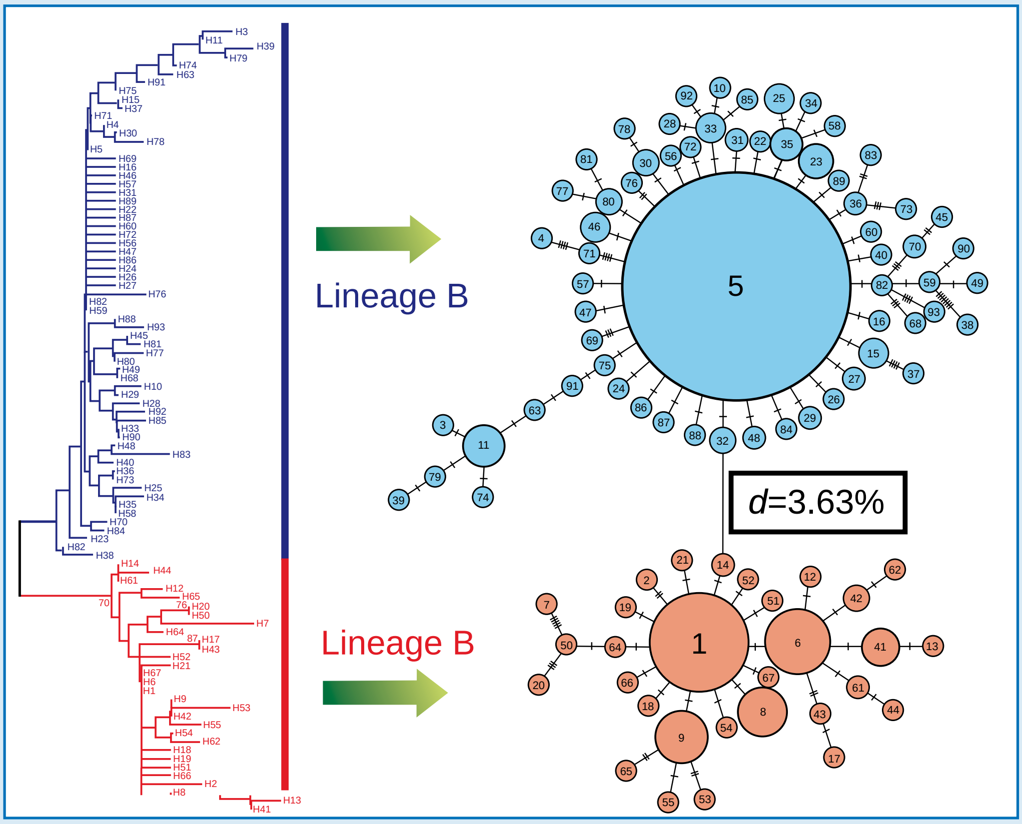

Figure 2. NJ tree and network based on the transversion haplotypes.

and Kimoto, 2006). The haplotype frequency of two lineages from both sides of the Japanese Islands revealed that the distribution of lineage B was highly limited by the annual sea temperature (Fig. 3). The lack of lineage B in Qingdao populations with a low sea temperature reflected the sea temperature barrier. The lack of genetic structure in the south and north groups indicates that the potential dispersal of Japanese sand lance is high. The ocean currents within the groups also facilitates the dispersal of this species.

Our results illuminate the combination of historical processes and contemporary factors to shape present population structure in *A. personatus*. The process of secondary contact between the two lineages and the distribution of the north and south groups was heavily influenced by sea temperature. The ocean current reinforces and weakens the sea temperature barrier. This gave us a lesson about how the cold-water species responds to the ocean current and sea temperature. This also provides information about the mechanism of ocean currents on population structure in marine species. Our results suggested that annual sea temperature could serve as an indicator for group identification. The fishery management of *A. personatus* can benefit from our results.

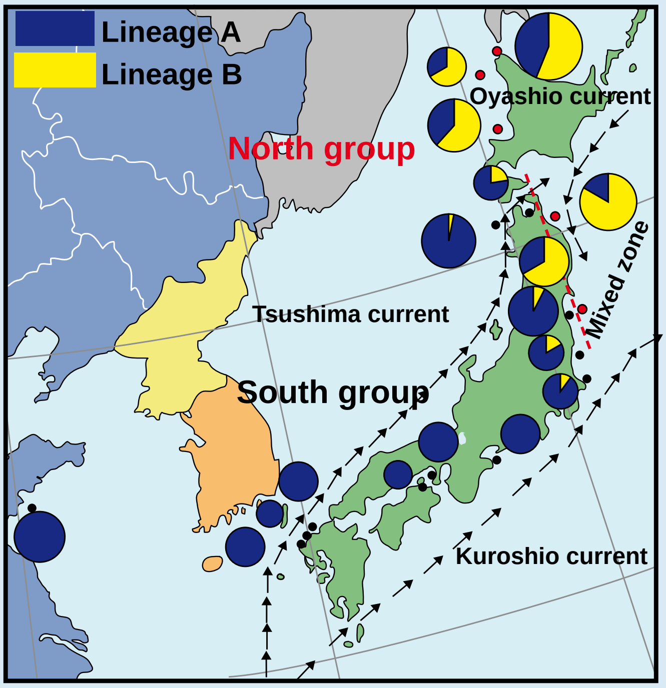

Figure 3. Haplotype frequencies for Japanese sand lance populations.

Acknowledgement
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Population genetics of two sciaenid species (*Pennahia argentata* and *Nibea albiflora*) in the northwestern Pacific inferred from mtDNA sequences

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The purposes of this research was to assess how marine species responded to the severe climatic oscillations in the Pleistocene ice ages and investigate the population genetic structures of two commercially important sciaenid species (*Pennahia argentata* and *Nibea albiflora*; Zhu *et al.*, 1963; Seikai National Fisheries Research Institute, 2001).

The mtDNA control region was sequenced for 132 individuals of white croaker *Pennahia argentata* collected from 12 localities and 65 individuals of *Nibea albiflora* collected from 3 localities over much of their ranges (Fig. 1). Population genetic structures were detected by AMOVA (analyses of molecular variation) and F_{ST} statistics (Nei, 1987; Schneider *et al.*, 2000). Demographic history was examined using neutrality tests and mismatch distribution analyses.

Two distinct clades with a net genetic divergence of 3% in the control region were detected, one in Chinese coastal waters and another in Japanese coastal waters, which might have been isolated and diverged during Pleistocene low sea levels (Fig. 2; Hewitt, 2000). Nucleotide diversity was much higher in the Chinese clade than in the Japanese clade. Molecular variance analyses and pairwise F_{ST} revealed significant differentiation between two Japanese populations and lack of genetic structure in Chinese populations. In conclusion, our results show that two clades of white croaker experience significant genetic differentiation at the mitochondrial DNA level, and exhibit deep phylogenetic separation, indicating that the Chinese and Japanese clades may be different subspecies or species. The Chinese populations cannot serve as a single stock, because panmixia cannot be confirmed by AMOVA for the Chinese clade, and there are different stocks in Japan coastal waters. These results have important implications for fisheries management of this species in China and Japan. However, a rigorous evaluation of the species status will need multilocus nuclear DNA, morphological and mark-recapture studies. More individuals and populations will be collected to detect the exact distribution of these two clades in the East China Sea. Based on these findings, conservation efforts are necessary to guarantee the genetic integrity of these distinct stocks.

No distinct clade was detected in *N. albiflora* (Fig. 3). AMOVA and pairwise F_{ST} revealed little genetic structure between the Yellow and the East China seas in *N. albiflora*. But based on the exact test of differentiation, the null hypothesis that *N. albiflora* within the Yellow and East China seas constitutes a panmictic mtDNA gene pool was rejected. The existence of high gene flow between stocks in the studied area was supported by our results. Annual migrations, larval drift in the ocean currents, and recent range expansion could be the reasons for little genetic structure in the studied area.

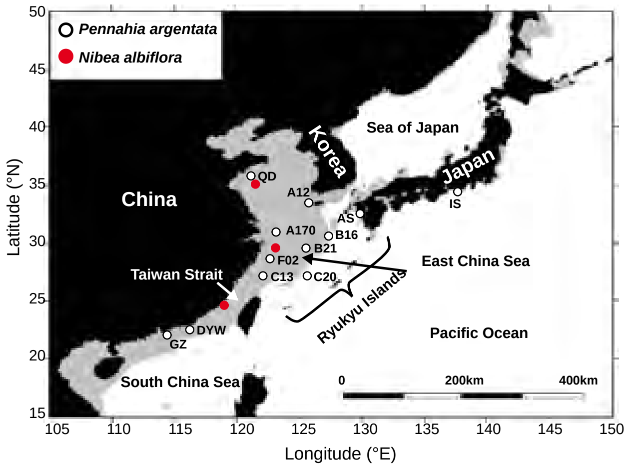

Figure 1. Sample locations for two species.

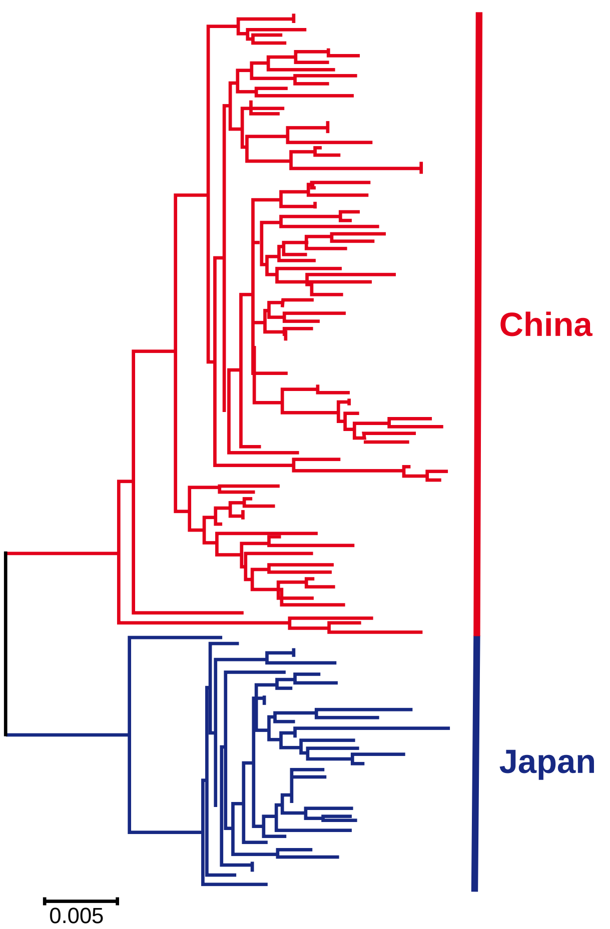

Figure 2. NJ tree based on the control region in Pennahia argentata*.*

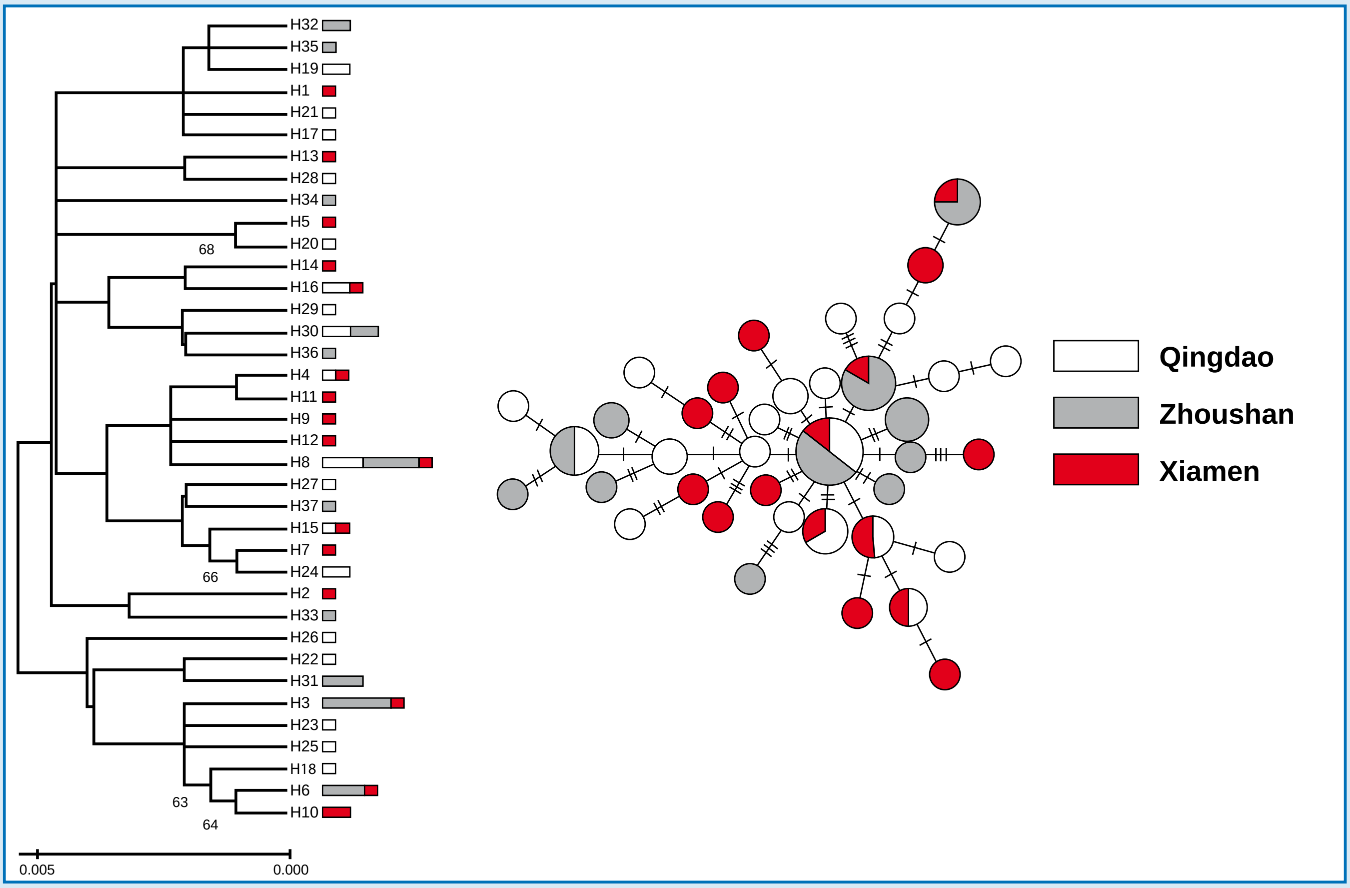

Figure 3. NJ tree and haplotype network for Nibea albiflora.

Acknowledgment

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Genetic variation in the small yellow croaker *Larimichthys polyactis*

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The small yellow croaker, *Larimichthys polyactis*, is a benthopelagic fish species of the family Sciaenidae, which inhabits coastal waters and estuaries (FishBase, 2005). The species is an important fisheries resource and is also becoming an important marine food fish species in Asian countries (FishBase, 2005). Global capture production for *L. polyactis* reached 320 thousand metric tonnes in 2000. Heavy exploitation has resulted in a decreasing catch in the Yellow Sea and East China Sea (Froese and Pauly, 2003). Although a number of studies of the species from morphological and ecological research have been made (Zhang and Chen, 2005; Xu *et al.*, 2005), the basic biological information obtained so far is not enough to elucidate the population structure. Also, there is no information about the genetic diversity, population genetic structure and demographic history of the wild stocks of this species.

Assessments of intraspecific genetic diversity and population genetic structure can provide important biological and

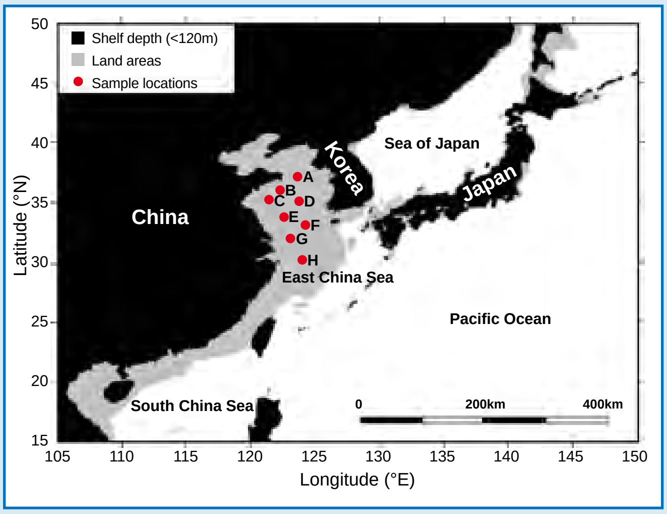

Figure 1. Map showing sample locations of L. polyactis, samples are marked by abbreviations as A-H. The North Yellow Sea group includes A-D, the South Yellow Sea group includes E-G and the North East China Sea group includes H based on the migrating routes of the species. Shaded sea areas are continental shelves that would have been exposed to the air during periods of low sea-level.

evolutionary data, which are also invaluable for the successful conservation or management of exploited species. From a biological perspective, the assessment can imply whether the species is panmictic throughout its range and help to identify the potential sites of historic refugium. From a management perspective, an accurate definition of population structure is important for the management of commercial marine fish (Utter, 1991). Failure to detect population units can lead to local overfishing and ultimately to severe declines (Waples, 1998).

In the present study, we examined the genetic diversity and population genetic structure of small yellow croaker using sequence analysis of a portion of the mitochondrial DNA (mtDNA) control region, a genetic marker that has been shown to be particularly sensitive in detecting population genetic structure of marine fish (Buonnacorsi *et al.*, 2001). We sequenced a 411 base-pair fragment of the mitochondrial DNA (mtDNA) control region from 114 individuals of small yellow croaker collected at eight localities from Yellow Sea to North East China Sea (Fig. 1). A total of 84 polymorphic sites were found in the control region, and 87 haplotypes were defined in the 114 individuals. The average nucleotide divergence between samples ranged from 1.0% to 1.6%. The demographic history of *L. polyactis* was examined using neutrality tests and mismatch distribution analysis, suggesting Pleistocene population expansion existed in the species. Hierarchical molecular variance analysis (AMOVA) and the conventional population F_{ST} comparisons revealed no significant genetic structure throughout the examined range of the small yellow croaker. Any long internal branches could not be found in the phylogenetic tree of the mtDNA haplotypes from all small yellow croakers and the network tree of small yellow croaker was star-like, which indicated population expansion (Fig. 2). An understanding of the genetic variability of the mitochondrial genome should provide an important basis for future detailed examination of population structure of small yellow croaker and potential implications for the management of the species as an important fisheries resource.

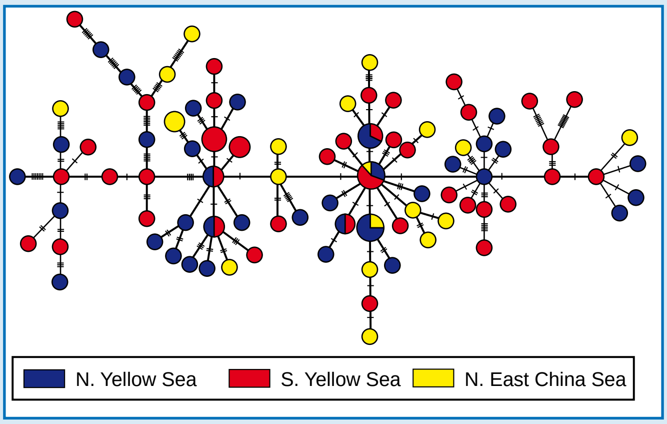

Figure 2. Unrooted minimum spanning trees showing genetic relationship among control region haplotypes for L. polyactis*. The sizes of circles are proportional to haplotype frequency.*

Five conclusions were drawn from the study:

- A high genetic diversity existed in the species demonstrated by the sequence analysis.
- No significant genealogical structure was found in the species from the genetic relationship analysis.
- No significant population structure was found in the species from the AMOVA analysis.
- Strong gene flow was observed among populations in the species from the conventional population statistic F_{ST} analysis.
- A significant population expansion was found in the species at about 49,300-197,000 years ago from the historical demography analysis.

Acknowledgements

The study was supported by State 863 High-Technology R&D Project of China (No. 2006AA09Z418) and the National Key Basic Research Program from the Ministry of Science and Technology, P.R. China (No. 2005CB422306).

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Regime shifts of mesopelagic fish – long-term biomass index change of *Maurolicus japonicus* in the Japan Sea

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Regime shifts are found in many parts of the ocean for various kinds of fish living in the pelagic zone. However there are few reports of a regime shift for a mesopelagic fish (Loeb and Rojas 1988). Mesopelagic fish reside deeper than 200 m at daytime, although some species undergo diurnal vertical migration at night time to the pelagic zone and thus play a significant role in the material cycle of the marine ecosystem (Hidaka *et al*. 2001). They also have a huge biomass and are an important prey organism for many pelagic fishes. Therefore, it is important to know if there is a long-term biomass change in the mesopelagic zone too.

In this study we examined the long-term biomass fluctuation of *Maurolicus japonicus*: a unique micronektonic mesopelagic key species distributed in the Japan Sea. *M. japonicus* feed on warm-water copepods and have an important position in the tertiary trophic level (Ikeda *et al*., 1994). Their biomass is huge; estimated at 3.3 million tons in 1973, which was almost three times the annual fisheries production of the Japan Sea (Okiyama, 1981). In the Japan Sea there is a long-term egg dataset of *M. japonicus* collected in the southwestern part, which is one of the main habitats of this fish. To detect the regime shift of *M. japonicus*, we used egg data as the index of the spawning adult biomass, and compared it with the environmental index (Tsushima Current Index: TCI - a strength index of the warm current in the Japan Sea) and biomass index of species that are known to have a regime shift in the Japan Sea (Japanese common squid *Todarodes pacificus*, Japanese anchovy *Engraulis japonicus* and Japanese sardine *Sardinops melanostictus*; Shimura, 2007).

Figure 1 shows the comparison of the environmental index (TCI) and biomass index of common squid, anchovy, sardine and *M. japonicus* from 1978 to 2005. The anomaly of average egg number of *M. japonicus* collected by a single Norpac net tow showed substantial temporal change; it fluctuated at a low level during 1978-1987 and increased during 1988-1993 to a level almost twice that during 1978-1987. This dynamic change correlated positively to the TCI, and also to the stock index of commercially important species like Japanese common squid and Japanese anchovy (Fig. 1).

In the Japan Sea, a regime shift is known to have occurred as a warm to cold shift in the late 1970s and cold to warm shift in the late 1980s (Zhang *et al*., 2004, Tian *et al*., 2006, Shimura 2007). This is revealed in the biomass fluctuation of sardine, anchovy and common squid and the fluctuation of TCI (Fig. 1). *M. japonicus* showed a similar fluctuation pattern to these biological and environmental parameters, which indicates this mesopelagic fish have a clear regime shift too.

One possible reason for the increase of *M. japonicus* under the warm regime is the increase of prey abundance. In the Japan Sea, *M. japonicus* mainly feeds on epipelagic warm-water species: *Calanus sinicus*, *Clausocalanus* spp., calanoids, *Oncaea media*, *O. mediterranea* and *O. venusta* (Ikeda *et al*., 1994). These copepods have better reproduction at warm temperatures and their range may extend under a warm regime (Hirakawa *et al*., 1999), which helps *M. japonicus* to spread too.

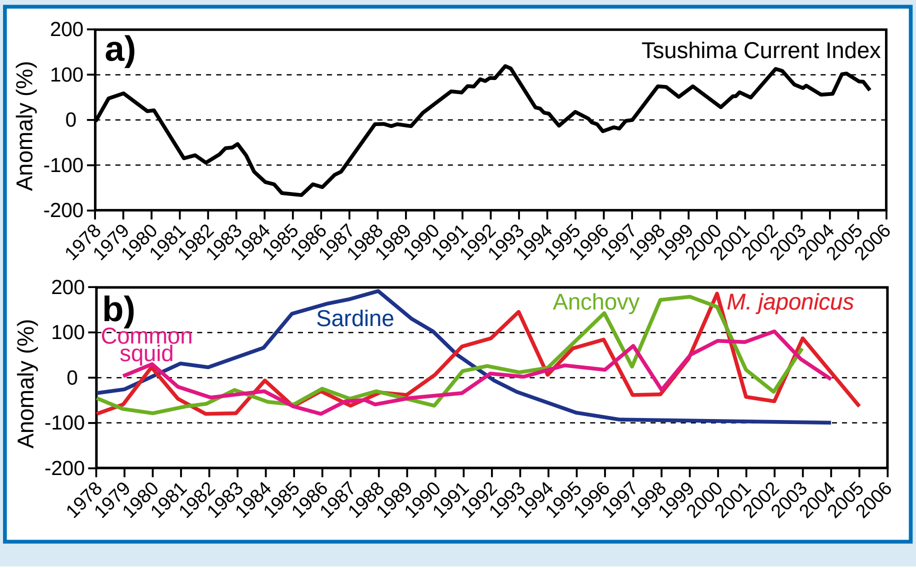

Figure 1. Fluctuation of the a) TCI and b) stock index of Japanese common squid, Japanese anchovy, Japanese sardine and M. japonicus *in 1978-2005.*

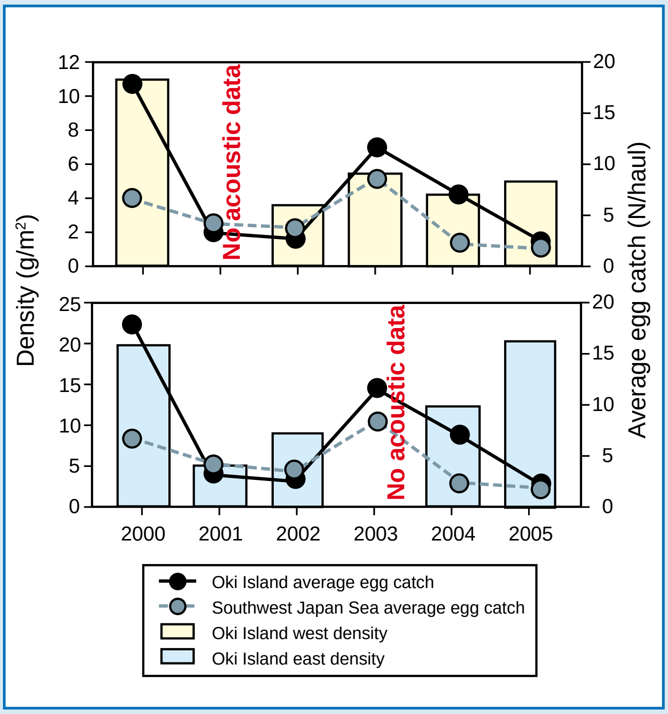

Figure 2. Comparison of M. japonicus *stock index obtained from acoustics (density) and Norpac net (egg number) in 2000-2005.*

The priority for future work is to continue the monitoring of this mesopelagic fish. Mesopelagic micronektonic fish have little commercial importance and their biomass fluctuation is independent of the fishing activity. Thus continuous monitoring of the abundance of this fish could provide a biological index, which is useful to detect the regime shift occurring in the marine ecosystem. However, the present egg survey data is obtained from surveys, and results can be obtained only once a year. For *M. japonicus* to have a practical application as a biological index, we need a faster way to obtain results, which requires less survey effort. For this purpose, we recommend the acoustic method, which uses a quantitative echosounder.

Figure 2 shows the comparison of the *M. japonicus* density obtained by a quantitative echosounder and average *M. japonicus* egg catch number from 2000-2005. The Oki Islands are one of the main habitats of *M. japonicus* in the southwest Japan Sea, and the acoustic data was collected east and west of these islands respectively. An example of acoustic data (echogram) is shown in Figure 3. For the species identification from the acoustic data, we used the method by Fujino *et al*. (2005). Average egg number was calculated both around the Oki Islands and for the whole Japan Sea. Even though the acoustic data is lacking for some years, we can see a similar fluctuation pattern to the egg number; a decrease of the abundance in 2001 (Oki east), increase of the abundance in 2003 (Oki west) and a decrease of the abundance in 2004 (Oki west) (Fig. 2).

The merit of the acoustic method is that less survey effort is required and that rapid results can be obtained. Acoustic data can be collected during a routine survey by simply switching on the quantitative echosounder, and results can be obtained quickly by post processing the digital acoustic data. Moreover, using the acoustic method, we can directly measure the density of the adults. In the Sea of Japan, there is a monthly ocean survey around the coast, so by using the acoustic method we would be able to have a more quantitative index of *M. japonicus* abundance quickly with a finer time scale.

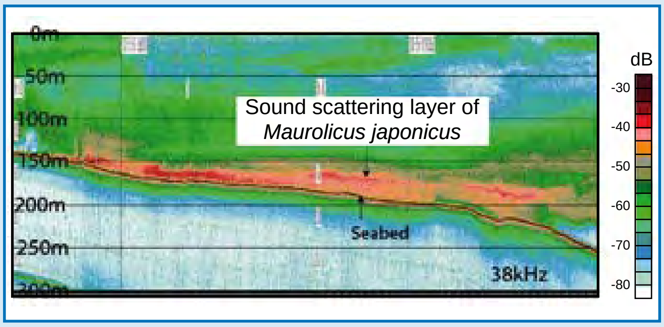

Figure 3. Example of the daytime echogram taken in the southwest Japan Sea that shows the sound scattering layer of Maurolicus japonicus.

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Using satellite remote sensing for mapping seaweed distribution

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Coastal mapping is considered to be an efficient and suitable way to assess and monitor complex ecosystems such as seagrass beds, mangrove or coral reefs. Seaweeds constitute some key habitats for numerous fish species (Komatsu *et al*., 2002) and their importance has even been enhanced by the ongoing global warming context. Indeed, as seaweed species are temperature sensitive, the distribution as well as the composition of "seaweed forests" is expected to be significantly modified. Moreover, as seaweed habitat is generally much more widespread than seagrass (e.g. in Japan, seaweed habitat is almost 7 times as widespread as seagrass; Environmental Agency and Marine Park of Japan, 1994), the benefits associated with accurate mapping are numerous. However, so far, mapping seaweed distribution remains an open challenge, as species generally overlap.

In this study, we propose to map seaweed distribution using an IKONOS image. The high resolution (4 m) of an IKONOS satellite image makes it a suitable tool. When dealing with coastal mapping, statistical classification methods such as supervised classification and unsupervised classification are generally used (Cuevas-Jimenez *et al*., 2003) and conducting radiometric correction prior to these classifications may significantly improve mapping accuracy (Mumby *et al*., 1998). In the scope of a previous study, we developed a new type of radiometric correction called the bottom reflectance index and demonstrate its efficiency with regard to seagrass mapping through two specific case studies. In the present study, we successfully apply this bottom reflectance index to seagrass mapping. Our study aimed to test if applying our index leads to a significant increase in mapping accuracy.

We selected the Oura Bay (off Shimoda City, Shizuoka Prefecture, Japan) as a study site. In order to overcome problems related to high species diversity (each species possessing a different radiance signature), we decided to focus on dominant species (i.e. *Ecklonia cava*, *Eisenia bicyclis* and *Sargassum species*).

We analysed the IKONOS image according to two different methods (Fig. 1). For the first method, the IKONOS image was classified via supervised classification without any radiometric correction while the second method converted the IKONOS image into a bottom reflectance index image before conducting the supervised classification. In both cases, supervised classification was based on the maximum likelihood decision rule.

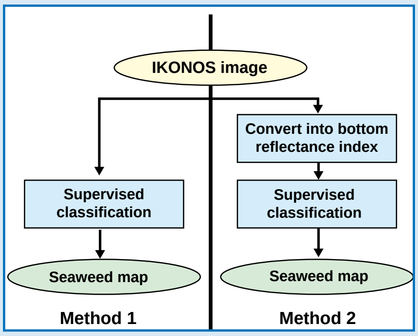

Figure 1. The two analyses under scrutiny.

Mapping results from these two methods were assessed by drawing error matrices which enable us to compare mapping with data collected *in situ*. Using these matrices, we calculated the respective overall accuracies and Tau coefficients and finally performed a Z test in order to assess the statistical significance of the difference.

While both methods display similar results for shallow areas, the mapping accuracy of the first method drops sharply in deeper water (< 10 m). As a result, the total mapping accuracy related to the second method was significantly superior to the first method accuracy ($p < 0.05$), as reported by Table 1.

Table 1. Mapping accuracies

	First method	**Second method**
Overall Accuracies	79.1	97.9
Tau Accuracies	0.624	0.961

Hence, using our bottom reflectance index for radiometric correction permits us to significantly improve mapping accuracy for this specific area and the accuracy level obtained (97.9% for the overall accuracy) is well beyond the accuracy level generally required for monitoring purposes (about 90%; Mumby and Clark, 2000). Interestingly, this accuracy level is even higher than some of the results we obtained previously for seagrass beds, despite the fact that seagrass is generally easier to map. For instance, the overall accuracy in Funakoshi Bay (Sanriku coastal area, Japan) was 83.3% while the one associated with the Mahares offshore area (Gulf of Gabes, Tunisia) did not go beyond 90.0% (Sagawa *et al*., 2007).

Finally, it is important to keep in mind that our result could only be obtained by focusing on dominant species. In order to remove this important practical problem, higher resolution satellite images at both spatial and radiation scales would represent an interesting first step.

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Distinguishing objectively resident from transient species to improve community monitoring: from artificial to natural habitats

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Species communities have been the objects of constant and important attention from ecologists (Guisan and Thuiller, 2005). While it is widely accepted that any community can be sub-divided with reference to species habitat association level (e.g. Talbot *et al.*, 1978; Hanski, 1982; Abbot, 1983) the number of sub-divisions as well as the distinction method to be employed have remained under debate. In 2003, Magurran and Henderson showed that fundamentally, any community is composed of two groups: resident species (i.e. species whose occurrences in samples are closely associated with the habitat under scrutiny) and transient species (i.e. species whose occurrences, generally random, are related to other factors). Moreover, a few methods were proposed to distinguish these two groups in practice. Nonetheless, Boisnier *et al.* (submitted a) highlighted that such methods were hardly suitable when dealing with artificial reef datasets, mainly due to sampling size. As a result, a new distinction method based on a habitat association index (HAI) was developed (Boisnier *et al.*, submitted b). This index is calculated for each species j present in the dataset as following:

$$HAI_j = Ln\left(Alt_j + e\right) \times \left(\frac{MP_j + MA_j}{AP_j + AA_j}\right) \times \left(\frac{N}{n_j}\right)$$

where Alt_j is the number of times presence and absence alternate in the dataset; e is the Napier's constant, MP_j is the maximum number of presences, MA_j is the maximum number of absences in a row, AP_j is the average presence in a row, AA_j is the average absence in a row, N_j is the total number of temporal units and n_j is the total number temporal units where species j appears. The main interest of this index is to provide an enhanced classification in comparison with a single occurrence rate and despite the fact that the latter has constituted so far the most common distinction tool. This point is illustrated by Figure 1.

In this example, we consider three different species (S1, S2 and S3) drawn from a similar dataset where n, the sample size, equals 24. For each species, each of the 24 circles represents a sample and its colour indicates either the presence (black) or the absence (white) of the species. Each line represents one year such that eight samples were collected each year. Each column represents a season (from spring on the left-hand side to winter on the right-hand side) such that six samples were collected each season. Every month was sampled twice but never twice in the same year such that every sample corresponds to a different month. We consider here three different scenarios: S1, late coloniser, appears lately in samples but is clearly resident, as it never disappears. S2, seasonal resident, occurs exclusively but repeatedly in spring and autumn samples. Contrary to S1 and S2, S3 occurs randomly in the dataset, as occurrence pattern is consistent with a Poisson process (time unit = years. S1: $X^2_{0.05,7} = 28.04$; $p < 0.001$. S2: $X^2_{0.05,3} = 11.24$; $p < 0.025$. S3: $X^2_{0.05,4} = 1.9$; $p > 0.75$). Despite these fundamental differences, the three species would have been generally perceived as they share a similar occurrence rate. Hence, this example shows that focusing exclusively on occurrence rate cannot be considered as a sufficient indicator for habitat association level.

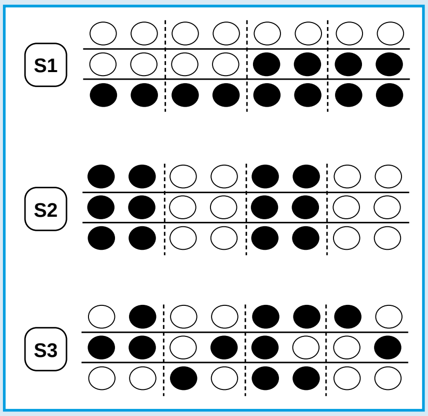

Figure 1. Occurrence rate and habitat association level: when apparent similarity hides extreme differences.

Using marine artificial reef datasets, Boisnier *et al.* (submitted b) showed that plotting HAI against occurrence rate and looking for the combination of species, which maximise the linear regression model enhancement constitutes an objective and easy method to distinguish in practice resident from transient species.

However, it remains unclear if such a method may also constitute an efficient distinction tool when dealing with natural habitat communities. In order to answer this question, we applied our distinction method based on a HAI calculation to the exceptional dataset used by Magurran and Henderson (i.e. fish species present in an English estuary with samples collected monthly for over 20 years). Interestingly, our method provides a species classification similar to the one highlighted by Magurran and Henderson. Hence, our method seems reliable not only for distinguishing resident and transient species in artificial habitats but also in natural habitats.

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Biased food taking between cormorant siblings: in a poor food environment, larger and closer chicks are fed more

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Seabirds respond to variable and unpredictable marine environments by changing their diet and breeding performance (Ramos *et al.*, 2002; Diamond and Devlin, 2003). Parents of species having broods with multiple chicks often feed some chicks disproportionately (Mock and Forbes, 1995). It is important to know this mechanism in order to understand how seabirds correspond to fluctuating food availability. Japanese cormorants (*Phalacrocorax capillatus*) have 2-4 chick broods. They feed on both epipelagic fish and demersal fish according to food availability (Kato *et al.*, 2001; Watanuki *et al.*, 2004). The foraging trips are longer in years of demersal fish than in years of epipelagic fish (Kato *et al.*, 2001; Watanuki *et al.*, 2004). Thus, parents may also change food allocation between siblings according to the interannual variation of food availability. We examined whether and how there was a bias of food allocation between siblings in years of different food availability.

The study was carried out in middle of June in 2005 and 2006 at Teuri Island, northwest of Hokkaido. We used 8 nests, with brood sizes of three chicks. After the chicks were weighed, measured and individually identified we observed the chicks. We recorded the time of arrival and departure by each parent, the time of start and end of begging by each chick, and feeding time to each chick. The data of their diet and feeding trips were from Teuri Seabird Monitoring data. The data feeding analyses were analysed by Generalised Linear Models (GLM) and Generalised Linear Mixed Models (GLMMs) with R (R Development Core Team, 2007).

The proportion of epipelagic fish in their regurgitations was approximately 55% in 2005, while it was 90% in 2006 (Fig. 1). Moreover, trip lengths in 2005 were longer than those in 2006 (male 2.28 hour±1.81SD, female 2.06±1.88SD in 2005; male 1.55±1.81SD, female 1.35±1.85SD in 2006; χ^2=61.96, P<0.001, GLMM). Sibling hierarchy of being fed first in a bout was affected by proportional body mass but not affected years (Fig. 2; χ^2=18.58, P<0.001, GLM), and larger chicks were given precedence in first feeding. Feeding frequency was affected by interaction between year and proportional body mass (Z=2.28 P<0.05, GLMM) and larger chicks received more food than smaller chicks in 2005 while all chicks received equally in 2006 (Fig. 3). Neither largest nor middle chicks died but all smallest chicks died in 2005, whereas no chicks died in 2006 (largest 4 chicks survive/4 nests, Middle 4/4 and Smallest 0/4 in 2005; 4/4, 4/4 and 4/4 respectively in 2006).

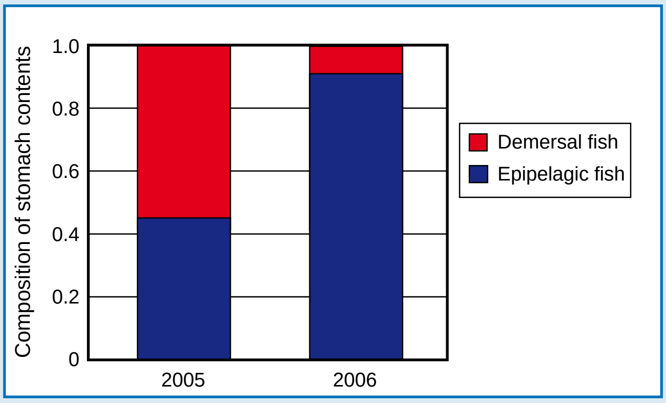

Figure 1. Diet in 2005 and 2006.

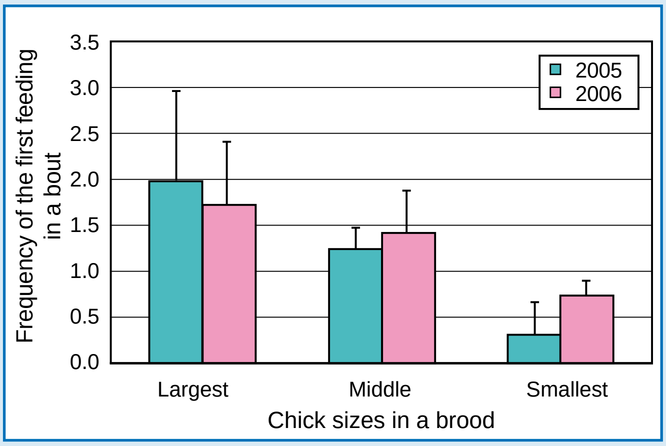

Figure 2. Hierarchy of feeding between siblings

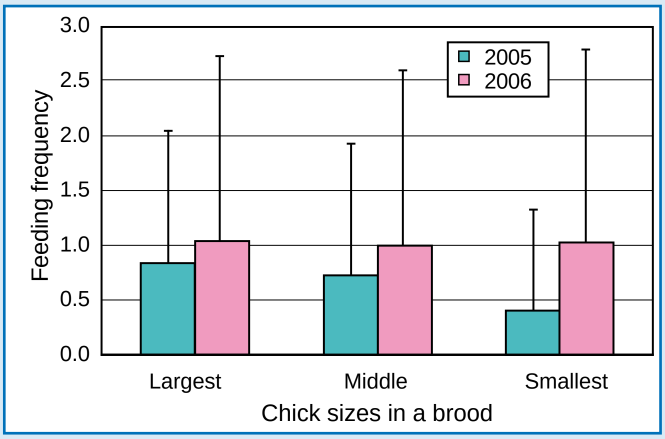

Figure 3. Feeding frequencies between chicks in years

Despite the difference in food environment between the years, which was found by a lower ratio of eqipelagic fish in the cormorant's diet and a longer length of trip duration in 2005, they did not change feeding order in a brood and in both years parents tended to feed on larger one more and first. The smallest chick's feeding frequency was lower than other siblings in 2005, whilst equal in 2006. This was because the turn of the smallest chick rarely came in 2005, whilst it's turn came enough in 2006. The mechanism induces all smallest chick's deaths in the year of poor food availability, whilst all chicks survive in the years of good food availability.

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Long-term population dynamics of the Kuril harbour seal around Hokkaido, Japan

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The harbour seal (*Phoca vitulina*) is only found in the northern hemisphere (Bigg, 1981). One of the subspecies, the Kuril harbour seal (*P. v. stejnegeri*), is distributed from Kamchatka via the eastern Pacific coast of Hokkaido, Japan (Itoo, 1999). The number of Kuril harbour seals that lived along the southeastern coast of Hokkaido, Japan during the 1940s is estimated to be between 1,500-4,800, based on a report by Inukai (1942) (Itoo and Shukunobe, 1986). The causes of this decline may be due to commercial harvesting of seals and other activities including coastal fishing (Marine Mammal Research Group, 1973).

In order to monitor the status of the Kuril harbour seal, population counts at the haul-out and breeding sites have been conducted by the Marine Mammal Research Group since 1974, and the Kuril Harbour Seal Research Group since 1982. The number of seals at each haul-out site was counted by sighting every 30 minutes during daytime for a week in May–June, which is the peak breeding season. We considered the maximum seal number from the daily counts for one week as the population number for that year.

The population size has increased since the early 1980s, and appears to have tripled in the past 30 years (Fig. 1). The increase in seal number per year was 5.0% after the late 1980s, when seal hunting was stopped. However, the number of haul-out sites was about nine, which did not vary in the years 1974-2006. About 70% of seals were found at two haul-out sites.

The population growth rate declined with an increase in rainfall. The results suggest that weather conditions affect the survival rate and breeding success. Sea surface temperature might also affect feeding. Large regional haul-out groups slightly increased in number, but the growth rate was lower than that of the small haul-out groups. We believe that these population dynamics may be an effect of population density.

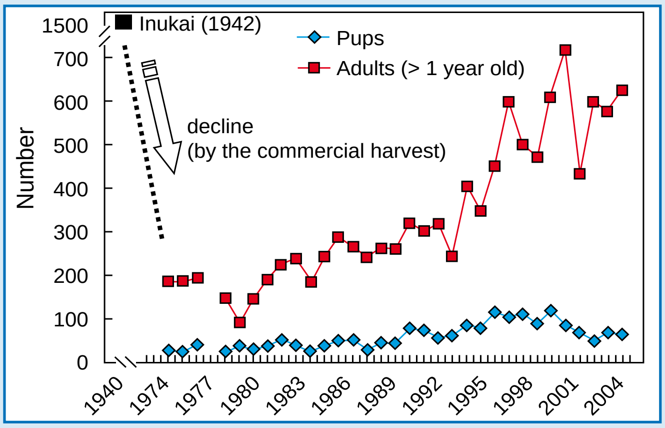

Figure 1. Total number of Kuril harbour seals during the breeding season (May-June) 1974-2006. The sum total of the maximum counts recorded at each site.

Acknowledgments

We would like to thank to the volunteer investigators total more than 1,000 people that the Marine Mammal Research Group and Kuril Harbour Seal Research Group. We wish to thank the local people and fisherman their supporting field works. This study was funded by World Wide Fund for Nature of Japan committee (WWF-J) in 1974-1976, 1981-1982 and 1984, Nippon Insurance Foundation in 1982-1983, the Toyota Foundation in 1985-1986, the Nature Conservation Society of Japan in 1990, Kiritappu Wetland Science Research Grant in 2005-2006 and Maeda Ippoen Foundation in 1984 and 2006. This study was partly funded by Earth Watch Japan project "Population Counts of the Kuril Harbour Seal in 1997", the 6th natural environmental preservation research (pinniped and sea otter) and conservation and management of seals research by the Japanese Ministry of the Environment.

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METAOCEANS: Elucidating the structure and functioning of marine ecosystems through synthesis and comparative analyses

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Major international programmes, such as JGOFS and GLOBEC, and parallel technological developments have resulted in large amounts of information on biogeochemistry, and functioning and structure of marine ecosystems. The resulting data represents a key resource to explore patterns and carry out comparative ecosystem analysis. Many of these large data-sets remain largely unexploited, as these data have been only used locally and few attempts have been made to synthesize them, and to link them with others, to provide a global perspective. This is partially due to a gap in the training of marine scientists in meta-analysis and comparative analysis.

METAOCEANS, funded by the European Union, recognises this problem and provides an early stage training programme dedicated to train young scientists in advanced meta-analysis and comparative analysis techniques applied to marine ecosystems. The project combines the development of expertise in all relevant fields, with emphasis on new approaches and analytical techniques. Twelve PhD students are currently working on subjects applying meta-analysis and comparative analysis techniques to the following topics: ecosystem metabolism, microbial food-webs, planktonic processes, trophic links and anthropogenic impacts (fishing and eutrophication).

METAOCEANS community, students and supervisors, at the last annual meeting in January 2008 at CSIC, Barcelona (from left to right: Damien Eloire, Patrik Stromberg, Roger Harris, Louis Legendre, Paul Tréguer, Irene Mantzouni, Carolina Alonzo, Martin Lindegren, Maria Jose Juan Jorda, Florence Dufour, Aurore Regaudie-de-Gioux, Brian MacKenzie, Frede Thingstad, Isabelle Rombouts, Xabier Irigoien, Carlos M. Duarte, L. Antonio Cuevas, Thomas Lefort, Nicolas Dupont and Adi Nugraha).

Below are short descriptions of PhD projects involved in METAOCEANS:

Fish stocks and population dynamics

Modelling of climate, eutrophication and fisheries effects on the Central Baltic ecosystem

Baltic cod (*Gadus morhua*) has been subjected to excessive fishing pressure and climate driven recruitment failure for many years. Integrating these forces in models is of great concern in developing a sustainable EBFM approach. By fitting a food web model to time series data from the Baltic Sea, we developed a fishing and climate driven multi-species model that not only accurately recreates the past dynamics of Baltic cod but may also predict its future. We simulated climate and management scenarios for the 21st century and explored the impact of commercial fishing in developing a sustainable management strategy for Baltic cod, herring and sprat in the face of climate change. Replicated model runs show that only drastic decreases in fishing mortality and climate sensitive management actions will avoid future stock collapses and ensure the existence of Baltic cod for future generations to come.

Martin Lindegren (mli@difres.dk)

Supervisor: Christian Möllmann
Institutions: Danish Institute for Fisheries Research (Denmark) and the University of Hamburg (Germany)

Assessing the effects of fishing on fish stocks of the family Scombridae: combining meta-analysis and the comparative method

There is a need for methods to determine the vulnerability and predict responses of "poor data" species to fishing using existing data such as basic life history information. The use of life history information has been shown to be a potential tool to determine species responses to exploitation. In this study, we will make use of meta-analysis, the comparative method and hierarchical Bayesian models to assess the responses of species to exploitation in terms of their life history considering their evolutionary relationships. We will use phylogenetic relationships among taxa to predict responses of "poor data" species to exploitation based on the responses of their "rich data" relatives, using the family scombridae as a case study. The family scombridae is comprised of 54 species distributed throughout the world oceans. This family shows considerable variation in life history strategies and through history has been exposed to different levels of human exploitation making it a good candidate for this study.

Maria Jose Juan Jorda (mjuan@pas.azti.es)

Supervisors: Lago Mosqueira and Juan Freire
Institutions: AZTI Tecnalia (Spain) and University of La Coruña (Spain)

Meta-analysis of carrying capacity and abundance-area relationships in marine fish species

This project aims to investigate how carrying capacity (CC) varies among stocks of selected fish species (like cod, haddock, herring, plaice and sole) and among different species, in order to investigate the spatial and temporal aspects of CC variation. CC reflects the maximum biomass or abundance that can be sustained over time and thus involves considerations of many levels of biological integration, from the population to the ecosystem level, playing a central role in fisheries management issues, such as the design of marine protected areas or the definition of target reference points. Hierarchical modelling (including mixed models and hierarchical Bayes) accommodates for such high-dimensional studies, allowing integration of data sources, uncertainty and stochasticity over multiple levels. The methods used to combine data across and among species and ecosystem variables range from hierarchically developed multi-stock and/or multi-species stock-recruitment models extended to include environmental effects, to meta-analysis of stock specific effect-sizes used to derive general patterns.

Irene Mantzouni (ima@aqua.dtu.dk)

Supervisor: Brian MacKenzie
Institutions: DTU Aqua-National Institute of Aquatic Resources (Denmark)

Meta-analysis of environmental effects on top predator stock dynamics

In recent years there is growing evidence of environmental effects on large pelagic fish population dynamics (e.g. stock-recruitment relationship, migrations and spatial distribution etc.). However, results published up to now come from individual, isolated and sometimes contrasting studies that make it impossible to extract global conclusions about general environment-population dynamics relationship. A joint study of different populations would resolve key general questions such as "Does environment affect large predators population dynamics?" Thus, an analysis of albacore and bluefin tuna phenology in the Bay of Biscay as well as the analysis of catch latitude has already been performed at the beginning of this PhD. Stock-recruitment relationship adjusted with environmental parameters will be conducted for some oceans and species, and will be compiled in a meta-analysis. Finally, the carrying capacity will be examined to see whether it changes according to environmental conditions or habitat, like it does for other species.

Florence Dufour (fdufour@pas.azti.es)

Supervisors: Haritz Arrizabalaga and Marc Jarry
Institutions: AZTI Tecnalia (Spain) and INRA (France)

Pelagic ecosystem and functioning

Modelling and data analysis of water clarity and "possible top-down effects" on marine ecosystems

Effects of light on primary production have been widely studied in marine ecosystems; the bottom-up effect of light is clearly recognised in ecology and in modelling. However, potential top-down regulations by light has been less studied, and the importance of such regulations remains unclear. The overall objective of this study is to evaluate possible top-down mechanisms associated with variability in optical properties and water clarity. One way to do this will be to explore visual constraints through e.g. the Secchi depth records for the Baltic and North from ICES. Another will involve modelling of food web, habitats and potential physical constraints that have been observed in the Norwegian fjords. Simulations and sensitivity analysis will be utilized to see if differences in optical properties, and concurrent alterations in other physical constraints, can account for observed differences in zooplankton abundance and size structure, zooplankton vertical distribution and predator composition (jellyfish vs. mesopelagic fish).

Nicolas Dupont (nicolas.dupont@bio.uib.no)

Supervisors: Dag L. Aksnes and Øyvind Fiksen
Institution: University of Bergen (Norway)

Large-scale geographic variations in diversity of marine zooplankton: theories, environmental controls, and functioning of pelagic ecosystems

One of the most consistent patterns in biogeography is the tendency for a decrease in species diversity from the equator to the poles. For several decades, extensive research has been carried out to provide ecological explanations for this latitudinal variation in species richness. Climate, in particular its energetic elements, have been proposed to influence biodiversity. Hydro-climatic forcing on pelagic marine diversity has been investigated at the ocean basin scale using zooplankton species composition time series. However, an examination of environmental controls on the temporal and spatial variation of zooplankton diversity on a global scale has not yet been attempted. This macro-ecological approach can elucidate the future effects of a changing climate on the diversity of copepods and functioning of pelagic ecosystems on a large geographical scale.

Isabelle Rombouts (isabelle.rombouts@etu.upmc.fr)

Supervisors: Grégory Beaugrand, Frédéric Ibañez and Louis Legendre
Institutions: University of Paris VI (France) and Laboratoire d'Océanographie de Villefranche-sur-Mer CNRS (France)

Spatial and temporal patterns of plankton in European coastal waters

Analysis of plankton long-term series is a relevant approach that allows description, comparison, and explanation of plankton variability in order to improve our understanding of community structure and ecosystem functioning. Time-series analysis is being undertaken to identify dominant groups and species characterising the temporal structure of the pelagic ecosystem at each site considered. Then, temporal variations of diversity indices and plankton abundance are being related to hydro-climatic parameters such as temperature, salinity, chlorophyll and wind, and regional climatic indices such as the NAO and Gulf Stream position. Finally, a coupling approach between the planktonic communities will be attempted to find out how these different components are connected. Here, analysis and comparison of appropriate plankton time-series allow us to identify factors that govern plankton variability, understand how these factors affect the community, and reveal the spatio-temporal scale of processes.

Damien Eloire (dmelo@pml.ac.uk)

Supervisors: Delphine Bonnet and Paul Somerfield
Institutions: Plymouth Marine Laboratory (United Kingdom) and University of Montpellier II (France)

Nutrient cycling and microbial community

Role of upper trophic levels in silicon, nitrogen and phosphorus cycling in the ocean, a box-model study

Robust estimates of biologically-mediated fluxes are critical to our understanding of nutrient cycling in the ocean. The magnitude of these fluxes is partly driven by the structure and the dynamics of the marine food web. To date the potential influence of upper trophic levels, on nutrient cycling has been seldom considered. Here we examine their potential influence on silicon, nitrogen and phosphorus cycling using different global ocean box models, which differ by their horizontal resolution. The vertical resolution considers an epipelagic (0-200 m), mesopelagic (200-1000 m) and bathypelagic (> 1000 m) layer. The biological model is derived from Tyrell's (1999) including the silica cycle, and upper trophic levels. The biological parameters are constrained using allometric laws. The role of large organisms is examined through sensitivity analysis of stoichiometry, food-web structure, or biomass size spectra. The results will show the effect of higher tropic levels in nutrient cycle and variability nutrient concentration on a horizontal and vertical resolution.

Adi Nugraha (Adi.Nugraha@univ-brest.fr)

Supervisors: Paul Tréguer and Philippe Pondaven
Institution: Institut Universitaire Européen de la Mer (France)

Comparison of steady state models with datasets for marine microbial food webs

Different studies indicate that the microbial part of the pelagic food web is in internal steady state (or close to). This steady state is determined by factors such as total nutrient content (degree of eutrophication) and the amount of predators over microbes. If this is true, there should be steady state relationships between the components of the microbial food web, and using conceptual and idealised mathematical models such relationships can be predicted. The main purpose of this project is to explore cross-system patterns in relation to control of bacterial biomass, production and growth using published data and conceptual models. In addition, limitation status (carbon or nutrient) of bacteria is being tested at a global scale. This project will contribute to a global understanding of the balance (or imbalance) between of bacterial growth and losses, nutrient cycling and the different behaviours of microbial food chains and its implication in the biogeochemistry of the ocean.

L. Antonio Cuevas (Luis.Cuevas@bio.uib.no)

Supervisor: T. Frede Thingstad
Institution: University of Bergen (Norway)

A meta-analysis of marine picoplankton community structure

In marine ecosystems, bacteria are abundant and significant players in the microbial food webs (around 106 cells/mL). Understanding their specific distribution is one of the primary goals in microbial ecology. Experiments relying on clone libraries and FISH analysis have shown that bacterial community structure could vary between ecosystems and seasons. However, factors controlling the bacterial community structure (BCS) are poorly known. In aquatic ecosystems, it has been demonstrated that different bacterial taxonomic groups can exhibit different responses to trophic levels, describing hump-shaped and U-shaped quadratic relationships. But, are the patterns similar when using a range of techniques for the estimation of BCS? Do the patterns observed depend on the phylogenetic level at which BCS are analysed? Following a meta-analysis approach, we are analysing the relationships between the BCS and the trophic level of the marine ecosystems, using FISH, clones libraries but also shotgun data published in literature.

Thomas Lefort (thlefort@icm.csic.es)

Supervisor: Josep M. Gasol
Institutions: Institut de Ciències del Mar-CMIMA and CSIC (Spain)

Ocean processes

The pattern in the metabolic balance of the ocean

The gross primary production (GPP) and the respiration (R) of oceanic plankton communities are compared here to elucidate the scaling of respiration to GPP and the associated insights into the distribution of heterotrophic (R > GPP) and autotrophic (R < GPP) communities in the ocean. The data compilation shows that R tends to exceed GPP in the Pacific Ocean and the Southern Ocean while the other oceans tend to be autotrophic. R is not proportional to GPP, such that R tends to exceed GPP in communities with GPP below 1.18 mmol O^2 m^{-3} d^{-1}. However, the threshold GPP for metabolic balance appears to differ across other basins, being much higher in the Arctic Ocean and the Mediterranean Sea, both with large watersheds relative to their volume, compared to other basins.

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Supervisor: Carlos M. Duarte
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Aspects of the metabolic function of the pelagic global ocean - investigated using modelling and satellite remote sensing

Using a combination of satellite ocean colour (data rich) and in-situ zooplankton data (sparse), an estimate has been made of the global zooplankton biomass. For example, it has been found that more energy is transferred to zooplankton when primary production (PP) is low (and visa versa). Currently I am developing a model to estimate the metabolic balance of the global ocean, where the community respiration (CR), is estimated by using allometric scaling equations. The equations are derived from metabolic theory, and combined with satellite Sea Surface Temperature (SST) and primary production (model 1, based on flow of carbon) or chlorophyll (model 2, based on size distributions). The CR is estimated from: model 1; community biomass, or model 2; the individual organisms. Gross PP is balanced with CR resulting in a global map showing areas of net auto- or heterotrophy. The model is assessed with *in situ* data.

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Supervisors: Tim Smyth, Icarus Allen, Sarah Cornell and Colin Prentice
Institutions: Plymouth Marine Laboratory (United Kingdom) and University of Bristol (United Kingdom)

Conclusion

A project like this, within the European Union, strengthens relations between institutes and adds weight to the European scientific community. It creates a unique opportunity for the students to develop a contact network within the international scientific community and to benefit from the combined knowledge. It shows the feasibility of a joint effort combining existing data to give on overview of large scale processes and patterns within and beyond European waters. It demonstrates the importance of keeping long-term series and that open access to these databases adds weight and value to the data. More science for money!

Acknowledgements

The METAOCEANS project is a Marie Curie host fellowship for early stage training on meta-analysis and comparative analysis in the marine sciences. This project is funded by the European Union 6th Framework Program. We would like to thank Roger Harris for his enthusiastic support of this article.

Why GLOBEC scientists and fishermen both benefit from the Global Ocean Observing System

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Should climate matter to fishermen? If you ask GLOBEC scientists the answer seems to be yes. Plenty of articles have appeared in this newsletter convincingly showing things like statistical relationships between changing ocean properties and the ranges of various species, regional 'regime shifts' diagnosed from multiple independent climatic and biological records, and long term correlations between proxies for fish abundance and climate from sediment cores. If you ask fishermen though, the answer is often no. They care primarily about things like competition, regulatory regimes, cost of operations and market price, and for the most part don't see climate as having a dominant influence on these variables (Alverson *et al.*, 2003). Who is right? The best way to find out – and thereby to sustainably manage marine resources - is to systematically observe the physical, chemical and biological properties of the global oceans.

For fifteen years, the Global Ocean Observing System (GOOS) has been meeting these and other important needs of global society. GOOS is designed to monitor and better understand climate, improve weather and climate prediction, provide ocean forecasts, improve management of marine and coastal ecosystems and resources, mitigate damage from natural hazards and pollution, protect life and property on coasts and at sea and to enable scientific research. Hosted by the Intergovernmental Oceanographic Commission of UNESCO and co-sponsored by the World Meteorological Organization, United Nations Environment Program and the International Council for Science (ICSU), GOOS provides international and intergovernmental coordination of sustained observations of the oceans, a platform for the generation of oceanographic products and services and a forum for interaction between research, operational, and user communities.

Important changes in physical, chemical and biological ocean properties being monitored by GOOS occur from seconds to decades with impacts over scales from metres to the globe. How can a single system be expected to monitor across such an enormous range of temporal and spatial scales? The answer is that it can't. Despite frequent calls to be everything for everyone, the only way to sustain the global ocean observing system is by focusing rigorously on a tractable set of key variables underpinning the provision of a core set of products and services with clear and tangible societal benefits.

For GOOS, focus is obtained by concentrating on two distinct modules: climate and coastal. Observations within these two modules are for the most part made by very different groups

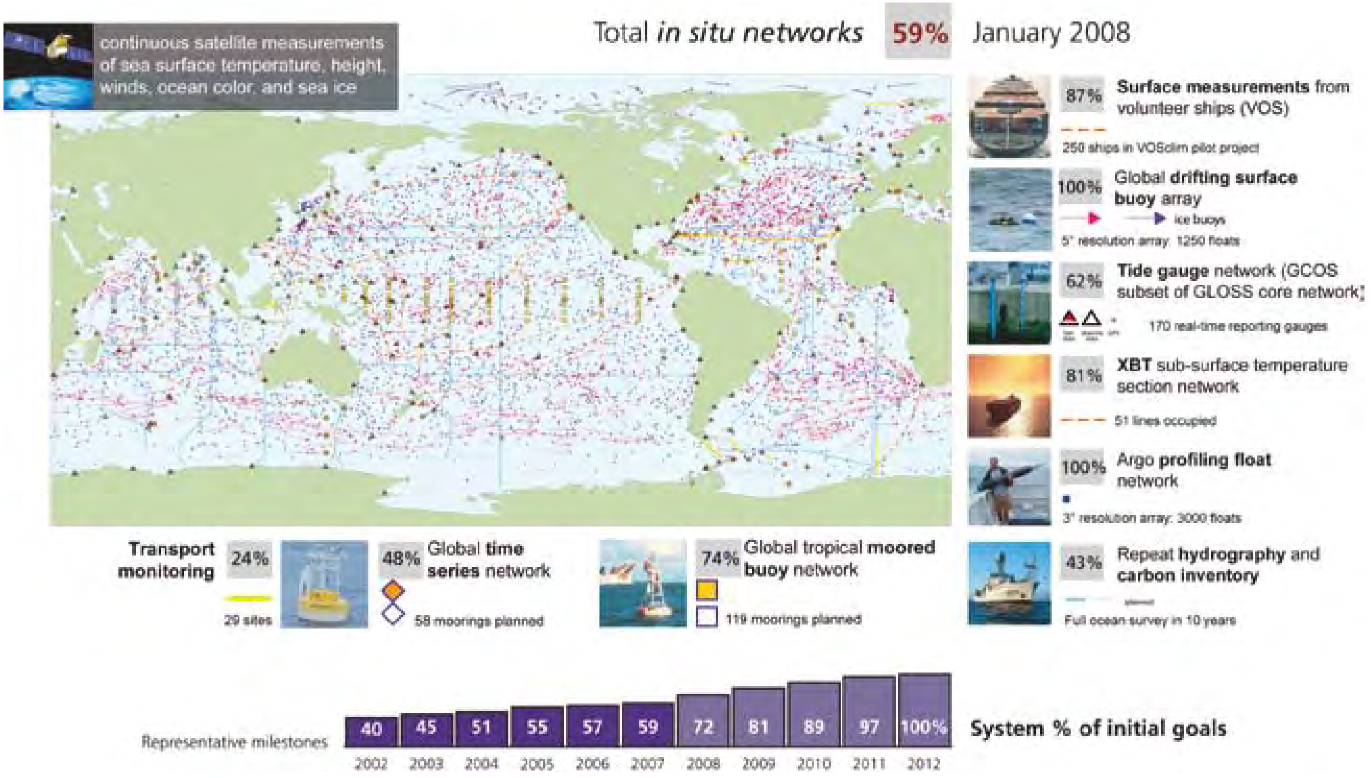


Figure 1. Map of GOOS remote sensing based and in-situ components as of January 2008 and planned timeline for completion to initial design specifications.

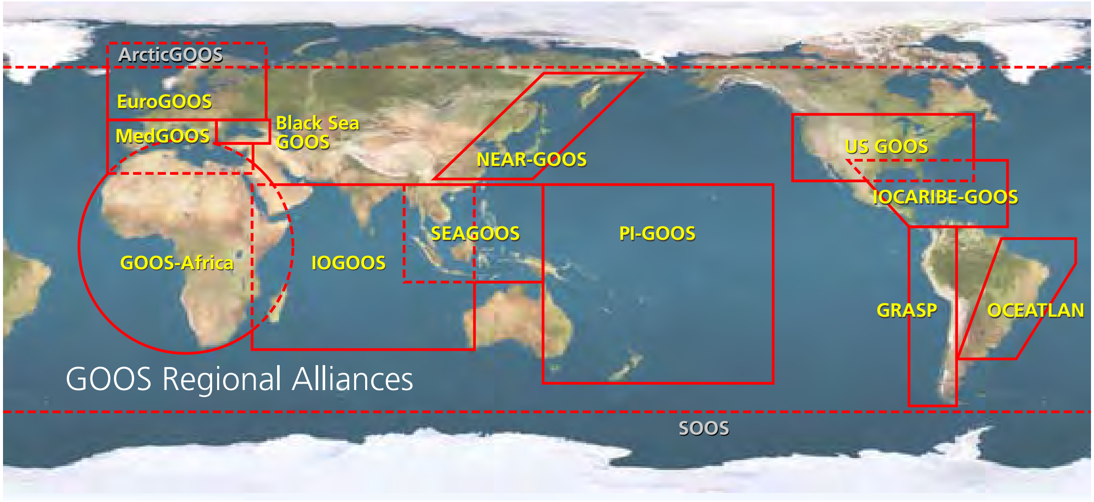


Figure 2. GOOS regional alliances as of January 2008.

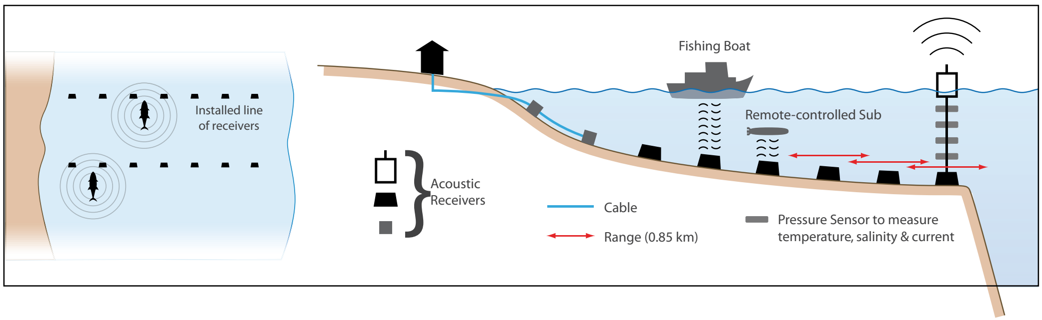
and also serve rather different users, though synergies between the two are possible and do exist. Observations for climate are largely made by a handful of rich countries and the dominant users are currently research scientists, although inroads into a broader user base in industry are certainly beginning to be made. Measurements contributing to the coastal module, on the other hand, are being made by more than 100 nations, from Albania to Mozambique to Vietnam and provide the backbone for an enormous range of products and services serving a diverse array of users including researchers, coastal zone managers, port managers, ship captains, coastal developers and the fisheries, tourism, oil and insurance industries.

As of 2008 substantial progress towards implementation of the climate module has been made, with decent global satellite coverage including altimetry, ocean colour and vector winds and well over 50% of the *in situ* system in the water including buoys, moorings, floats, tide gauges and repeat ship of opportunity XBT hydrographic lines (Fig. 1). However, current and projected future levels of national support for these measurements are clearly insufficient to either complete the system to its initial design specifications or sustain it over the long term. These later challenges will require substantial new commitments from governments, which can probably best be achieved through strengthened, preferably binding, multilateral agreement amongst the dozen or so member states most engaged (Alverson and Baker, 2006).

As compared with the climate module, observations within the coastal module are taken by, and of interest to, a far broader community. This breadth of interest is a two edged sword. On the one hand it provides very strong and diverse user pull – a clear requirement to maintain any sustained observing system. But on the other hand it also leads to an unwieldy menagerie of conflicting interests that cannot possibly all be satisfied, and thus strategic plans and system designs that appear so grandiose, broad and inclusive that they are simply not tractable.

Implementation of the coastal elements of GOOS is the primary remit of GOOS regional alliances (Fig. 2). Cooperation and coordination amongst the existing regional alliances takes place through a biannual forum with rotating hosting responsibility. The last of these was hosted by GOOS Africa in Cape Town in November 2006 and the next will be hosted by the GOOS Regional Alliance for the South Pacific, in Guayaquil, Ecuador, 17-19 November 2008. Initial efforts are now underway to form regional alliances covering the Arctic and Southern Oceans as a sustained legacy, of the ICSU-WMO International Polar Year in 2007-8. The most difficult challenge facing these regional alliances as they seek to implement the coastal module of GOOS is the mismatch between resources and expectations. Resources are provided by individual governments and institutions participating in the regional alliances while expectations are laid out in strategic plans for the coastal module drawn up by the GOOS coastal panel of experts and adopted multilaterally by more than 100 Member States at the level of the IOC Assembly. Unfortunately, to date the two have been nearly orthogonal in their approach and expectations. A second difficult challenge will be to ensure that regional observing systems, particularly those providing data relevant to coastal inundation hazard warnings (Alverson, 2005), are fully compatible with regional and local cultural, social and economic needs. As with so many things, successful implementation of coastal GOOS will require thinking globally and acting locally.

Figure 3. The Ocean Tracking Network (www.oceantrackingnetwork.org) is a global initiative that comprehensively monitors ocean conditions and the response of marine life response to changes in these conditions.



Ocean observations received plenty of media attention recently when a manned submersible planted a titanium flag on the sea floor at the North Pole (International Heral Tribune, 2 August 2007). Meanwhile, around the globe powerful monsoon rains and floods killed hundreds and displaced tens of millions more across Bangladesh and North India (Associated Press, 4 August 2007); Arctic summer sea ice retreat surpassed all previous records with another month of summer melt still to come (International Herald Tribune, 9 August 2007); Pacific coral reefs were found to have declined 20% in the past two decades, far faster than expected (International Herald Tribune, 7 August 2007); Due to weak La Niña tendencies in the tropical pacific, US government forecasters slightly reduced their Atlantic seasonal hurricane forecast, though they still await an above average season with up to 9 hurricanes and 16 tropical storms expected to form (Associated Press, 9 August 2007); A 7.5 magnitude submarine earthquake struck near the Island of Java but was located too deep in the earth to generate a destructive tsunami in the Indian Ocean (Pacific Tsunami Warning Center Bulletin, 8 August 2007); the Australian Bureau of Meteorology confirmed that 12 month rainfall deficiencies had expanded and intensified over large areas of the country and are likely to remain for some time (Bureau of Meteorology, Australian Government, 3 August 2007); and the first span was welded into place for a new $14 million bridge across the Grand Canal in Venice (International Herald Tribune, 12 August 2007), a city being protected by construction of a $2.6 billion system of floodgates that may still leave the city vulnerable to future sea level rise. This list may at first seem like nothing more than an eclectic smorgasbord of media coverage from August 2007, but in fact each one of these stories highlights the importance of ocean observations, and together they clearly demonstrate the need for such observations to be brought together in a global system. That all these events occurred so close together is no doubt a coincidence. That they testify to the societal benefits of the global ocean observing system is not.

Although ocean observations were not mentioned explicitly in any of these stories, the societal and economic impacts that make them of interest to the public, and hence news agencies, are provided by the global ocean observing system. Exploitation of submarine resources, prediction of monsoon onset and intensity, monitoring of arctic ice dynamics for a range of users from climate researchers to the shipping industry, protection of marine ecosystems, prediction of point landfall and degree of intensification of tropical storms, provision of tsunami warnings, understanding of patterns of protracted drought, and protection of coastal infrastructure are all services that can only be maintained based on the ready availability of sustained and coordinated ocean observations.

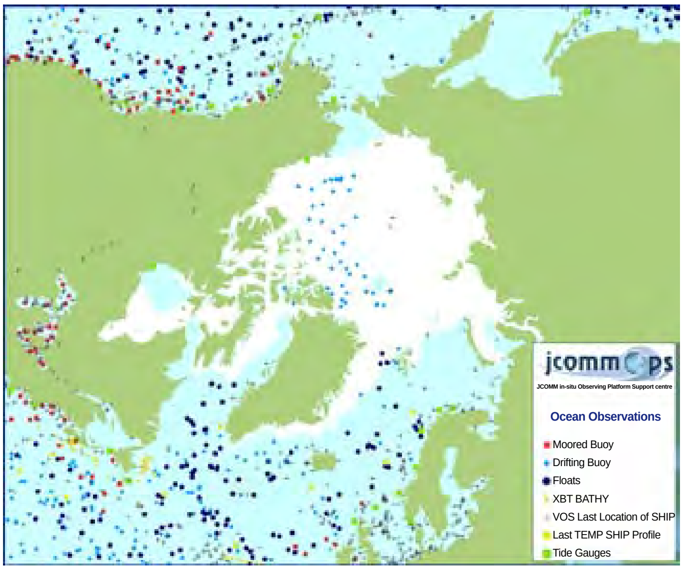


Figure 4. Near real time GOOS data availability in the Arctic on 23 July 2007 from the Observing Platform Support Center (JCOMM-ops) of the Joint IOC/WMO Commission on Oceanography and Marine Meteorology.

One of the reasons ocean observations aren't mentioned in articles in the mainstream press is that they are, by design, relatively boring. In order to serve such a diverse array of users and products, operational observing system components are designed to be inexpensive, simple, reliable and adhere to common standards and protocols. Hardly headline material. As with levees in New Orleans and highway bridges in Minnesota, for example, the ocean observing system is designed to unobtrusively provide public services that generally only receive attention when they fail.

Briefly putting aside the importance of simplicity as a means to ensure reliability and sustainability, it is clear that pressure will always exist to fill gaps and improve accuracy. Indeed, many exciting new technologies are being developed as pilot projects for potential future inclusion in the Global Ocean Observing System and, as with any new technology, there will no doubt be myriad exciting spinoffs from these innovations. One example, is the recently approved GOOS pilot project the Ocean Tracking Network (OTN), to simultaneously monitors ocean conditions and marine life response to these conditions by tagging sea creatures, from salmon to whales, with tiny transmitters so that their movements can be tracked for over 20 years by receivers placed at one-kilometre intervals along the ocean floor across continental shelves (Fig. 3). The OTN has been kick started with a $35 million grant from the Canadian Foundation for Innovation and is bringing together international scientists, industry and government in an effort that could potentially add a biological monitoring component to the ocean observing system for the first time.

Another gap in the system occurs in polar regions, underneath the sea ice (Fig. 4). An ocean observing scheme for the Arctic Ocean, for example, is being implemented as a time limited research project by the European Commission 6th Framework Program funded project DAMOCLES which includes an extensive system of floats and gliders exploring the upper ocean, receiving navigation information and communicating their data to satellite via a net of ice-tethered platforms. Interested member states within GOOS are working to sustain an operational Arctic Observing System, based on many of these technologies worked out through successful research programmes, as a legacy of the International Polar Year (IPY: 2007-2009). European nations in particular are moving ahead quickly. An Arctic Regional Ocean Observing System has been established by a group of fourteen institutions from nine European countries working actively with ocean observation and modelling systems for the Arctic Ocean and adjacent seas. Arctic ROOS has established a secretariat at the Nansen Environmental and Remote Sensing Center in Norway. At the same time, the oceanographic community is working towards a fully international effort, integrated with other Arctic observing systems, as its contribution to the Sustained Arctic Observing Network (SAON: www.arcticobserving.org), via a series of international workshops being hosted by Sweden, Canada and Finland during the IPY.

The prospect of filling gaps in our observational capabilities with novel research and technologies developed in pilot projects such as OTN and DAMOCLES is extremely exciting. At the same time it is important to note that the value of such regional and disciplinary efforts is dramatically increased if they are brought together as components within the coordinated global system serving multiple users (Alverson, 2006). For example the GLOSS tide gauge array provides real time data vital for tsunami warning systems, but this infrequent use does not alone provide sufficient support to maintain the network. It is because local sea-level data are also of use for more quotidian purposes – such as offshore development, routine marine transport planning and coastal zone management – and because these data are combinable with other observations – such as satellite remote sensing altimetry measurements for calibration and validation and with subsurface density measurements from Argo floats for quantification of the steric expansion of a warming global ocean - that the tide gauge system is sustainable (Alverson, 2005). Can even more benefit be extracted from ocean observations by integrating them still more broadly within a comprehensive system encompassing all earth observations? In the hope that such integration may add value, GOOS has accepted responsibility as the ocean component of the Global Earth Observing System of Systems (GEOSS) and is a founding participating organisation in the Group on Earth Observations (GEO).

As highlighted in this article, new technologies are being incorporated in GOOS, gaps in the system are being filled, and a broad base of user communities – including both GLOBEC scientists and fisheries managers - are being served. However, existing intergovernmental mechanisms have enabled surprisingly little progress toward a truly integrated global system with long-term funding commitments. Monitoring and stewardship of the global oceans is a global responsibility and GOOS is working with its sponsors in the United Nations, the Intergovernmental Oceanographic Commission (IOC) of UNESCO, UNEP and WMO, the International Council for Science (ICSU) and the Group on Earth Observations (GEO) and the many individual nations that support these groups to ensure that our responsibilities are met.

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Atlantic Meridional Transect programme news

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The Atlantic Meridional Transect (AMT) is entering its third phase following funding within the OCEANS 2025 strategic marine science programme of the UK Natural Environment Research Council (NERC). The AMT programme undertakes biological, chemical and physical oceanographic research during the passage of one of the UK research fleet between the UK and the Falkland Islands or Cape Town, a distance of up to 13,500 km (Fig. 1). This transect crosses a range of ecosystems from sub-polar to tropical and from euphotic shelf seas and upwelling systems to oligotrophic mid-ocean gyres. AMT began in 1995, and between 1995 and 2005, the programme included 17 research cruises, involving ~180 scientists from 11 countries, and has contributed to 110 refereed publications and 68 PhD theses. This unique spatially extensive decadal dataset continues to be deposited and made available to the wider community through the British Oceanographic Data Centre.

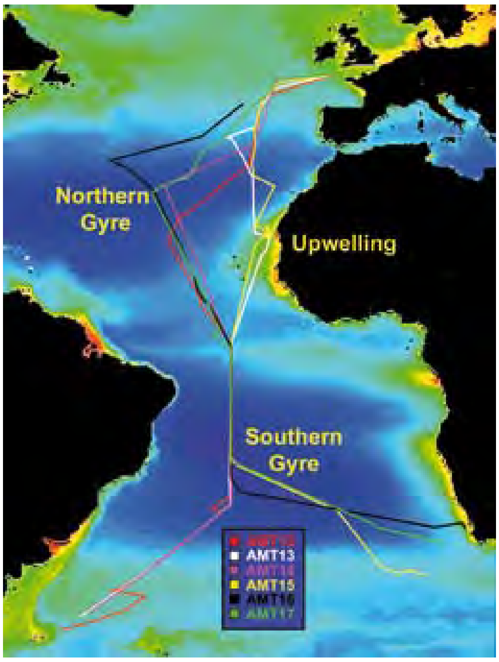

Figure 1. AMT 12-17 cruise tracks, 2003-2005.

Our new round of funding will extend the series of research cruises until at least 2012, and will begin with AMT18 which is scheduled to leave the UK in October 2008. The programme is hosted by the Plymouth Marine Laboratory and provides an exceptional opportunity for nationally and internationally driven collaborative research and provides a platform for excellent multi-disciplinary oceanographic research. As an *in situ* observation system, AMT informs on changes in the biodiversity and function of the Atlantic ecosystem during this period of rapid change to our climate and biosphere.

More information about the AMT programme can be found from the website http://www.amt-uk.org/, and data can be accessed from http://www.bodc.ac.uk/projects/uk/amt/, or please feel free to contact Dr. Andy Rees at Plymouth Marine Laboratory (apre@pml.ac.uk).

Inferring distributions of organisms from sparse occurrence data: KGSMapper

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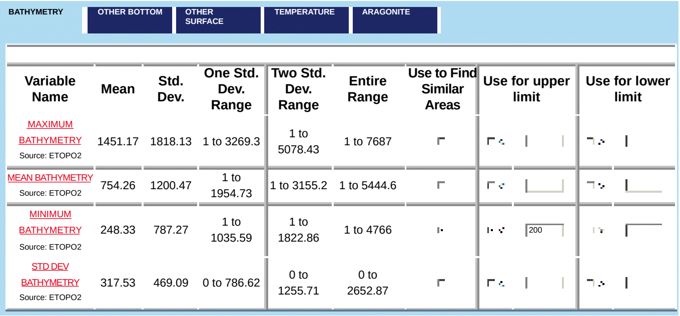
The true distribution of most marine organisms is poorly known, but modern technology is making rapid inroads to improve knowledge in this critical realm. Relevant technologies include both direct and indirect methods of understanding marine organism distributions. We have developed a tool to infer from existing distributional data where else individuals of particular species might occur.

The time-honoured method of determining what occurs where is by documenting occurrences in the field. Some modern technologies that allow such direct measurements without having to be in the field (including passive acoustics, image analysis systems, and telemetry) are not practical for the vast majority of marine species. This includes nearly all invertebrates, which make no noise, move little or not at all, are of little or no direct economic value, and may be very small; furthermore, individuals typically occur among, on, or in other organisms.

We and collaborators have developed the web resource "Biogeoinformatics of Hexacorals" (http://www.kgs.ku.edu/Hexacoral) that consists of biological and environmental data linked to each other and to a geographic information system. The biological component contains published occurrence records of sea anemones, corals, and their relatives. Directly accessible as "Hexacorallians of the World" (http://geoportal.kgs.ku.edu/hexacoral/anemone2/index.cfm), it is underlain by a relational database that includes bibliographic, taxonomic, and biogeographic data. The environmental data, drawn from public sources such as the World Ocean Atlas, currently include global coverage for 43 physical and chemical parameters gridded in register at a half-degree resolution.

Both the biological and environmental data are served to OBIS – the Ocean Biogeographic Information System – a growing inventory of occurrences of marine organisms described by Vanden Berghe (2007). OBIS passes the biological data on to GBIF – the Global Biodiversity Information Facility (http://www.gbif.org). These distributed systems rely on contributors making data publicly accessible, recognising that multiple sources of distributional data can provide a more accurate biogeographic picture than any one alone.

The biological and environmental data interact through KGSMapper, a tool that allows us to infer, based on known occurrences, where else individuals of a species might occur. It is one of the "software tools for data exploration and analysis" referred to by Vanden Berghe (2007). It resembles conceptually a growing number of such tools that rely on modern computing power applied to increasingly accessible, and increasingly rich, biodiversity data (see Elith *et al.*, 2006 for a review). Accessible through "Hexacorallians of the World," OBIS, and FishBase (http://www.fishbase.org), KGSMapper provides a workspace into which anyone can import organism occurrence data for analysis, alone or in combination with data from the database through which it is entered.



Variable Name	Mean	Std. Dev.	One Std. Dev. Range	Two Std. Dev. Range	Entire Range	Use to Find Similar Areas	Use for upper limit	Use for lower limit
MAXIMUM BATHYMETRY Source: ETOPO2	1451.17	1818.13	1 to 3269.3	1 to 5078.43	1 to 7687	☐	☐	☐
MEAN BATHYMETRY Source: ETOPO2	754.26	1200.47	1 to 1954.73	1 to 3155.2	1 to 5444.6	☐	☐	☐
MINIMUM BATHYMETRY Source: ETOPO2	248.33	787.27	1 to 1035.59	1 to 1822.86	1 to 4766	☐	☐ 200	☐
STD DEV BATHYMETRY Source: ETOPO2	317.53	469.09	0 to 786.62	0 to 1255.71	0 to 2652.87	☐	☐	☐

Figure 1. Display for some of the environmental parameters used by KGSMapper and boxes for selecting which are to be used in generating the model output.

KGSMapper displays the value of all 43 parameters for each half-degree cell in which an organism has been recorded (more than 43 values are shown because some of the datasets are divided temporally; e.g. values for chlorophyll *a* concentration are provided on an annual basis and in three month periods). For an organism that occurs in more than one cell, KGSMapper calculates the mean and standard deviation for the values of all parameters in all cells in which an occurrence is recorded. These data give an idea of some of the physico-chemical attributes of the environment suitable for the target organism. KGSMapper then searches for, and displays, all cells in the world having values matching those for places where members of the target species are known to occur. These are places where the habitat is most likely to be suitable for the species, whether or not it has been recorded from there.

Inferring undocumented occurrences by using attributes of the habitat where individuals are known to occur is common to all such biodiversity modelling tools. Aside from having been designed to operate in the marine environment (where some of the others perform poorly), KGSMapper is distinctive in input, processing, and output.

INPUT:	The user controls which of the 43 parameters will be used to search for other cells that have similar values (Fig. 1). This allows the user to apply expert knowledge about which parameters may control a species' distribution (e.g. aragonite saturation) and which are likely to be irrelevant to it (e.g. oxygen saturation). Trying combinations of parameters allows exploration of the factors important to a species.

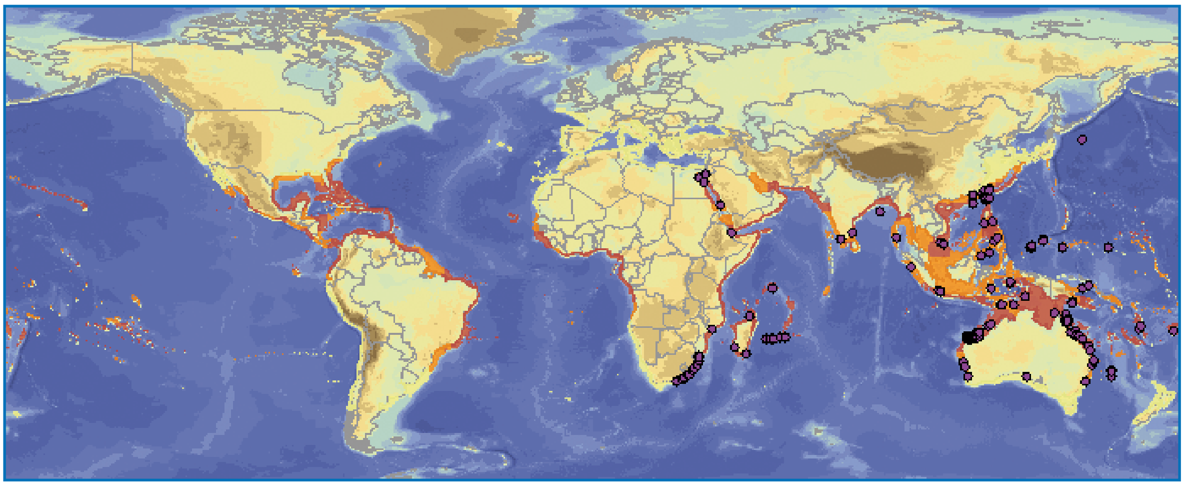


Figure 2. World map showing known occurrences of Pterois volitans (purple-ringed dots) and inferred suitable habitat (red and orange areas).

PROCESSING: The basis of the match is simple statistics. For each parameter, the algorithm calculates the mean and standard deviation of all cells containing at least one occurrence of the target species. It then finds all other cells with values within the 1-SD range for cells containing occurrences, within the 2-SD range, and in the entire range for all the parameters selected.

OUTPUT: All cells in which all parameters selected to generate the map are within the 1-SD range of the value of those parameters of cells in which the species is known to occur are displayed in red. Cells in which parameters outside of 1-SD are all within the 2-SD range are displayed in orange. Cells in which parameters are within the full range, but at least one is beyond the 2-SD range, are displayed in ochre.

The colour-coded output map serves as a rough measure of probability. It also serves as a means of data-cleaning. We have found that values beyond two standard deviations are often the result of a misplaced point or an anomalous habitat (for example, an intertidal organism might occur on a small island surrounded by deep water, so the average depth of the half-degree cell is not representative of the habitat of the target organism). KGSMapper can remove the values beyond 1 or 2 SD; we have found the red areas of a map very likely to provide a suitable habitat. Guinotte *et al.* (2006) described KGSMapper in detail, and assessed some facets of its accuracy and precision.

Expert knowledge is essential. Figure 2 is a world map showing the distribution, according to FishBase, of *Pterois volitans*, the Red Lionfish, in purple-ringed dots. Areas suitable for the occurrence of this fish – using the parameters of annual mean surface temperature, minimum monthly surface temperature, and minimum depth (constrained to depths no greater than 200 m; see Figure 1) are coloured red and orange (the ochre is faint and there is very little of it). Clearly the fish is endemic to the Indo-West Pacific. But inferred suitable habitats also exist in the eastern Pacific and Atlantic. Within the native range of the fish, the map can be used to infer where the fish might occur other than where it has been reported (as in planning a fieldtrip, or assessing areas for conservation value). Outside that area, the map can be used to identify areas vulnerable to invasion. Most of the western Atlantic coast from southern Brazil to the central US appears to be suitable or very suitable for *P. volitans* with respect to the parameters used to generate the map. And, indeed, recently-established breeding populations of *P. volitans* have been reported from the central eastern United States (e.g. Semmens *et al.*, 2004).

Currently, KGSMapper is linked to environmental data for the surface (e.g. SST and chlorophyll *a* concentration) and the bottom (e.g. depth and bottom oxygen saturation). In theory, it could be used for the pelagic realm. Likewise, the grid size could be reduced to increase precision. We have demonstrated that KGSMapper is scale-independent by using it with finely-gridded data for the Hawai'ian Islands (http://hercules.kgs.ku.edu/hexacoral/hawaii/biodata). Extending KGSMapper to the pelagic realm and a finer grid would require significantly more environmental data and commensurate slowing of the process. But in future, with faster computers, such tools are certain to be developed.

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A frontal attack during IPY

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As reported in a previous GLOBEC Newsletter (Drinkwater and Hunt, 2006), the Ecosystem Studies of Sub-Arctic Seas (ESSAS) regional programme is the leader of the IPY consortium ESSAR (Ecosystem Studies of Subarctic and Arctic Regions). This consortium consists of 10 separate IPY projects led by scientists in 9 countries. The Norwegian contribution is called NESSAR whose overall goal is to investigate the impact of climate variability on the structure and function of Arctic marine ecosystems of the Nordic and Barents seas with special focus on the fronts separating colder, fresher waters of Arctic origin from warmer, saltier Atlantic waters in both the Barents and Nordic seas. The reasons for focusing on fronts are several. These fronts form barriers to the distribution of many marine organisms and thereby represent biogeographic boundaries. Also, fronts are usually regions of high biological productivity and are known to be important feeding areas for several commercial pelagic fish species. For example, observed distributional shifts of Atlantic herring in the Norwegian/Iceland seas and capelin in the Barents Sea over time scales of decades and longer have been shown to be related to movements of the frontal positions (Vilhjálmsson 1997a,b). Under climate change, these fronts are expected to shift location but it is unknown by how much or what the processes are (Loeng *et al*., 2007). Finally, frontal studies in the two different regions separated by 10 degrees of latitude provide the opportunity to compare and contrast the effects of differences in seasonal light levels and sea ice on frontal processes.

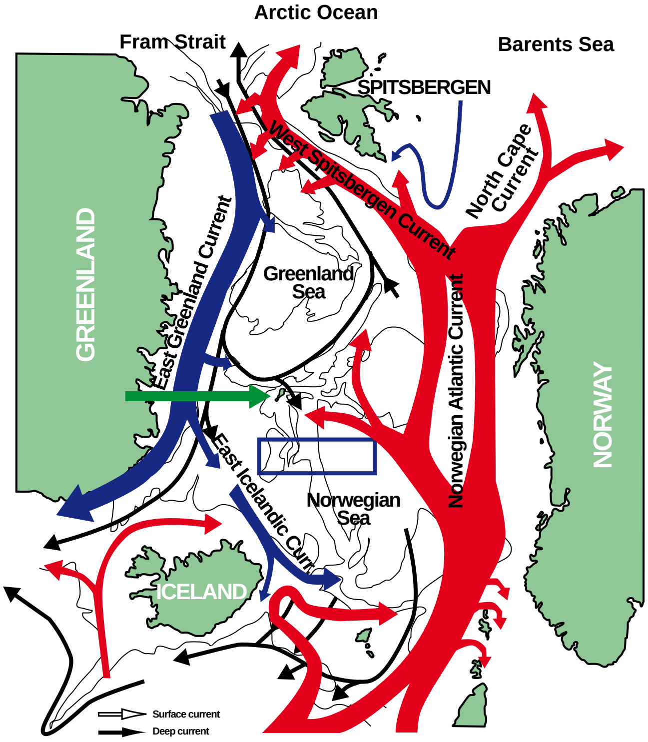

Figure 2. The Nordic Seas showing the circulation patterns (from S. Østerhus, personal communication) and the IPY NESSAR study area (box). The large green horizontal arrow points to the island of Jan Mayen.

To address the aims of NESSAR, intensive field studies were undertaken during 2007 to explore the dynamical frontal processes, such as mixing, upwelling, convergence and frontal eddies, and their role on the biological processes in the vicinity of the front. In this article, some initial results from the work carried out in the Norwegian Sea are presented.

During 1-21 June 2007, the research vessel *G.O. Sars* focused upon the Jan Mayen front in the Norwegian Sea south of the island of Jan Mayen (Figs. 1 and 2). Current meters were first moored along the Jan Mayen ridge just to the west of the front. Scheduled to be recovered in June 2008, these will provide the first direct measurements of the Atlantic water inflow into the Iceland Sea. A preliminary survey verified the existence of the front and showed that it consisted of a shallow (30-50 m deep) surface salinity front approximately 5-10 km eastward of a deeper (50-300 m) temperature and salinity front (Fig. 3). Acoustics and fishing trawls also revealed plenty of herring schools in the area. A Web© autonomous glider obtaining hydrographic and fluorescence measurements was deployed and traversed back and forth across the front eight times in the course of approximately two weeks. This was the first ever deployment of such a glider by Norway. Mixing at the front was measured using a microstructure profiler. Nutrient, dissolved organic carbon and phytoplankton samples were obtained from water bottles and further phytoplankton samples taken using net hauls. Fluorescence data were obtained from both a profiling and a towed CTD. Light spectra profiles were taken and a fast repetition rate fluorometer (FRRF) was used to obtain an index of phytoplankton production. Zooplankton samples were collected from a variety of nets and data were obtained using a towed optical plankton counter (OPC). Herring trawls were taken to obtain stomach samples for diet analysis, which will then be compared with the zooplankton samples. While much of the analysis of the data is still underway, some initial results are interesting.

Figure 1. The island of Jan Mayen.

The hydrographic data from the glider has revealed large interleaving between the cold, fresh Arctic waters and the warm, salty Atlantic waters at the deeper front. These features were

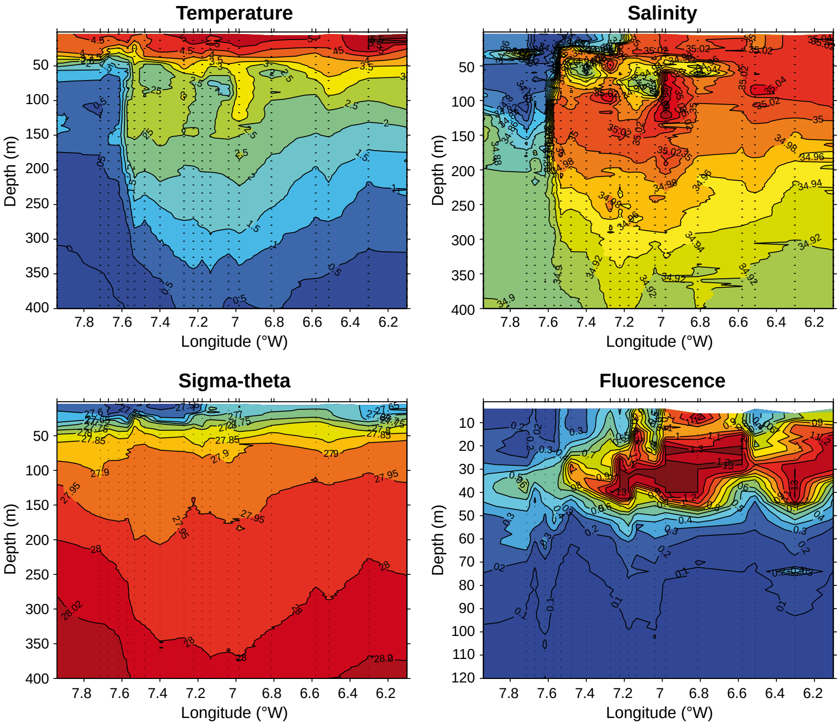

Figure 3. Temperature, salinity, density (sigma-theta) and fluorescence along 68°N. The dotted vertical lines indicate station locations.

typically 10-20 m thick and extended several kilometres in the horizontal (Fig. 4). Increased vertical mixing was occurring at the front based on turbulence data and appears to be generated both through current shear as well as double diffusive processes. Preliminary results also indicate relatively low phytoplankton biomass and clear waters on the Arctic side of the shallow front while on the Atlantic side of the shallow front, the concentration of phytoplankton tended to increase with distance from the front. There was no increased phytoplankton concentration at the front. The plankton data showed distinct community structure on opposite sides of the front. On the Arctic side of the deep front, small flagellates dominated while on the Atlantic side the portion of diatoms increased with increasing distance from the front. Between the deep and surface fronts the dominant phytoplankton group varied between stations. The zooplankton in the colder Arctic water were in a less developed stage than further east in the Atlantic waters. The biomass of crustaceans, *Benthosema glaciale*, and gelatinous zooplankton were highest immediately to the west of the deep front in Arctic waters. Otherwise the data analysis shows no clear difference between Arctic and Atlantic waters, however this is related to the vertical distribution of animals, which generally showed highest abundance below 200 m where Arctic intermediate water was found along the whole transect (although salinity increased towards the east). *Meganyctiphanes norvegica* was the dominant contributor to biomass of crustaceans and small fish at all stations. Ctenophores tended to dominate the biomass of gelatinous zooplankton. Herring were the dominant large fish and tended to be distributed in schools from 300 m up to surface. While the herring were observed in both Atlantic and Arctic waters, they were primarily found in the former (Fig. 5). An initial examination of the stomach contents indicated that the herring had relatively full stomachs and that their diet contained mostly *Calanus finmarchicus*, *C. hyperboreus*, amphipods and krill.

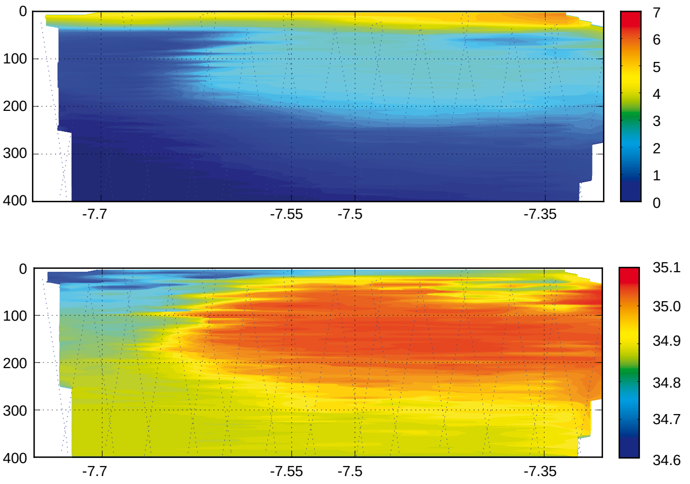

Figure 4. Temperature (top) and salinity (bottom) transects across the Jan Mayen Front. The vertical axis in depth in metres and the horizontal axis is the longitude in °W. The deep Front is located at about 50-300 m located west of 7.55°W. Note the interleaving between the cold, fresher Arctic waters and the warm, salty Atlantic waters in layers 10-20 m thick.

One of the highlights of the trip was the opportunity to go ashore for a couple of hours on the island of Jan Mayen. The military administrative head of this Norwegian island welcomed us upon our arrival and invited us to coffee in the recreation hut where we were able to talk to some of the people living on the island. There are approximately 20 or so occupants, all except the head of the island are civilians conducting research, taking meteorological measurements or involved in maintaining the station. The island is of volcanic origin and is dominated by the active volcano, Beerenberg (2277 m; Fig. 1), which last erupted in 1985. The waters around the island are extremely productive with high phytoplankton and zooplankton biomass and large bird colonies.

Many thanks go out to the scientific staff from the Institute of Marine Research, the University of Tromsø, Aqua-Plan Niva in Tromsø, the Norwegian University of Science and Technology in Trondheim and the University of Bergen (Fig. 6) and the crew of the *G.O. Sars* for a successful and enjoyable cruise.

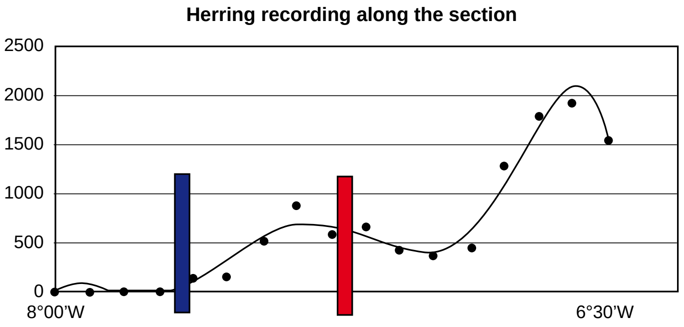

Figure 5. A relative index of herring abundance across the Jan Mayen Front. The blue vertical bar denotes the location of the deep front and the red bar the shallow front.

Figure 6. Scientific staff on the G.O. Sars investigating the Jan Mayen Front in June, 2007.

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Announcement of a CCC Workshop on Cod and Future Climate Change

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Many of the regions presently occupied by Atlantic cod are predicted to undergo significant warming in response to climate change and in recent years much of the North Atlantic has experienced such 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 have been limited. Indeed, the few published studies have usually considered the response of Atlantic cod to increased warming without considering other components of the marine ecosystem, such as what will happen to their prey or predators. However, climate change is expected to impact both the structure and function of marine ecosystems and hence to develop more plausible impact scenarios we must consider not only the species but other parts of the ecosystem as well. Therefore, the ICES/GLOBEC Cod and Climate Change (CCC) programme is sponsoring a Workshop on Cod and Future Climate Change in June 2008. Using the increased understanding gained through the CCC programme, including past workshops, plus other research on the effects of climate variability on cod and its supporting ecosystem, this workshop will develop scenarios on the impact of future climate on the marine ecosystems of the North Atlantic with a special focus on cod.

The terms of reference are:

A Workshop on Cod and Future Climate Change (WCFCC) (Co-chairs: K. Drinkwater, J. Dippner and C. Schrum) will meet at the ICES headquarters, Copenhagen, Denmark, 14-17 June 2008.

In response to future climate change scenarios to:

1. adopt 20-50 year probabilistic projections of future temperature, salinity and nutrients as a basis for projections of fish population dynamics and distribution determine the most likely response of the physical oceanography, including nutrient concentrations, in the North Atlantic;
2. develop methodologies and make projections of likely changes to phytoplankton and zooplankton production and distribution, especially those eaten by cod and their predators and prey during their life histories;
3. develop methodologies and make projections of likely changes to predators and prey of cod , including the forage fishes such as capelin, herring, sprat and mackerel;
4. develop methodologies and make projections of likely changes in cod production (growth, reproduction, mortality, recruitment) and distribution.

This will be carried out using a combination of retrospective data analyses and a variety of modelling approaches.

The idea is to structure the workshop around a potential paper or papers with the ultimate goal to develop scenarios of the effects of future climate change on Atlantic cod throughout its distributional range. While the amount of information on cod and their supporting ecosystems varies geographically, the goal is to be able to say something about all of the cod stocks, if possible, and provide some estimate of the likelihood of the scenarios.

If you would like to attend the workshop please contact one of the co-convenors (ken.drinkwater@imr.no; Corinna.Schrum@gfi.uib.no; joachim.dippner@io-warnemuende.de) or Keith Brander (kbr@difres.dk). As there will be a website set up for people to post their ideas and information prior to and during the meeting, even if you cannot attend but would like to contribute, please contact us. Our hope is to have as much preliminary material on the website prior to the meeting and spend the meeting in discussions and writing.

From Cod and Climate Change to the IPCC reports

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The Cod and Climate Change (CCC) programme was the earliest component of GLOBEC to get underway, in the early 1990s. The aim was to investigate how ocean climate acted on marine ecosystems in which cod occurred and specifically to study the causes of year-to-year variability in recruitment. Cod was chosen as the target species because of its commercial importance and the long history of demographic information and scientific investigation available. It also served to bring together research efforts in all the countries around the North Atlantic, including the Baltic Sea. Because of the large body of existing research one of the first activities, rather unusually, was a major symposium in 1993, which assembled and synthesized much of the work and history to date. This also provided an excellent milestone against which our subsequent progress can be judged.

The principal questions being addressed during the early years of the programme concerned the causes of interannual variability in recruitment and of decadal trends, such as the gadoid outburst in the North Sea (1960-1985) or the changes in distribution and abundance of many marine species in the northern North Atlantic from the mid 1920s to the 1940s and later. Global, long-term anthropogenic climate change became an element of the CCC programme from the late 1990s on, although it had of course been known about for many years.

The CCC programme was also conceived as a pilot project to widen the environmental and biological perspectives of fisheries management advice within ICES. The ICES/GLOBEC office was established in 1996 as a "pump-priming" exercise to give the ICES Secretariat additional expertise in this area and to bring together the environmental and fisheries strands of the advisory system. Now, over a decade later and with two years of the CCC programme and GLOBEC to run the office has moved to the Danish National Institute of Aquatic Research (also in Copenhagen) and the ICES scientific advice is still struggling to move beyond the traditional biological bookkeeping of numbers at age for a few major species. The reasons for both of these circumstances would occupy another article, but do not reflect well on the ability of scientific organisations to foster progress and show that they can act as inhibitors rather than catalysts in relation to fisheries and marine ecosystem advice (ICES, 2006).

With a title like CCC it was inevitable that many of us involved in the programme would be drawn into the increasing activity on the impacts of anthropogenic climate change. In effect the meaning of the programme title shifted to the longer time-scales which had become such a subject of scientific, political and public concern. The strong tradition of climate-fisheries research of course gave us a head start in many ways. Fisheries scientists have been aware of and used the major indicators of climate, such as ENSO and the NAO, well before our terrestrial counterparts did so.

Apart from providing reviewers comments on parts of the second IPCC report in 1995, my first co-author contribution to a climate impact study was the ACACIA report (Parry, 2000), which provided the basis for the European chapter on impacts of climate change in the IPCC Third Assessment Report. This was followed by the Arctic Climate Impact Assessment (ACIA, 2004, which brought together a strong interdisciplinary team of marine scientists under Harald Loeng to work on all aspects of the Arctic marine system. From 2003 I joined the team preparing the Impacts, Adaptations and Vulnerability part of the IPCC Fourth Assessment Report. Marine systems were not dealt with together in one chapter, but spread over many; material on aquatic ecosystems is found in the chapters on observed impacts, ecosystems, food and regional issues. At various times in the process we coordinated our drafts in order to ensure that we avoided repetition and contradictions and that the main elements emerged. The extra work generated by this dispersed treatment of marine systems was compensated by working with and learning from colleagues in completely different scientific fields and the rest of this article aims to present some of the insights which I gained.

Keith Brander with Martin Parry, co-chair of IPCC WG2, celebrating over a cup of coffee.

One of the strengths of the IPCC process is the use of common methodology in relation to causal attribution and consistent language to convey uncertainty and likelihood (IPCC, 2004, 2005). The first workshop I attended in 2003 brought together experts in climatology, cryosphere, hydrology, extreme events, disasters, ecosystems, agriculture, sea-level, and human health to discuss detection and attribution of climate effects. The evidence from our various fields of expertise was assembled to ask: (i) How far can detectable regional changes of climate be seen to be affecting local systems? (ii) Which systems are more or less sensitive or resilient to climate variability and change? (iii) What time lags occur in the responses? (iv) Are there adaptive responses from which lessons can be learnt?

Most of the work I did for the IPCC report was for the chapter on "Food, fibre and forest products" and the team included experts in agriculture, forestry, food security, pastoralism, sustainable development and economics. We put together tables showing expected changes in production of different foods over a range of temperature increases, but the fisheries contribution to these is embarrassingly small, because we simply cannot make such predictions. The crop and forestry predictions are based on very extensive field studies and experiments of a kind which do not exist for fish and this led me to review what marine scientists in general and GLOBEC in particular could do to improve our capability.

There is some scope for experimental work, particularly to investigate the joint impacts of several climate related pressures, including acidification, hypoxia and temperature, but fisheries are not like crops in agriculture, where a small number of species are grown under controlled conditions. The representation of ocean processes in global circulation models is improving, with better vertical resolution providing a basis for primary production models. These developments will no doubt be vigorously pursued in the IMBER programme in relation to both biogeochemical cycles and productivity of aquatic resources. As regards changes in global fish productivity, the default position is that changes in primary production will cause commensurate changes further up the food chain. The challenge for GLOBEC is improve on the default in order to evaluate the consequences for sustainable production and to identify regions and countries which are likely to be vulnerable to changes in fisheries. This challenge has been picked up in programmes such as the new UK QUEST-Fish (http://web.pml.ac.uk/quest-fish/; Jennings *et al.*, in press).

The report of IPCC Working Group II landed on the doorstep in early March, weighing over 3kg, of which I think I contributed about three pages. The news of the award of the Nobel Peace Prize to the IPCC was broken by Manuel Barange during a project evaluation meeting in Swindon – a very memorable occasion. The authors of the Food chapter contributed papers to a Special Feature on Climate Change and Food Security (Easterling, 2007) in December 2007, including mine on “Global fish production and climate change” (Brander, 2007); perhaps not an expected outcome of the CCC programme, but nevertheless a product of the insights we have gained from it.

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Cod and Climate Change – a review of some recent studies

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Publications related to CCC emerge almost daily. Here I review just a few which give new insights into some of the consequences for managing fisheries under changing climate conditions.

There has been a welcome increase in the number of papers using historical, archaeological and palaeo-ecological data to reconstruct past states of marine ecosystems and fish stocks (Quero, 1998; Jackson *et al.*, 2001; Rosenberg *et al.*, 2005; Ojaveer and MacKenzie, 2007). The latter paper is the introduction to an outstanding linked group of studies recently published in Fisheries Research. These are particularly valuable in helping to overcome the “shifting baseline” syndrome (Pauly, 1995), which restricts our perception of the past to the period we have personally experienced and the duration of acceptable time series. Most fish stocks assessments cover only the past 20-50 years, but this is a period of unprecedentedly high fishing mortality and rapid climate change, which only permits weak inferences concerning earlier states of exploitation (and climate).

A paper by Hjermann *et al.* (2007) develops the insight that species interactions, exploitation and climate variation cannot be dealt with as separate issues. It presents a general approach for studying the dynamic structure of such interactions, built around an analysis of the recruitment of the world’s largest cod stock, the Northeast Arctic cod. The proportion of older fish in this stock has been steadily decreasing and the spawning stock now consists of relatively few age groups. They develop a model for the effect of capelin (the cod’s main prey) and herring on cod recruitment since 1973 and then use it to analyse data on cod, herring and temperature going back to 1921. They find that food-web effects explain a significant part of cod recruitment variation. The paper supports the results of other recent studies in showing that the strength of the effects of climate (NAO, temperature) depend on the level at which a stock is being exploited (Brander, 2005; Ottersen, 2006). It also highlights some interesting similarities and differences in the interaction between cod and pelagic species in the Baltic and the Barents Sea.

A short communication on harvest control rules (HCR) might seem like an unlikely source of new insight and inspiration for CCC, however the paper by Bob Mohn and Ghislain Chouinard (2007) provides both. It uses a moving window time series analysis on cod in the southern Gulf of St Lawrence to show that there have been three periods with very different levels of production since 1950 (see Table 1). Growth, natural mortality and especially recruitment contribute to the altered productivity and although the underlying causes are not investigated, they point out that changes in ambient temperature are likely to be implicated. The paper exposes the risk of treating productivity and its associated reference points as constant, which is exactly what most fisheries management strategies do. A biomass based HCR is inadequate to manage this stock, because of the shifts in productivity. Productivity and its components (growth, survival, recruitment) has to be monitored in order to match harvest with production and to provide warning of any change in the regime. Of course it is possible to set precautionary reference points which are robust to variability in productivity, but as a glance at the Table shows, these would have to be very conservative indeed, because MSY is close to zero during some periods and the corresponding sustainable level of fishing is very low. Understanding the environmental and other causes of changes in productivity would obviously be worth a great deal in terms of reducing risk of overexploitation while maximising harvest potential. GLOBEC and the CCC programme should have much to offer here.

Table 1. Production (as indexed by MSY) for Southern Gulf of St Lawrence cod, with the corresponding management reference points for biomass and fishing mortality.

Period	MSY (kt)	B_{msy} (kt)	F_{msy}
1950-1972	67	329	0.30
1973-1985	150	520	0.45
1986-2003	4	92	0.12

One of the papers in the volume of Fisheries Research mentioned above analysed fish bones from Mesolithic Stone Age excavations in Denmark to provide a record of catches of a number of warm water species which occurred during the Atlantic period (*ca.* 7000-3900 BC), when mean summer water temperature was 1.5-2.0°C higher than at present (Enghoff *et al.*, 2007). However, in addition to the warm water species which were present then and are returning again now (anchovy, sea bass), cod were also abundant, indicating that the higher prevailing temperatures did not cause the population to decline. Recent results from cod carrying data storage tags demonstrate that the thermal tolerance limits of individuals are quite high and that their behaviour in relation to temperature is by no means simple (Neat and Righton, 2007). The majority of cod tagged in the North Sea remained in a warmer fraction of the sea than was potentially available to them. In summer, many cod in the south experienced temperatures considered superoptimal for growth. Although cooler waters were within the reach of the cod only a small number of individuals migrated there, suggesting that the changing thermal regime of the North Sea is not yet causing adult cod to move to cooler waters. It is also worth recalling that the only cod stock which increased from 1970 to the mid 1990s is the one in the Celtic Sea, which experiences higher average temperature than any other (Brander, 2007). This does not fit our general expectation of how cod respond to high temperatures and serves as a warning against oversimplified assessments of the effects of temperature on change in distribution and abundance.

Many other papers would be worth reviewing and putting in context, including an excellent meta-population model of cod stocks around the British Isles by Mike Heath and others, which explores the evidence for and consequences of natal fidelity (in press in Fisheries Research). However I will finish with one which looks forward in time at the consequences of 21st century climate change on the Baltic Sea fish community and fisheries (MacKenzie *et al.*, 2007). It brings together several of the insights of the other papers mentioned here and adds a few more. The first is that temperature is not the only climate factor and in some situations is not the most important. Cod in the Baltic Sea is at the extreme of its salinity tolerance. Below 11 psu the sperm become inactive and the eggs to sink into deep anoxic layers (there is also an interaction between salinity and oxygen tolerance). However the dynamics of cod in the Baltic is also strongly influenced by the dynamics of its prey during larval life (*Pseudocalanus*) and forage species in later life (sprat and herring), which in turn prey on cod eggs (Fig. 1).

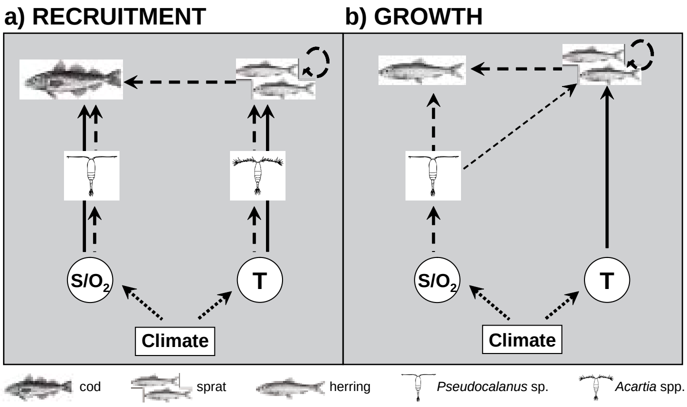

Figure 1. Conceptual model of major climate effects on a) recruitment and b) growth of three fish species (cod, sprat and herring) in the eastern Baltic Sea. Dotted arrows – effect of climate on hydrography, dashed arrows, indirect effects; and solid arrows direct effects; S, salinity; O_2, oxygen; T, temperature.

The Baltic is expected to become fresher during this century, due to increased precipitation and decreased inflow of saline Atlantic water. This is likely to trigger major changes in the marine ecosystem including further decline in the cod stocks as the volume of water with properties suitable for reproduction shrinks. Reference points or thresholds which trigger fisheries management responses will have to be reassessed as the composition and productivity of the system changes. New strategies are needed in relation to resident or immigrant species which increase as conditions become more favourable for them. The Baltic situation illustrates some of the uncertainties and complexities associated with forecasting how fish populations, communities and industries might respond to future climate change.

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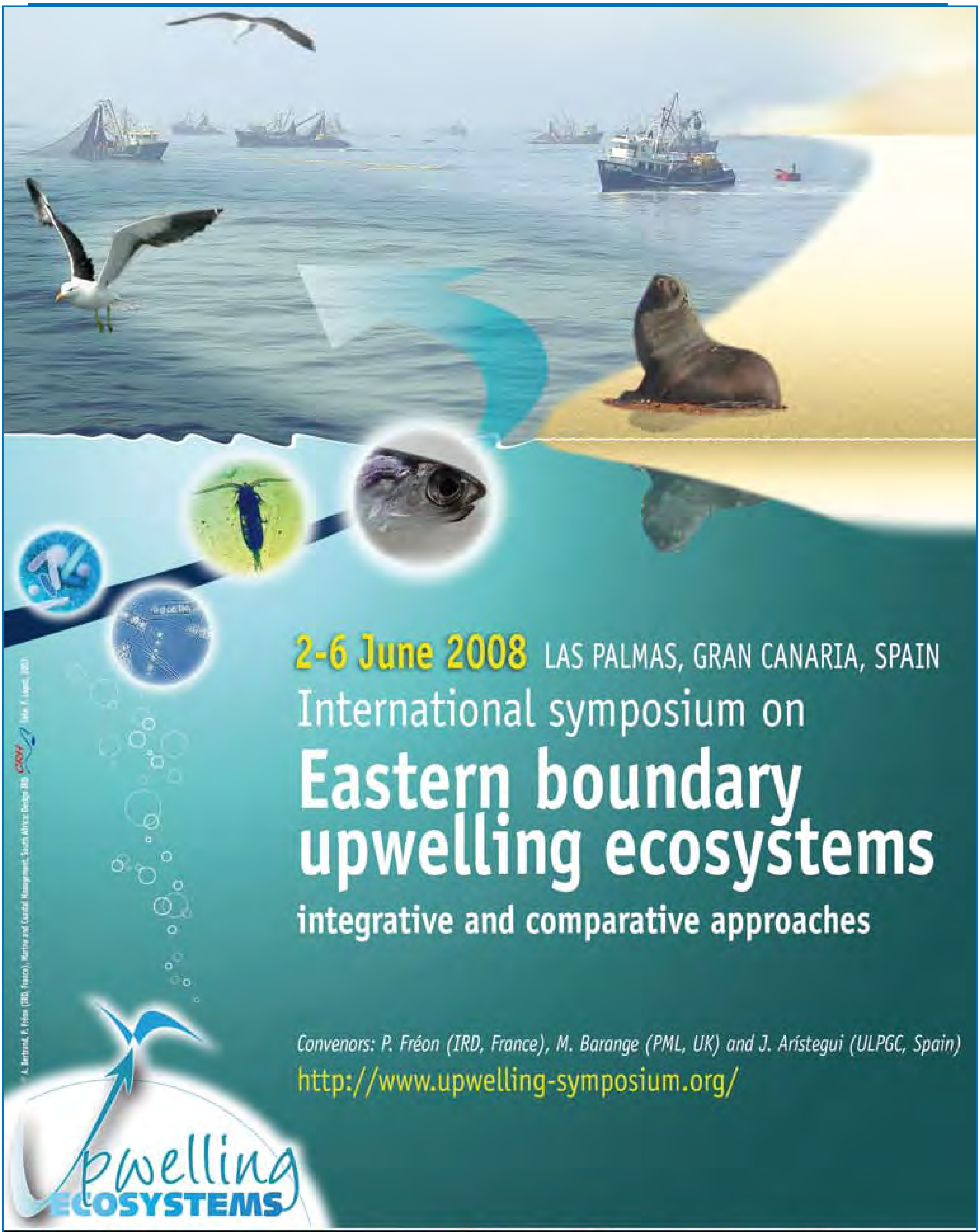

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UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

Report on recent ESSAS activities

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During the last several months the Ecosystem Studies of Sub-Arctic Seas (ESSAS) regional programme of GLOBEC has been active on several fronts. The following summarises some of the products and activities within ESSAS.

ESSAS special volume

At the end of 2007, the Deep-Sea Research II special volume on Climate Variability and Sub-Arctic Marine Ecosystems was published containing 35 papers presented at the ESSAS kick-off Symposium held in Victoria, Canada, in May 2005 (Fig. 1). The overarching scientific objective of the symposium was to present the current knowledge of the effects of spatial (regional) and temporal (seasonal to multi-decadal) climate variability on the structure and function of sub-arctic marine ecosystems. The volume consists of regional reviews of four sub-arctic regions (Oyashio Current, Eastern Bering, Iceland Sea, and Barents Sea) and a comparative paper on climate forcing in several sub-arctic areas. These regional review papers will serve not only as introductions to the marine literature of each region, but also as benchmarks against which future change may be measured. Disciplinary papers focused on physical and chemical aspects, on primary production, on zooplankton, on higher trophic levels, including benthos, fish, seabirds and marine mammals, and on the human dimension side of climate impacts on marine ecosystems. Many papers focused on mechanisms whereby climate might impact biological processes in marine ecosystems.

Figure 1. ESSAS special issue of Deep-Sea Research II. G.L. Hunt, Jr., K. Drinkwater, S.M. McKinnell and D.L. Mackas. (Eds.). Effects of climate variability on sub-arctic marine ecosystems: A GLOBEC symposium. Deep-Sea Research II 54(23-26): 2453-2970.

Several sub-arctic seas have experienced high air and water temperatures in recent years with subsequent reductions in the extent of sea ice. Moreover, the large-scale atmospheric forcing of the sub-arctic regions can account for the regional patterns of the responses across widely separated sub-arctic seas. Major changes in community structure and changes in the productivity and abundance of major commercial fish species have taken place or are presently occurring. Many species have extended their geographic boundaries northward. Biophysical models have made great strides during the past 5 to 10 years in their ability to simulate the observations, and offer great potential to improve our understanding and predict future changes over the coming years. While it was clear that climate variability affects sub-arctic seas, it was also equally clear that industrial fisheries have played a major role in the restructuring of these marine ecosystems. One major challenge to the scientific community will be to develop a better understanding of ecosystem responses to climate forcing, and to evaluate how these natural forcing factors interact with anthropogenic impacts (activities) to produce the changes that we observe. Another major challenge is to make the results of the research understandable and relevant to the communities affected, including fisheries management.

MENU

The Marine Ecosystem Comparison of Norway and the United States (MENU) involves scientists from NOAA in Wood's Hole and Seattle, the University of Washington, the University of Alaska, and from the Institute of Marine Research in Bergen. MENU is comparing the ecosystems of the eastern Bering Sea, the coastal region of the Gulf of Alaska, the Gulf of Maine/Georges Bank region, and the Barents/Norwegian seas. A MENU workshop funded by the Research Council of Norway was held in Bergen during March 2007. The participants, who covered various components of the ecosystems, brought their datasets and modelling results to the meeting. Based on the synthesis efforts at the workshop, five papers were outlined. Two dealt with the responses to recent climate variability in the different regions, one on physical oceanography and the second on the biota. The other three compared selected characteristics of the ecosystem. These included recruitment of functionally analogous fish stocks, community and trophic structure based on energy budgets and system metrics, and trends in the biotic communities including synchronies, differences, and commonalities. These papers were presented along with the four regional overviews of the different ecosystems to a MENU-sponsored theme session the 2007 ICES Annual Science Meeting in Helsinki Finland titled "Comparative Marine Ecosystem Structure and Function: Descriptors and Characteristics". Four of the comparative papers were also presented at the PICES 16th Annual Science Meeting held in Victoria, Canada, during late October-early November. A special volume of Progress in Oceanography has been commissioned to publish the papers presented at the ICES theme session. The five MENU comparative papers will be submitted to this special volume. In addition to the presentations, talks and journal articles that emerged from the work within MENU, the collaboration between Norway and US investigators has also resulted in an effort to develop a MENU II proposal. This proposal will be based on what has been achieved in the MENU project, but will be a much larger proposal including more basic research. It is hoped to submit the proposal jointly to the Research Council of Norway and NOAA later this year.

NORCAN

The 3rd meeting of the Norway-Canada Comparative Study of Marine Ecosystems (NORCAN) was held on 14-17 January 2008 in Bergen, Norway. The project includes Norwegian scientists from the Institute of Marine Research in Bergen and Canadian scientists from the Northwest Atlantic Fisheries Center in St. John's, Newfoundland, and the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. It has been funded jointly by the Research Council of Norway and the Newfoundland Region of the Department of Fisheries and Oceans in Canada. NORCAN is comparing different aspects of the ecosystems in the Labrador Sea and Labrador/Newfoundland Shelves with the Barents and Norwegian seas. Eight separate papers are in progress on: climate forcing and physical oceanography; phytoplankton dynamics; ecology of *Calanus finmarchicus*; fish community structure; capelin recruitment; capelin distribution; cod dynamics; and marine mammals. During the first day of the meeting, reports on the progress of the various writing groups were given and linkages between the various papers discussed. The next two days, the different writing groups meet to discuss their papers and proceed with the writing. The final day was spent discussing the progress that had been made at the meeting as well as the form of the synthesis paper that should be written. The plan is to have first drafts of the papers by June and to publish the papers together in the ICES Journal of Marine Science.

Ocean Sciences Meeting Theme Session and Workshop

On 3 March 2008 in Orlando Florida, ESSAS sponsored a theme session on Climate Impacts on Sub-polar Seas: Mechanisms of Change and Evidence of Response. A total of 10 oral presentations and 13 posters were included in the theme session. Two of the former were comparative papers, one on the recent responses in four northern hemisphere regions and the other on the ecology of *Calanus finmarchicus* in the Norwegian and Labrador seas. The remainder dealt with regional issues within specific areas, including the Bering Sea, the North Pacific, the Barents Sea, and the Antarctic. These covered all components of the ecosystem including chemistry, phytoplankton, zooplankton, fish, marine mammals and seabirds. Another ESSAS/MENU-associated theme session on Comparing Aquatic Ecosystems was held on 4 March that attracted five oral presentations and two posters.

During the noon break on 3 March, ESSAS also sponsored a mini workshop on Understanding Climate Impacts on Sub-Arctic Seas: Ecological Issues and Comparative Approaches. The purpose of the Workshop was to exchange experiences and ideas on how to conduct comparative studies. Following presentations on programmes in the eastern Bering and Barents seas and on the MENU programme's comparative studies of the eastern Bering, Gulf of Alaska, Gulf of Maine/Georges Bank and the Barents Sea, a general discussion was held. Methods included the use of ecosystem models and using similar models for different regions and different models for one or more regions. Also it was suggested it is useful to gather together data from each region that one is going to compare and let the data determine the ideas rather than coming with preconceived hypotheses.

Establishment of an ESSAS Project Office

The Research Council of Norway and the Institute of Marine Research (IMR) in Bergen have recently agreed to fund an ESSAS Project Office at IMR. The goal of the ESSAS Project Office will be to facilitate ESSAS activities. The Office will be run by an ESSAS Coordinator, under the direction of ESSAS Co-chairs and SSC. The Office will: organise annual and special ESSAS meetings and workshops including arranging meeting logistics in cooperation with local hosts; help guest editors of ESSAS special volume publications by acting as managing editor (i.e. oversee the review process and participate in editing through ensuring correct formats, proper figures, etc.); write reports of ESSAS meetings including those of the SSC; write summaries of ESSAS meetings for newsletters and the web; liaison with the various institutions involved in ESSAS; develop and maintain an ESSAS website; foster communications amongst ESSAS members; promote ESSAS activities and philosophy; provide information on ESSAS to scientists outside the programme, to funding agencies, the media and the general public; and provide information on ESSAS to the GLOBEC International Project Office and other international organisations when requested. The Coordinator's position will be half time and will be for 5 years. It is presently planned to combine it with a half-time position in physical oceanography at IMR and to hire the person by at least the summer of this year.

2008 ESSAS Annual Meeting

The 2008 annual meeting of ESSAS will be held 15-17 September in Halifax, Nova Scotia, Canada, followed by a two day meeting of the ESSAS SSC. The ESSAS meeting will occur the week prior to the ICES ASC meeting, also to be held in Halifax. The ESSAS meeting will consist of three workshops: (1) the Role of Transport in Sub-arctic Marine Ecosystems; (2) Future Climate Scenarios and their Impacts on Subarctic Regions; and (3) Modelling of Subarctic Marine Ecosystems. The Workshop on Transport will examine the effects of advection on the physical oceanography and biology of sub-arctic seas. The latter includes the role of transport on the supply of zooplankton from the deep ocean onto to the continental shelves, on the drift of fish eggs and larvae, and on biogeographic shifts. The Workshop on Future Ecosystem Impacts will use the most recent IPCC climate scenarios and their physical oceanographic consequences to generate discussion on the possible biological consequences. The Workshop on Modelling Sub-arctic Seas will discuss the use of various biophysical models and how to compare model results from different regions. There will also be presentation and discussion of papers that were outlined and commenced based on workshops held at the June 2007 ESSAS Annual Meeting in Hakodate, Japan. These papers include investigation of the effects of climate change on thresholds affecting ecosystem function and the role of hotspots in sub-arctic seas. Anyone who is interested in attending the 2008 ESSAS meeting and workshops please contact either George Hunt (geohunt2@u.washington.edu) or Ken Drinkwater (ken.drinkwater@imr.no). All are welcome.

The first CLIOTOP Symposium: An overview

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CLIOTOP is a ten year (2005-2014) GLOBEC programme focusing on oceanic top predators and high seas ecosystems. CLIOTOP aims at stimulating international scientific collaborations to improve our knowledge of the processes and dynamics of oceanic pelagic ecosystems, in a context of both climate variability and change and intensive fishing of top predators. The ultimate goal is to develop a reliable predictive capacity for single species and ecosystem dynamics at short, medium and long term scales.

CLIOTOP held its first Open Science Symposium in the beautiful environment of La Paz, Mexico from 3 to 7 December 2007. Thanks to the convenors and local organisers (CICIMAR and CIBNOR) and to all the enthusiastic participants, the symposium was a great success. The participants particularly enjoyed the diversity and the high level of the scientific presentations, as well as the very friendly atmosphere and various touristic activities that were proposed during the free afternoon in the middle of the week.

By bringing together scientists working on the biology and ecology of pelagic top predators, the functioning and modelling of their ecosystem, and their management and conservation in a climate change perspective, this first international symposium was definitely a key step in the implementation of CLIOTOP towards the achievement of its objectives. The conference was very stimulating and provided the marine science community with an up-to-date view on research, knowledge and future needs for understanding and managing top predators and their ecosystems.

Nearly 200 participants, including many students and young scientists, from 25 different countries attended the conference. 93 oral communications and 73 posters were presented in the course of 9 sessions. Most oral presentations and some posters are available online at http://www.globec.org/structure/regional/cliotop/symposium/opening.htm. Some of them have been submitted for publication in the Special Issue of Progress in Oceanography.

CLIOTOP is structured around 5 collaborative Working Groups which each held a "Town Hall" meeting during the evening to inform the conference participants about WG activities and to attract potential newcomers for developing projects and collaborations within the international scientific community and between cross-disciplinary research teams. Such collaborative works are indeed the backbone of CLIOTOP with the idea that the variety of climatic and oceanographic conditions in different oceans provides a unique opportunity for large scale comparative analysis of open ocean ecosystem functioning.

CLIOTOP symposium structure

Five Working Group sessions:

- WG1: Early life history of top predators
- WG2: Physiology, behaviour and distribution of top predators
- WG3: Trophic pathways in open ocean ecosystems
- WG4: Synthesis and modelling
- WG5: Socio-economic aspects and management strategies

Four crosscutting sessions:

- CS1: Climate change and top predators/pelagic ecosystems
- CS2: Meso-scale issues (including downscaling and upscaling from and to the global scale) in CLIOTOP
- CS3: Global change implications for management and conservation strategies of top predators
- CS4: Future scientific challenges: what is needed from the field, what is needed from the models, where are the gaps.

The symposium started with an opening talk from Olivier Maury "From Pandora to CLIOTOP". Then Cisco Werner gave an introductory keynote presentation entitled "Marine ecosystem science: trajectory, synthesis and future directions (a GLOBEC perspective)". The four crosscutting sessions of the symposium were introduced by invited keynote presentations from Nathan Mantua ("Patterns of variablity, predictability, and scenarios for change in the tropical and temperate oceans"), William J. Sydeman ("Local effects of climate change: upwelling, ice, food webs and seabird archipelagos"), Scott A. Shaffer ("Changes in the foraging behaviour of albatross, sea lions and elephant seals in response to changing conditions in the North Pacific, 2003-2007"), Philippe Gaspar ("Monitoring and modelling pelagic animals' behaviour at the mesoscale: a challenge for the next decade"), Rebecca Lent ("Climate and NOAA's stewardship responsibilities: research and policy") and James F. Kitchell ("Lessons from the ecosystem approach").

The sections below give an overview of the WG sessions and corresponding evening meetings. Readers interested in the crosscutting sessions should download the abstract book from the conference which is available at http://www.globec.org/structure/regional/cliotop/symposium/opening.htm.

John Sibert asking one of his difficult questions...

...and Henri Weimerskirch trying to answer it.

WG1: Early life history of top predators

Considering the relative scarcity of research on the early life history of top predators, the contribution of WG1 to the first CLIOTOP symposium was very successful since 15 oral presentations and 13 posters were presented as well as 3 presentations relative to mesoscale features influencing tuna spawning habitats presented in the CS2 session. Many presentations focused on the early life history of billfishes and tunas with a first start by R. Cowen showing exciting novel sampling equipments to examine spatial and temporal distribution of top predator larvae relative to zooplankton community structure and oceanographic processes. Mesoscale structures were also highlighted in relation to trophic ecology (e.g. larval billfishes, tunas and mackerels off the Florida Straits by J. Llopiz) and larval distribution (striped marlin and sailfishes off the Gulf of California by R. de Armas).

Research effort recently undertaken by Japanese and Spanish scientists provided a number of presentations and posters related to various aspects of bluefin tuna and associated species larval ecology. The spawning habitat preferences of Mediterranean bluefin tuna and its associated species (frigate and albacore tuna) were described (A. García) from a sequence of 5 yearly surveys carried out off the Balearic archipelago, revealing significant associations with surface temperature, salinity, oxygen, depth and geographic location. Juvenile tunas in the Pacific Ocean exhibit a preferential distribution in the convergence zones between the north and south equatorial currents (T. Tanabe).

Bluefin larval growth variability and condition indices based on the estimation of RNA/DNA ratios were analysed against the environment. Changes in the environment of the Mediterranean bluefin spawning grounds resulting from the 2003 summer heat wave impacted the growth of bluefin larvae (A. García) and their condition and abundance (D. Cortes). In a similar research focus, Pacific bluefin larval survival probability was analysed through otolith microstructure analysis and biochemical estimates of larval nutritional condition (Y. Tanaka), suggesting that bluefin tuna larvae have a low tolerance to starvation with immediate growth retardation and 10 to 50% death after one starving day.

Research conducted under controlled conditions are considered by WG1 to be of great potential for developing understanding of exogenous factors that affect larval survival. Progress on growth dynamics and larval ageing of tropical scombrids in the eastern Pacific Ocean as well as the development of methods for the collection and husbandry of larvae and juveniles were reviewed (D. Margulies). The effect of oceanic turbulence on larval survival is critical. Laboratory experiments on bluefin larvae and *in situ* observations showed that optimal wind mixing (7.5m/s) is needed for bluefin larval survival (Y. Kato), whilst high turbulence levels (15m/s) are highly detrimental. An individual based model (IBM) of the Mediterranean bluefin tuna early life history was presented (P. Mariani) using outputs from a three dimensional hydrodynamic model to transport eggs and larvae until the metamorphosis and to simulate their trajectories. Seasonal and inter-annual simulated patterns of aggregation, retention and dispersion of particles in the area were reconstructed and analysed.

Presentations in the CS2 session highlighted the importance of mesoscale hydrographic features to characterise bluefin spawning grounds, e.g. around the Ryukyu Islands, between the Kuroshio current and its counter-current (D. Inagake). A comparative approach (P. Vélez) to analyse the common hydrographic features that predominate in the Mediterranean bluefin spawning grounds (Balearic archipelago, Sicilian and Cyprus coasts) suggested that all the spawning zones share a common feature: a frontal situation between incoming water masses from the Atlantic and Mediterranean water masses which generate anticyclonic eddies in interaction with the topography. Those mesoscale structures seem to be the *sine qua non* condition for bluefin tuna spawning.

Rounding up the analysis of tuna spawning habitat, A. Bakun proposed an original hypotheses on the role of mesoscale eddies and its application to the predator pit. He suggested a conceptual framework for viewing the bluefin life-cycle strategy, whereby bluefin tuna employ their size-related swimming capabilities to travel long distances to arrive *en masse* in restricted zones of particularly low concentration of potential predators for their larvae. They also probably further lower the predator abundances by their own predation. This allows the local predator pit for bluefin larvae to be reliably bridged, offering a “lowrisk / limited reward” strategy in agreement with the limited variations in reproductive success that are observed.

The WG1 session was usefully complemented by the decadal scale fluctuations of tuna larvae abundance off the Gulf of Mexico (B. Muhling). Interesting information was provided in poster format on sailfish, *Coryphaena* spp. as well as other top predators that characterise the marine fauna of the eastern Pacific coasts.

An evening "town hall" meeting chaired by Alberto García and Robert Cowen was held where the symposium participants were informed of WG1 activities throughout CLIOTOP's life span. WG1 chairs presented an update about the groups' activities including workshops held in Malaga (Spain) and Shimizu (Japan). Participants were encouraged to participate in WG1 future activities, stressing the need of broadening the number of top predator species in WG1 that has mostly focused on tunas to date.

WG2: Physiology, behaviour and distribution of top predators

There were 17 oral presentations and 21 posters for this session. Tuna was the most addressed group of species and among these, bluefin tuna came first. Another well covered group was the sharks. Marine mammals and turtles were similarly represented. The emergence of non-tuna groups in this symposium reflects the increasing attention given to biodiversity issues in relation to fisheries and climate change. Movements and habitat utilisation composed the bulk of the presentation and posters. This is the result of the recent but generalised use of electronic tags on a wide diversity of species that have generated a considerable amount of precise observations on the behaviour and the proximate environment of these animals. These datasets give a renewed vision of the way marine animals occupy their habitat. The technological barriers are continually pushed away, and following the steady increase of these tagging technologies, we can speculate on other surprising discoveries in the near future. The challenge is to achieve feedback between observation and modelling, targeting a more comprehensive appraisal of the role of environmental cues on population dynamics at various space- and time-scales.

As the other Working Groups, WG2 held an evening "town hall" meeting chaired by Francis Marsac and Richard Brill. WG2 addresses four main focus areas that are the influence (and limits) of proximate cues on tuna movements and distribution, the role of environmental variability on schooling dynamics, environmental determinants of foraging and reproduction, interaction between natural variability and fishing on population structure. The debate covered all these questions. As WG2 research relies extensively on electronic tagging and environmental data, the participants emphasized the need of standardisation of datasets and well-described methodology of data treatment. A specific methodological workshop could be one of the options to develop and disseminate *ad hoc* tools to the CLIOTOP community. A tagging data repository is now accessible through the internet and should be expanded. The spatial dynamics of populations has to be investigated at various nested scales, considering the processes that are relevant at each scale. Meso-scale appears as the new frontier to be investigated and several presentations during the symposium highlighted the structuring role of eddies and fronts into aggregation and movements of pelagic communities. There is a need to investigate more deeply the implications of these highly-structured entities for the management of resources. Physiology remains a core area of interest since it acts as a transfer function between environmental variability and behaviour such as individual movements. Since experiments in controlled conditions are extremely difficult to envision for most top predators, the participants recognised the need to move towards *in situ* experimental physiology using the sophisticated physiological tags that are currently being developed and tested. Overall, the connection between physiologists, ecologists and oceanographers must be strengthened as each community is contributing to the "big picture" through its specific instruments and methods of the marine ecosystems.

Patrick Lehodey (1st from left) and Olivier Maury (2nd from right) working hard with colleagues during a boat trip in the Isla Espiritu Santo National Park.

WG 3: Trophic pathways in open ocean ecosystems

Recent years have produced near-universal recognition that selective removal of oceanic top predators from the food web can impart changes in trophic structure and stability via complex trophic interactions and trophic cascades. The importance of understanding trophic structure and function was underscored by 12 oral presentations and 17 posters.

Some of the most important characters of the symposium: the colony of sea lions during the snorkelling trip.

The comparative approach was strongly emphasised. Lacking long-term datasets to examine ecological changes under changing environmental conditions, comparisons conducted in regions with different environmental conditions might provide a proxy for the effects of climate change. J. Young presented food web comparisons for three regions of the Pacific Ocean that span tropical and temperate waters, using a novel qualitative modelling approach. F. Ménard compared the trophic ecology of several tropical upper-level predators for different regions of the Indian Ocean.

Several novel tools and approaches were highlighted. A. Lezama used acoustic surveys to study spatial relationships between albacore tuna and their prey aggregations. F. Ménard used inferences from comparisons of simultaneous stomach contents analysis and stable isotope analysis (SIA) for studies of trophic ecology of upper-level predators. The important role of squid in pelagic ecosystems was well represented. R. Diáz-Gamboa illustrated predation trends of cetaceans on jumbo squid in the Gulf of California using stable N and C isotopes. In addition to predation pressure, about 100,000 mt of jumbo squid are removed by fishing each year in the Gulf of California. W. Gilly reviewed the ecological importance of this cephalopod as predator, prey, competitor, and opportunistic invader into marginal habitats. R. O'Dor proposed collaborations with the expanding Global Ocean Tracking Network (OTN) for understanding the role of squid in ocean ecosystems.

The development of SIA as an effective tool in understanding pelagic food webs was further highlighted. Robert Olson showed the importance of determining the nitrogen signal at the base of the food web when interpreting $\delta^{15}N$ values of yellowfin tuna (and other predators) from different water masses. J. Logan showed that for Atlantic bluefin tuna, SIA was a relatively simple method of tracking trophic dynamics spatially and temporally. A. Edwards showed that SIA of albatross feathers could be used to track seasonal and temporal variability in feeding success.

S. Glaser showed how stomach contents data could be used in bioenergetics models, and for her efforts won the inaugural CLIOTOP student prize. S. Griffiths used an Ecopath with Ecosim model to show the impacts of selective harvesting on top predators off northern Australia based on, in part, detailed food webs of that region. C. Salvadeo reported the close relation between Brydes' whale distributions and the southern oscillation index and the consequences of potential change brought by climate change.

An evening meeting was convened during the symposium at which input to Working Group 3 was sought. The session was attended by approximately 40 specialists including modellers, biochemists, feeding ecologists, biological oceanographers and acousticians, underlining the point that, even in this restricted field, a multidisciplinary approach was needed. Group 3 chairs Jock Young and Robert Olson presented an update on the groups' activities to that point. These activities included workshops on stable isotope analysis (Olson *et al.*, 2005) and the role of cephalopods in marine ecosystems (Olson and Young, 2007). Collaborative projects comparing food webs within the Pacific Ocean have been initiated. A short presentation was given by P. Lehodey on the progress of the global secondary production models developed in WG4 that are used to simulate the distribution and dynamics of forage organisms.

Discussion then led to the future research directions of the working group. A number of points were reiterated that were important for the development of CLIOTOP science:

- Importance of biochemical studies to support and augment existing dietary data.
- Encourage long term collections and subsequent data storage.
- Initiate between-ocean comparisons of pelagic food webs.
- Further develop the concept of latitudinal and inter-ocean comparisons of pelagic food webs as a proxy for climate change.
- Investigate possibilities of integrating existing data bases from different regions within and between oceans.
- Support the development of an independent acoustic sampler (the MAAS; Maury, 2007) to ground-truth secondary production models.
- Encourage development of EwE models from a range of pelagic ecosystems so that temporal changes in ecosystem structure can be assessed from the viewpoint of climate change.
- Development of qualitative models of pelagic food webs to complement quantitative models.

Andy Bakun answering questions after his stimulating talk.

Raphaël Duboz, Ana Corbineau and Emilie Tew Kai, three of the 20 students sponsored by CLIOTOP to attend the conference.

WG4: Synthesis and modelling

The development of models synthesizing the scientific achievements of the CLIOTOP Working Groups and their use for simulation and prediction is an important objective of CLIOTOP. The WG4 session covered a large range of modelling approaches ranging from an overview of uncertainties in stock assessment methods (A. Fonteneau) to end-to-end integrated models (C. Moloney). The mid-trophic component of the integrated ecosystem model APECOSM (Apex Predator ECOSystem Model) developed in the WG4 framework was presented (O. Maury) as well as a basin scale biogeochemical analysis in the Indian Ocean (V. Koné) and individual based modelling of albatrosses foraging strategies (R. Duboz). New statistical methodology for analysing population fluctuations (T. Rouyer), cetacean-habitat relationships (J. Redfern), bayesian estimations of dolphin populations trends in the Pacific Ocean (G Watters) were described as well as the Pacific-Atlantic Sea Turtles Assessment (PASTA) project (S. Heppell). Climate change simulations conducted in the WG4 framework using SEAPODYM were presented in the crosscutting session CS1 (P. Lehodey).

The Modelling and Synthesis Working Group chaired by George Watters and Raghu Murtugudde held its town-hall meeting to publicise the objectives of the working group. Special emphasis was placed on the role of WG4 as the facilitator of interactions between all other working groups in bringing together the data and models to synthesize the objectives of each working group into CLIOTOP science themes and goals. A brief presentation was made by R. Murtugudde on the history of the working group and by G. Watters on his participation in the WG5 workshop in Santa Barbara. Some of the ongoing research activities funded under the WG4 themes were discussed with descriptions of tools and products being used. Extensive discussions were also held on available resources for the community such as ocean and atmosphere reanalyses products and forward model outputs to drive process studies related to any CLIOTOP research projects. Pending funding opportunities and proposals in review were briefly discussed such as the HiSEA to the European Union and CLIMEO opportunity within the US. It was noted that joint working group meetings between WG4 and other working groups have been successful in the past with a joint WG1-4 workshop in 2007 in Japan. The next CLIOTOP SC meeting in Plymouth, UK in June 2008 was seen as an excellent opportunity to consider a WG2 and WG4 joint workshop since WG1 appears most ripe for such a joint working group meeting.

WG5: Socio-economic aspects and management strategies

Six talks were given in the WG5 session. They covered socioeconomic aspects of the challenges facing both national and international efforts to manage exploitation of oceanic top predators and options for more effective management. J. Mbendo began the session with a talk describing tuna harvesting activities by DWFN fleets in the western Indian Ocean, the different levels of engagement of coastal and island countries with that industry and the difficulties that these countries experience in negotiating favorable access agreements and preventing illegal exploitation of their fishery resources. A. McIlgorm followed with a presentation on the economic implications of climate change for top predator fisheries. F. Alcock discussed the political challenges associated with establishing property rights schemes (transferable quotas) in Regional Fisheries Management Organizations. M. Pan described a bioeconomic model of turtle avoidance options that incorporates sea surface temperature and other variables to explore trade-offs between the effectiveness of turtle avoidance and the economic return of fishing. R. Jiménez-Toribio described the rapid development of tuna fattening operations in the Mediterranean Sea, and the impacts of that activity on the Spanish tuna trap fishery. Finally, R. Mongruel closed the session with a talk describing price evidence of the oligopolistic structure of the tuna canning industry and its implications for fisheries management.

Symposium participants during the coffee break by the pool.

The evening breakout meeting of Working Group 5 was chaired by Kathleen Miller and Rémi Mongruel, both co-chairs of WG5. It focused on identifying opportunities for joint research and further community-building. The group discussed the role of WG5 both within CLIOTOP and more broadly with respect to engagement with fishery managers and policy makers. A progress report on the proposed book based on the Santa Barbara WG5 meeting (provisionally entitled: Fast Fish, Faster Fishers, and a Changing Environment: Challenges for the Sustainability of Oceanic Top Predators) also was presented.

A general conclusion of the discussion is that if our goal is to promote effective fisheries and ecosystem management, better biophysical science is not the only thing that is needed. Research contributions from WG5 are also needed to better understand the drivers and dynamics of human exploitation such as demand growth, changes in harvesting strategies and technology, changes in industry structure and the dynamics and effectiveness of management arrangements. In particular, research is needed on the functioning of Regional Fishery Management Organizations (RFMOs), especially regarding 1) how to overcome barriers to effectiveness and 2) the need for and use of scientific information in management negotiations, monitoring and enforcement. This includes information about climate-related changes in species abundance, behaviour and distribution that could be coupled with information on the economics of exploitation to develop management strategies that can serve both economic and biological objectives.

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The CLIOTOP Symposium:

A personal perspective

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The first CLIOTOP (Climate Impacts on Oceanic Top Predators) Symposium was held on 3-7 December 2007 in La Paz, Mexico. The symposium aimed to stimulate international scientific collaboration among researchers studying the responses of oceanic top predators to climate variability and change and to intensive fishing pressure, and also to showcase current research and identify future challenges. The symposium was largely successful in these endeavours, although there were few marine mammal specialists present, apparently due to a concurrent marine mammal conference held in Cape Town.

There were approximately 175 presentations at the symposium, of which about half were presented orally and half as posters. All oral sessions were held in plenary, which provided a good opportunity to obtain an overview of marine top predator research across species and regions. Poster presentations were split into two sessions. Details of the abstracts, presentations and many of the posters can be obtained from the GLOBEC website (http://www.globec.org/structure/regional/cliotop/symposium/symposium.htm). In this article I will not attempt to summarise the range of topics presented, but will confine my comments to some personal perspectives on general scientific topics.


Symposium participants on a boat trip.

One of the interesting topics that recurred in a number of presentations was the link between oceanic mesoscale features and the movements and distributions of top predators, often linked to "hot spots" and high-use areas. Judicious use of ocean satellite data and logging devices attached to animals provided fascinating insights into the behaviour of top predators in relation to oceanic features and the related ecology of these systems. These studies covered a number of taxa, including squid, fish, sharks, turtles, seabirds, seals and cetaceans, and there appears to be huge scope within CLIOTOP for comparing the strategies adopted by animals with different biology and life history traits, and predicting differential responses to climate change.

Links to climate change were elaborated in a number of presentations, highlighting the advantages of using highly mobile top predators to integrate ecological signals in the ocean. I was impressed at the widespread use of stable isotopes to try to understand the food webs in which the top predators occurred. Of particular interest was the unifying effort made within the CLIOTOP research community to standardise methods and thus enable meaningful comparisons. This carried over into other attempts to carry out global integration, but clearly more such efforts are needed for cross-taxa comparisons and comparisons among oceanic regions. Discussions along these lines occurred during some of the Working Group meetings held during the symposium, further highlighting one of the strengths of the CLIOTOP project (coordinating comparative studies).


CLIOTOP symposium participants, La Paz, Mexico.

There were some extremely interesting presentations on uses of technology, including the tracking of both ocean features and animals (ranging from small fish to whales), and *in situ* image analysis of ichthyoplankton. The early life history of top predators is a focus of one of CLIOTOP's five working groups, and this was manifested at the symposium as a number of presentations elaborating the biology and ecology of the eggs, larvae and juveniles of a variety of fish species. The range of methods that have been employed in these and other studies illustrated the utility of the single-species approach adopted in CLIOTOP in bringing together many research disciplines. The human dimensions of top predator research were represented in a few presentations, mostly linked to fishing policy issues.

Having had limited previous exposure to the research falling within the CLIOTOP project, I found the combination of single-species ecology and large-scale forcing issues to be intellectually stimulating, both at the level of the natural history of the organisms and globally. Links from top predators to biogeochemistry were explicit in some of the modelling presentations and to some extent in the plankton-focused research (including ichthyoplankton). The long life spans and broad ranges of many of the species increase the scope of the time and space scales of the research, with fascinating presentations on the jumbo squid (*Dosidicus gigas*) representing a notable extreme with regard to the scales of responses.

The symposium was a great success, showcasing some fascinating science and pointing to some useful future activities. Some of this will be captured in publications emanating from the symposium, many in a special issue of Progress in Oceanography that will be published within the next year or so.

CLIOTOP: People, fish and climate change

Forecasting the effects of climate change on tuna catches and tuna populations

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The GLOBEC's CLIOTOP programme is self-consciously multidisciplinary. During a CLIOTOP Working Group 5 (WG5: Socioeconomic aspects and management strategies) workshop[1] the participants were asked what products Working Group 4 (WG4: Synthesis and modelling) needed from WG5 and vice versa. Several times during the workshop and during some of breakout sessions, we modellers indicated that we absolutely need a means to forecast fishing effort. Here is why: if you don't know fishing effort you can't compute catch, and if you can't compute catch, you can't compute the population size.

Our general approach is to assume that catch at point (*x*,*y*) on the ocean surface at time *t* is some function of the population density at the point, i.e. $C_{xyt} = g(P_{xyt})$. There are probably many possible forms for the function *g()*, but the one we use most commonly for a fishery with many fishing fleets *(f)* usually looks something like (ignoring age, size and selectivity issues).

$$C_{xyt} = P_{xyt} \Sigma_{f} \cdot Q_{ft} E_{fxyt}$$

Q_{ft} is the "catchability coefficient" expressing he proportion of the population caught by one unit of fishing effort. Q_{ft} is usually assumed to be constant over time, but we know it is more likely to be variable reflecting technological changes in the efficacy of the fishing fleet. We sometimes represent Q_{ft} as a stochastic autocorrelated time series, but we really don't understand how Q_{ft} depends on technological innovation or on sociological and economic forcing. E_{fxyt} is, of course, fishing effort expressed in days fished, sets, number of hooks, or some other convenient measure. In retrospective studies, e.g. stock assessment models or SEAPODYM, we use the observed fishing effort from a variety of sources. This all works fairly well and model predictions of catch can be made to agree well with observed catch.

Giant bluefin tuna headed for the processing plant in Favignana, Sicily, May 1979. Photographer: Danilo Cedrone. Courtesy of United Nations Food and Agriculture Organization and NOAA Photo Library.

The problem comes in trying to deal with the future in both the short and long term. In the sort term, forecasts of fishing effort are required to compute maximum sustainable yield for the next year of fishing. Assessment scientists often assume that future distribution of fishing effort will be equal to the average of the estimated fishing mortality for the last few years.

In the long term, we are really at a loss to know what to do. The modellers could simply invent a suite of arbitrary scenarios for future effort redistribution. A more satisfactory approach would be to enlist the help of social scientists and economists to develop models that would predict fishing effort under different management, stock abundance and global warming scenarios. A complete reparametrisation of the fishing mortality function, *g()*, might be even better. Such a reparametrisation could have additional value for stock assessment specialists who are obliged to solve the inverse problem, $P_{xyt} = g^{-1}(C_{xyt})$, with little information about *g()* and its parameters.

In my opinion, the lack credible projections of fishing effort limits the credibility of forecasts of the effect of climate change on fisheries resources. CLIOTOP, as a multidisciplinary international research programme, is mandated to answer the challenge of forecasting fishing effort. I encourage colleagues to take up the challenge and to begin a dialogue on this subject.

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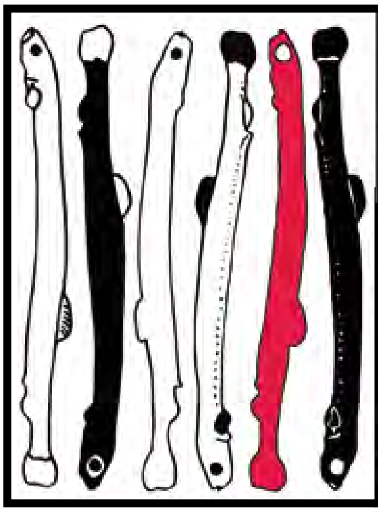
[1] The Challenge of Change: Managing for Sustainability of Oceanic Top Predator Species, A National Science Foundation (NSF) Community Building Workshop, 12-14 April 2007, Marine Science Institute, University of California, Santa Barbara.



Fish enzymes as biochemical markers of marine pollution

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The aquatic environment is the ultimate sink for many organic trace pollutants such as polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzofurans (PCDs) and dibenzo-*p*-dioxins (TCDDs). These contaminants come either from direct discharges or from hydrologic and atmospheric processes (Stegeman and Hahn, 1994). However, with the growth of civilisation the number of chemicals that are introduced to the aquatic environment are increasing, many being hazardous to living organisms, to humans and to ecosystems as a whole (Arinc *et al*., 2000).

Chemical analyses are able to measure quantitatively and accurately a wide range of pollutants in the aquatic ecosystem; however, the complex mixture of chemical pollutants cannot be fully determined, and unfortunately such a mixture does not show the real impact of chemical pollution on the aquatic environment. Besides, the presence of xenobiotic compounds in a segment of an aquatic ecosystem does not, by itself, indicate injurious effects (Van der Oost *et al*., 2003). In the environment, pollutants are present in mixtures rather than alone, and thus the observed effects can be additive or synergistic, or their effects can be counteracted by antagonistic chemicals (Andersson *et al*., 2006).

Connections must be established between external levels of exposure, internal levels of tissue contamination and early adverse effects (Van der Oost *et al*., 2003). Pollutants that bioaccumulate in the organism, first cause effects at the molecular and cellular levels, which lead to adverse effects in the organism, that may cause changes at the population and community level in the years to come (Arinc *et al*., 2000). Figure 1 represents a general scheme of the interrelationships among different levels of biological organisation that can be affected by pollutants and their sequential order of action.

Fish populations living in highly polluted areas often have high incidences of gross pathological lesions and neoplasm that may be associated with the elevated levels of toxic chemicals found in the marine sediments, water and tissues (Payne *et al*., 1987; Malins *et al*., 2006). Fish, which are ectothermic organisms, adapt their biochemical machinery to fluctuations in changes of their surroundings, hence making them very sensitive to changes in the aquatic environment. This reason has allowed scientists to choose fish as a bioindicator species that plays an important role in monitoring water pollution (Jonsson *et al*., 2002; Morales-Caselles *et al*., 2007; Zhu *et al*., 2008). Adaptation of fish enzymes from different tissues, to physical and chemical factors of the aquatic environment, has interestingly been studied for many years with a variety of species living from pole to pole (Somero 1975; Coppes *et al*., 1982; Coppes and Somero 1990, 2007; De Vecchi and Coppes 1996; Pavlisko *et al*., 1997; Hochachka and Somero, 2002).

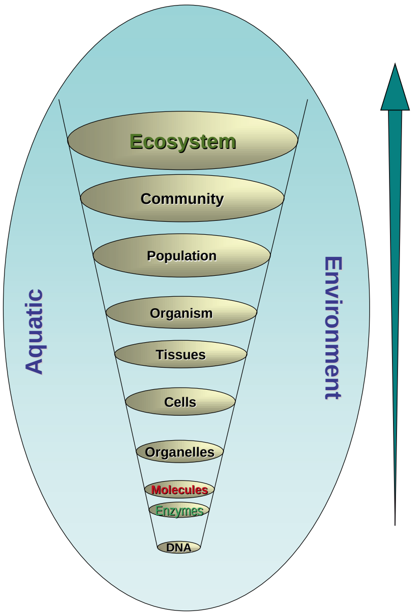

Figure 1. Interrelationships among different levels of biological organisation in fishes that can be affected by chemical pollutants in the aquatic environment (modified from Van der Oost et al., 2003).

The present work reviews the relevance of fish enzymes as biochemical markers for monitoring organic chemical pollutants such as PAHs in the aquatic environment.

Biomarkers of aquatic pollution

There are several definitions for the term biomarker which is generally used in a broad sense and includes almost any measurement reflecting an interaction between a biological system and a potential hazard, which may be chemical, physical or biological (WHO, 1993). A biomarker is defined as a change in a biological response (ranging from molecular through cellular and physiological responses to behavioural changes) which can be related to exposure to or toxic effects of, environmental chemicals (Peakall, 1994; Handy *et al*., 2003).

Biomarkers can be divided into three classes according to the National Research Council (NRC; 1987) and the World Health Organisation (WHO; 1993). Ideal biomarkers must correlate with the health or fitness of the organism, and the basic biology and physiology of the organism should be known, in order to be able to minimise uncontrolled variation (growth and development, reproduction, food sources) (Van der Oost *et al*., 2003).

Why fishes? Changes in age and species distribution in a stock fish population are general indicators of water pollution, but there are also responses specific to a single pollutant or a group of pollutants (Siroka and Drastichova, 2004). According to McCarthy and Shugart (1990) and reaffirmed by Van der Oost *et al*. (2003), fishes have been found to be useful as sentinels, surrogates and predictors. Fish biomarkers are relevant since they measure the biologically available fractions of the contaminant and, at temporal exposure to readily metabolised and excreted pollutants, the biomarker response in fish may last longer than the presence of the active compound (Handy *et al.*, 2003). On the other hand, and not least relevant, fish biomarker responses often are easier, faster and less expensive to analyse than the corresponding chemical pollutant (Jonsson, 2003).

Chemical pollutants of the aquatic environment: PAHs as an example

Of the chemical pollutants that fish must cope with, PAHs are probably the most studied. PAHs are a family of compounds routinely monitored in the environment because they are toxic to wildlife and humans, owing to their persistence, potential for accumulation and toxicity in marine organisms and hence in the humans that consume them. They are a group of hydrophobic organic compounds that are ubiquitous pollutants derived from pyrogenic and petrogenic sources (Vuorinen *et al.*, 2006). Fishes absorb PAHs via the gills and body surface but also by ingestion of food or through contaminated sediments (Neff *et al.*, 2005). Due to human influences, PAH concentrations are increasing in estuarine and coastal waters and are also commonly found in the marine sediment, water and tissues of marine organisms (McElroy *et al.*,1989; Lee and Kang, 2005). When PAHs are deposited in the aquatic environment, they become rapidly associated with particles in the water and are deposited in the sediment, and thus consumed by benthic organisms. As a recent example, PAH concentrations in the Galician coast after one year of the oil spill from the tanker Prestige, are higher than those before the spill (Morales-Caselles *et al.*, 2007). A battery of enzymes are available to detect PAH contamination in fish. The CYP1A complex (cytochrome P450) is the most studied biochemical marker because of its high sensitivity to low PAH concentration.

Biochemical markers of aquatic pollution

The term biomarker is most commonly used to refer to measurements in body fluids, cells or tissues, which are indicative of bioaccumulation of toxic chemicals, biochemical and cellular modifications provoked by specific toxicants or secondary responses of host tissues to these toxicants (Stephensen *et al.*, 2002; Jonsson 2003; Van der Oost *et al.*, 2003; Andersson 2007). McKenzie *et al.* (2007) assumed that such modifications at these lower orders of biological organisation are indicative of, or directly linked to, modifications in the systemic and organismal function which, in turn, lead to changes in the populations and communities that comprise the ecosystem (Fig. 1). However, these assumptions, remain to be demonstrated (Van der Oost *et al.*, 2003).

The principle of biochemical marker approach is to analyse the organism's physiological or biochemical response to pollutant exposure (Lee and Kang, 2005). Entering an organism, xenobiotics bind to specific cellular structures called receptors that are localised on the cell surface or inside the cell either in the cytoplasm or on cell organelles. The binding of a xenobiotic with its receptor may induce cellular processes that have toxic or other adverse effects on the cell (Siroka and Drastichova, 2004). Thus, biochemical markers are measurable responses to the exposure of an organism to xenobiotics and detect the type of toxicity; in some of them, the magnitude of their response correlates with the level of pollution. The great advantage of biochemical markers is providing evidence of the state of pollution in a comprehensive way based on the synergistic and antagonistic effects of all contaminants involved (Jörgensen *et al.*, 2002).

Several biochemical and physiological parameters in fish have been tested for their responses to toxic substances in the aquatic environment and their potential use as biomarkers of exposure or effect. Fish enzymes are, of the biochemical markers, the most intensively investigated that are involved in the detoxication of xenobiotics and their metabolites. There are two types of fish enzymes for detecting and transforming chemical pollutants: biotransformation enzymes and antioxidant enzymes. Table 1 summarises most fish enzymes studied for detecting chemical pollution in the aquatic environment. In this review, biotransformation enzymes have been chosen as an example of biochemical markers that can detect PAH pollution levels in the aquatic environment.

Table 1. Fish enzymes commonly used as biochemical markers of aquatic pollution

Parameters	Enzymes
PAHs Pesticides Chlorinated Hydrocarbons TCDDs PCBs OCPs	Phase I Enzymes: CYP4501A Phase II Enzymes: GST (Glutathione-S-transferase) UDPGT (UDP-glucoronyl transferases) AChE (Acetyl cholinesterase)
Oxidative Stress	SOD (Superoxide dismutase) CAT (Catalase) GPox (Glutathione peroxidase) GRED (Glutathione reductase)
Heavy metals	Phosphatase
Organotin	Chymotrypsinogen Trypsinogen
Chromate	ATPase

Modified from Haard (2000).

Enzymatic markers of aquatic pollution: biotransformation enzymes

One of the most intensively studied biochemical markers either in laboratory or in field, is the enzyme complex cytochrome P450. This system has been demonstrated to be the most sensitive, suffering evident alteration in its levels and catalytic activities and being easily detected. Many studies have reported the determination of CYP450 levels all over the world, as a response of fishes to the presence of pollutants in the aquatic environment (Payne *et al.*, 1987; George *et al.*,1995; Stephensen *et al.*, 2002; Sturve *et al.*, 2006; Zhu *et al.*, 2008).

Of the many CYP450 isoforms, CYP4501A is the most extensively isoform studied in fish. CYP450 has primarily been studied as a biochemical marker in fish, indicating pollution of the aquatic environment by industrial or agriculture sewage. However responses to xenobiotics differ among different species (Siroka and Drastichova, 2004).

PAHs are the most important inducer of fish CYP1A. Induction of CYP1A by PAHs is mediated through the binding of xenobiotic to a cytosolic aryl hydrocarbon receptor (AhR) (Jonsson, 2003). The receptor contaminant complex linked to a lineal translocator is transported to the nucleus where its linkage to DNA results in expression of the gene coding for CYP1A. The toxicity of a pollutant is generally related to the degree of its affinity to AhR. Pollutants with a high binding ability for AhR also have a high capacity to induce CYP1A which has adverse consequences (Billiard *et al.*, 2002). The generation of reactive PAH intermediates by CYP1A has long been known as a source of DNA adducts that can lead to carcinogenesis (Varanasi *et al*., 1989). The presence of increased CYP1A levels is a biochemical marker that, out of a few, is accepted as an ISO standard to determine aquatic environment contamination with PAHs, PCBs and TCDDs. Thus, CYP1A, is used as an early signal of possibly more serious pathologies (Payne *et al*., 1987).

Species of fishes most commonly studied as bioindicators

The main reason of using fish biochemical markers in environmental monitoring of aquatic pollution is as an "early warning" signal (Andersson, 2007). Table 2 summarises only some marine species used as bioindicators, however there are more fish species listed that are very well documented by Van der Oost *et al.* (2003). Marine fishes have the capability to accumulate both organic and inorganic compounds in their tissues and some species are commonly accepted as bioindicators (sentinels) for monitoring both the presence and the deleterious effects of chemical pollutants (Regoli *et al*., 2005). Hence, understanding toxic responses in fish is of high ecological relevance. Thus, biochemical, physiological or histological responses can be a measure of the effects of exposure to sublethal levels of pollutants preventing bad health of fish populations and the ecosystem as a whole, including man.

Table 2. Examples of marine fishes used as sentinels for PAHs contamination

Species	Reference
Antarctic fish: *Notothenia gibberiforus*	McDonald *et al.* (1995) Regoli *et al.* (2005)
Atlantic cod: *Gadus morhua*	Sturve *et al.* (2006)
Eel: *Anguilla anguilla*	Rotchell *et al.* (2000) Schlenzinger and Stegeman (2000)
Polar cod: *Boreogadus saida*	George *et al.* (1995)
Sea bass: *Dicentrarchus labrax*	Lemaire *et al.* (1996)
Southern flounder : *Paralichthys lethostigma*	Little *et al.* (1984)
English sole: *Parophys vetulus*	Varanasi *et al.* (1989)
Sparus aurata	Morales-Caselles *et al.* (2007)
Red mullet: *Mullus barbatus*	Porte *et al.* (2002)
Fundulus heteroclitus	Zhu *et al.* (2008)
Platichthys flesus	Vuorinen *et al.* (2006)

What fish tissues are commonly used to study biotransformation enzymes as CYP450?

Jonsson *et al.* (2002) have studied the importance of using fish gills for determining CYP450 activity and concentration, as a biochemical marker for monitoring aquatic pollution, together with liver enzymes. Fish gills are very efficient not only for extracting O_2 but also organic pollutants from surrounding water. Hence fish gill is sensitive to chemical pollutants in water, owing to its filaments and lamellae which provide a very large surface area for direct and continuous contact with contaminants (Cecchetto *et al*., 1996; Morales-Caselles *et al*., 2007). Normally, most studies published of fish biochemical markers are concerned on how the biotransformation enzymes like cytochrome P450 from liver, not from gill, increases its activity in the presence of a chemical contaminant. So liver is the tissue usually used as a tool for monitoring pollutant levels in the aquatic ecosystems (Jonsson, 2003). Van Veld *et al*. (1997) suggested that as readily biotransformed agonists like PAHs are absorbed from the water and diet, they may be metabolised before reaching the liver. Thus, enzyme biomarkers in liver, probably do not always accurately reflect the level of pollution, hence pollution level may be underestimated (Levine and Oris, 1999). Jonsson (2003) found that gill filament enzyme assay is a handy, robust and relatively cheap method, as a biochemical marker of chemical pollutant as well as good monitoring tool. Recent research is beginning to consider fish gills together with liver, for monitoring chemical pollutants such as PAHs through CYP1A enzyme activity (Jonsson *et al*., 2003; Lee and Kang 2005; Andersson 2007; Jimenez-Tenorio *et al*., 2007; Morales-Caselles *et al*., 2007).

Conclusion

If the above criteria are unified for most research and mixture of agonists (pollutants) are considered, it should be possible to further understand the real action of water pollution on the ecosystem as a whole. Industry needs to be aware that it has a moral obligation to consider the ecological impacts of discharges of pollutants from waste products deposited in the aquatic environment and hence, avoid bioconcentration of pollutants in the biological tissues and resulting toxic effects from chronic, low level exposure. In summary, biochemical markers as enzymes, and bioindicators like fishes, are two measurements among others, that must be taken into account when studying aquatic contamination by chemical pollutants. Fish is a good bioindicator species for monitoring chemical pollution owing to their great sensitivity to changes in the aquatic environment.

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Plankton occurrence in relation to nutrient concentration in estuaries along the east coast of Tamilnadu, India

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Estuaries are typically shallow systems, sheltered from major wave action; with variable temperatures, salinities, turbidity and oxygen content and they are among the most productive ecosystems on earth (Odum, 1983). Their high productivity, scenic and physical diversity, abundant mineral resources and strategic location are of great biological and economical importance. The distribution of plankton and other species directly or indirectly depends upon the amount of dissolved nutrients present in the estuarine systems. Thus it is important to assess the relationship between the nutrient levels and the species distribution over a period of time. Four estuaries along the east coast of India were selected for this study. These estuaries receive a large amount of nutrients from various sources, including agricultural runoff, domestic discharges and industrial effluents. The study reveals that nutrient concentrations increased during the monsoon months and were generally low in the dry months. Nitrate was found to be very high during the study period at Cauvery compared to other estuaries. This could be attributed to the fact that it receives a large input of nitrogen from agricultural fields and aquaculture operations. Silicate was found to be one of the limiting factors for phytoplankton production.

The coast of Tamilnadu is intersected by several estuarine systems joining the Bay of Bengal, ranging from small water bodies which are only occasionally connected to the ocean and large permanently open systems, to coastal lakes connected to the sea via a narrow channel (Ramachandran, 2001). It has been observed that coastal areas with large estuaries tend to support high fishery yields.

Aquatic primary productivity, especially in surface waters, is frequently limited by the availability of nutrients. The identification of nutrient limitation of phytoplankton growth and the identity of the limiting factor(s) in a water body is of considerable importance to our understanding of the ecology of aquatic systems and to water management practices. It enables managers to draw up appropriate nutrient loading budgets for catchments and to respond to possible perturbations on an informed basis (Beardall *et al.*, 2001).

Anthropogenic loading of nutrients into rivers has increased over the last few decades (Jickells, 1998). Concentrations of nutrients such as nitrogen and silicate are often several times higher in rivers and estuaries than in the receiving coastal seawater (Ryther *et al.*, 1967; Gibbs, 1970; Edmond *et al.*, 1985; Shen, 1993). The high nutrient levels promote primary productivity in receiving coastal waters and can cause algal blooms. Eventually they result in eutrophication if the algae are not efficiently grazed by zooplankton. Thus the study of zooplankton composition and abundance in relation to phytoplankton production and nutrient concentrations over a period of time assumes importance.

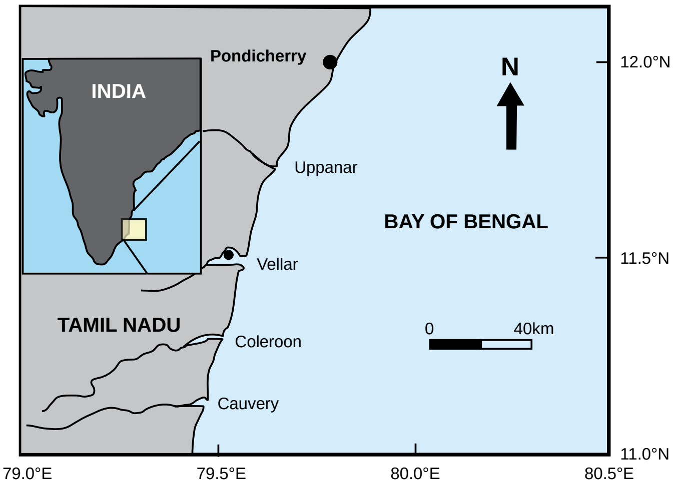

Figure 1. Location of the study area.

In recent years, there has been an increased interest in studying zooplankton from freshwater and marine ecosystems in terms of their importance in the food chain. The biomass of meso- and macrozooplankton usually exceeds that of the microzooplankton (Beers and Stewart, 1969) and acts as a significant food source for a variety of invertebrate and vertebrate predators. Species occurrence in estuaries should be considered in the context of their dependence on marine as well as freshwater requirements (Weerts and Cyrus, 2001).

Four estuarine systems, Uppanar, Vellar, Coleroon and Cauvery from the east coast of Tamilnadu, were sampled during the period from July 2002 to March 2004 on a monthly basis (Fig. 1). The Uppanar is an offshoot of the river Cauvery joining the sea at the industrial town of Cuddalore (11°42’ 23.1”N; 79°46’ 35.5”E). This estuary is characterised by the presence of a vast mussel bed. There is a tremendous stress on the estuary posed by the industries surrounding it. The Vellar estuary (11°29’ 15.5”N; 79°47’ 40.1”E) is well documented for its fauna and flora by many researchers. The estuary is bestowed with many planktonic species.

Coleroon River (11°19’ 42.4”N; 79°42’ 57.6”E) is one of the major tributaries of river Cauvery. It serves as a major source of irrigation in the area. Cauvery, on its course to join the sea divides into several tributaries. The main river joins the sea at Poompuhar (11°08’ 10.2”N; 79°51’ 29.9”E). The mouth of this estuary remains closed for most of the year due to the failure of monsoonal rains.

Selected physico-chemical parameters were measured at three sites within each system. Site 1 was the mouth region; Site 2 was 1 to 2 km away from the mouth and Site 3 was above the tidal range of the estuary. Temperature was measured using a laboratory mercury thermometer to the nearest 0.1°C. pH was measured with an ELICO model pH meter. Salinity, dissolved

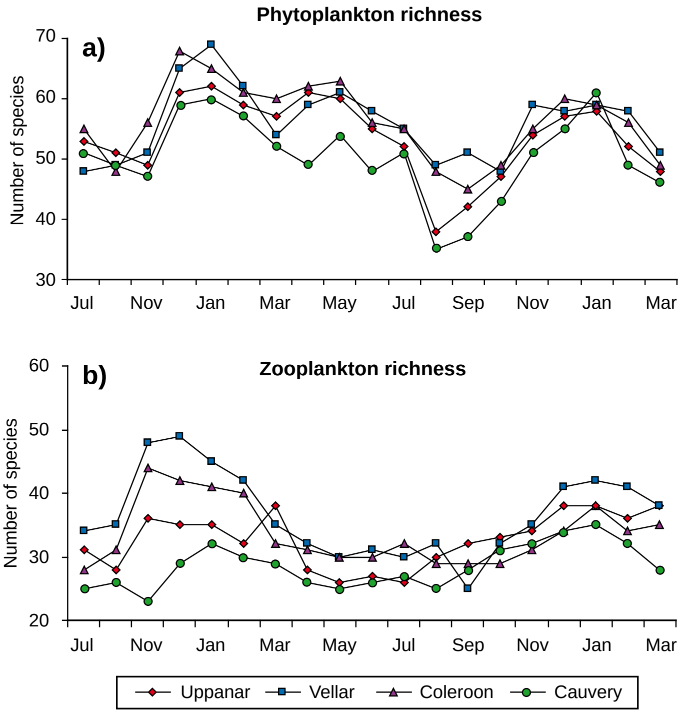

Figure 2. Monthly dynamics of a) phytoplankton and b) zooplankton species richness in four estuaries.

oxygen (DO), chlorophyll *a* (Chl *a*), total suspended solids (TSS) and nutrients (PO_4-P, NO_2-N, NO_3-N and SiO_2) were also estimated using standard protocols (APHA, 1995).

The plankton were sampled using 50 µm and 250 µm plankton nets by filtering 100 l of surface water through them. The concentrated plankton sample was preserved with 4% buffered formalin and made up to 100 ml. Plankton species were identified using species identification keys (Desikachary, 1959; Kasthurirangan, 1963; Subrahmanian, 1964; Anand, 1989, 1998).

A total of 94 phytoplankton species were identified along with 43 zooplankton species. *Asterionella japonicus*, *Biddulphia sinensis*, *Ceratium tripos*, *Chaetoceros affinis*, *Chaetoceros diversus*, *Coscinodiscus marginatus*, *Oscillatoria subbrevis*, *Pleurosigma aesturi*, *Skeletonema costatum*, *Spirulina laxissima*, *Triceratium favus*, *Thallassionema nitzschioides* and *Thallassiothrix frauenfeldii* were the more commonly occurring species. Among the zooplankton, copepods were most abundant, represented by nine species belonging to calanoid, cyclopoid and harpacticoid groups. The rotifers were represented by eight species of which *Brachionus plicatilis* was the most common species. About 16 species of tintinnids were also recorded during the present study. Studies on the planktonic coelenterates from the Vasishta Godavari estuary showed about 28 species of planktonic coelenterates (Sai Sastry and Chandramohan, 1989).

The dynamics of zooplankton and phytoplankton species richness during the study period are given in Figure 2. The maximum number of phytoplankton species was recorded during December 2002, December 2003 and January 2004 which are the months with the maximum rainfall. Among the four estuaries, Vellar recorded the maximum phytoplankton species. The zooplankton species richness followed the same trend as the phytoplankton in all the estuaries. The minimum number of species was recorded at the Cauvery estuary. Estuarine copepods typically reach very high densities and tend to dominate the fauna of estuaries in a particular period of the year (Vieira *et al.*, 2003).

The monthly variations of nutrient concentrations in the estuaries studied are shown in Figure 3. The phosphate (PO_4-P) levels ranged from 0.159 µg l^{-1} in the Coleroon estuary during March 2002 to 1.2739 µg l^{-1} in Vellar during January 2004. SiO_2 concentrations ranged between 1.504 µg l^{-1} in Cauvery during November 2002 to 8.414 µg l^{-1} in Coleroon during January 2004. NO_3 concentrations ranged between 0.204 µg l^{-1} in Uppanar during July 2002 to 2.077 µg l^{-1} in January 2004 at Cauvery. The concentrations of nitrate were very high compared to other estuaries studied. NO_2 ranged between 0.0209µg l^{-1} at Uppanar during September 2003 and 0.0722 µg l^{-1} at Coleroon during January 2003.

Among the four estuaries studied, Vellar showed the highest phosphate concentrations during the monsoon months followed by Cauvery. The silica and nitrite concentrations were slightly higher in Coleroon compared to the other three estuaries. Nitrate concentration in the Cauvery estuary was much higher during all the months compared to other estuaries.

The correlations between plankton and nutrients are given in Table 1. In the Uppanar estuary, zooplankton were highly correlated with nitrate and phytoplankton and with nitrite concentrations. Zooplankton had a high positive correlation with phosphate and phytoplankton whereas it had a negative correlation with nitrite.

Phytoplankton had a highly significant positive correlation with silicate at Uppanar and Vellar, whereas, they showed a highly significant positive correlation with phosphate and nitrite in Cauvery. In the Coleroon estuary the phytoplankton had a positive correlation with zooplankton. Silicate and phosphate were also positively correlated. In Cauvery, zooplankton showed a positive correlation with phytoplankton, phosphate, nitrate and nitrite. Among the nutrients, phosphate had a positive correlation with nitrate and nitrite. Nitrate and nitrite were also correlated. The results from the studies conducted by Wu and Chou (2003) in a subtropical eutrophic Tamsui estuary in Taiwan indicated that enrichment with silicate gave rise to a greater enhancement in phytoplankton biomass, mainly of diatoms, than did enrichment with nitrogen or phosphorous.

According to Gliwicz (1969) the structure and composition of zooplankton assemblages are significantly altered with increasing eutrophication. The total zooplankton abundance increases and larger species are replaced by smaller ones. The analysis of plankton and climatic variables by Reid *et al.* (1998) showed a correlation between plankton and climatic variables. This is true for the present study where the climate-influenced factors are the nutrient concentrations, which show a strong correlation with the plankton composition.

Acknowledgements

One of the authors would like to thank the Council of Scientific and Industrial Research for the financial assistance in the form of a Junior Research Fellowship and Senior Research Fellowship.

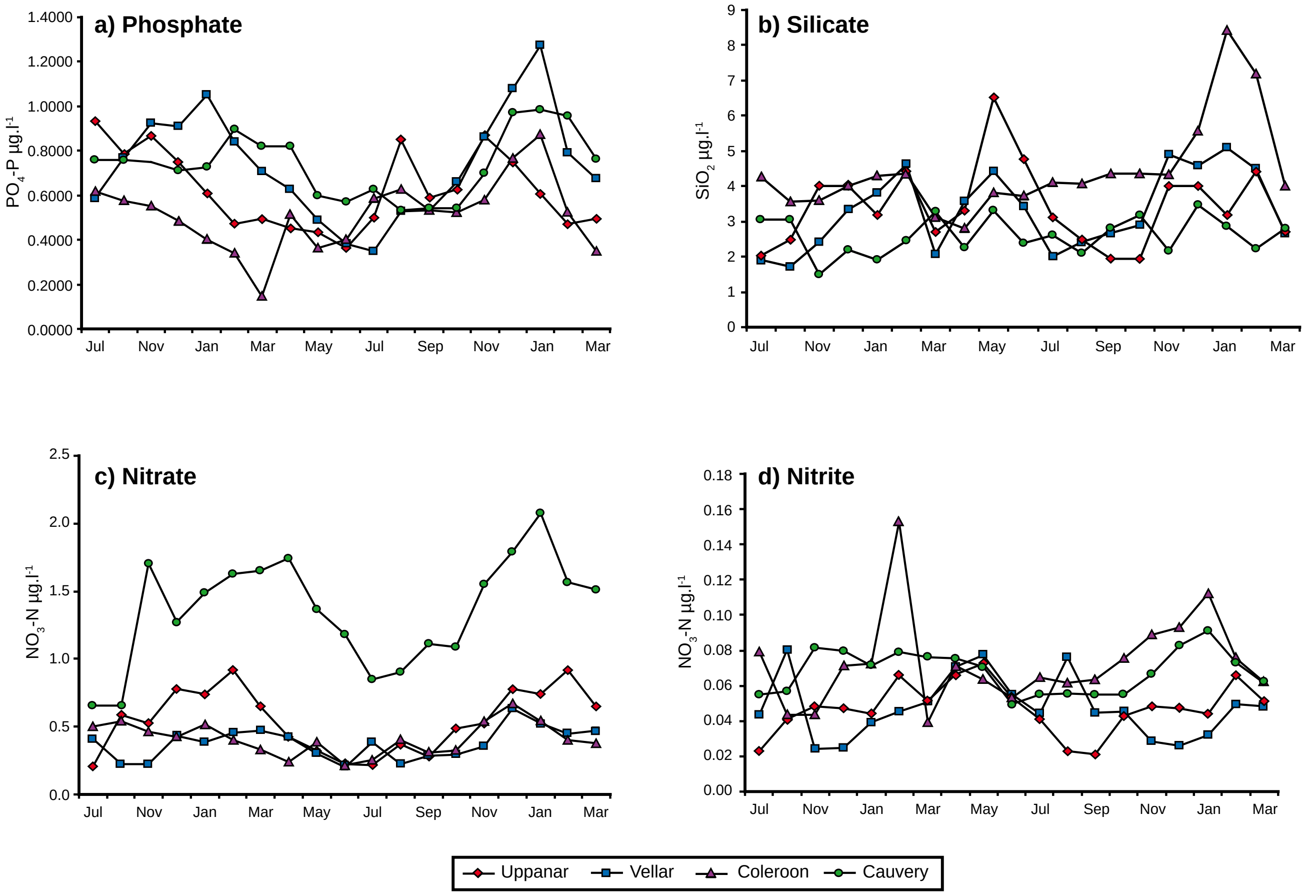

Figure 3. Monthly variation of a) phosphate, b) silica, c) nitrate and d) nitrite in four estuaries.

Table 1. Correlations between the plankton richness and nutrient concentrations

Station		Zooplankton	Phytoplankton	Phosphate	Silica	Nitrate	Nitrite
Uppanar	**Zooplankton**	1.000	0.057	0.202	-0.173	0.693**	-0.028
	Phytoplankton	0.057	1.000	-0.313	0.531*	0.371	0.632**
	Phosphate	0.202	-0.313	1.000	-0.354	-0.047	-0.61**
	Silica	-0.173	0.531*	-0.354	1.000	0.172	0.759**
	Nitrate	0.693	0.371	-0.047	0.172	1.000	0.410
	Nitrite	-0.028	0.632*	-0.616*	0.759**	.410	1.000
Vellar	**Zooplankton**	1.000	0.459*	0.781**	0.302	0.385	-0.579*
	Phytoplankton	0.459*	1.000	0.402	0.684**	0.371	-0.255
	Phosphate	0.781**	0.402	1.000	0.521*	0.537*	-0.567*
	Silica	0.302	0.684**	0.521*	1.000	0.447	-0.287
	Nitrate	0.385	0.371	0.537*	0.447	1.000	-0.444
	Nitrite	-0.579**	-0.255	-0.567*	-0.287	-0.444	1.000
Coleroon	**Zooplankton**	1.000	0.542*	-0.035	0.185	0.313	0.263
	Phytoplankton	0.542*	1.000	-0.187	0.031	0.139	0.279
	Phosphate	-0.035	-0.187	1.000	0.598**	0.495*	0.261
	Silica	0.185	0.031	0.598**	1.000	0.417	0.484*
	Nitrate	0.313	0.139	0.495*	0.417	1.000	0.285
	Nitrite	0.263	0.279	0.261	0.484*	0.285	1.000
Cauvery	**Zooplankton**	1.000	0.472*	0.532*	0.190	0.529*	0.458*
	Phytoplankton	0.472*	1.000	0.596**	0.057	0.454	0.662**
	Phosphate	0.532*	0.596**	1.000	0.082	0.638**	0.750**
	Silica	0.190	0.057	0.082	1.000	-0.150	-0.118
	Nitrate	0.529*	0.454	0.638**	-0.150	1.000	0.843**
	Nitrite	0.458*	0.662*	0.750**	-0.118	0.843**	1.000

* Correlation is significant at the 0.05 level (2 tailed).

** Correlation is significant at the 0.01 level (2 tailed).

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Results of a survey on krill, environment and predators in CCAMLR division 88.1 in the Austral summer 2003-2004

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The Ross Sea is unique in Antarctica in that two similar and competing species of krill (*Euphausia superba* and *Euphausia chrystallorophias)* dominate the biomass and play a central role in this pelagic ecosystem. The coexistence of similar species in the same area requires their dynamics and/or foraging strategies to be different (Levin, 1974; Gopalsamy, 1977; Sala *et al*., 2002).

Krill data for this region are already available from six large scale hydroacoustic surveys carried out from 1989 to 2000. The aim of our surveys was to gain a deeper understanding into the mechanisms that allow the coexistence of the two krill species in the Ross Sea, and the relationship of each species with predators and the environment.

The survey results are not only of importance in understanding the ecology of the region, but also for the future management of krill fisheries in the Ross Sea. Both species are devoured by carnivores, but *E. superba* is preferred by whales and is used for human food. *E. superba* fisheries are presently underexploited but could increase in the future and thus altering the mechanisms that allow the coexistence of the two species.

The aims of the last survey carried out in the Austral summer 2003-2004 were:

- To study in depth the abundance, spatial distribution and ecology of the two krill populations living in the Ross Sea.
- To study the demography, genetic structure and biochemical composition of the two krill populations of the Ross Sea and the possible genetic differences between the populations of *E. superba* that live in the Ross Sea and the adjacent area of the Pacific Ocean.
- To use krill as a model organism to investigate the interactions between the physical and biological environment.

The acoustic survey on krill lasted 33 days (from 28/12/2003 to 31/01/2004) and the census on the krill predators 25 days (from 28/12/2003 to 23/01/2004). Both the acoustic and the visual surveys were taken 24 hours a day. *E. superba* and *E. chrystallorophias* were acoustically recognised, examined (average length) and discriminated from other zooplankton using the three frequency method (Azzali *et al*., 2000).

The census of krill predators was achieved with both traditional- and digital-binoculars, which can photograph the observed animals and file the photographs, with the time and geographical position, in the acoustic database. This allowed a more accurate recognition of the animals and facilitated the studying of the interaction between krill and its predators.

A new plankton net, called HPRI-1000, designed in Italy at the CNR-ISMAR of Ancona was used for the surveys. The net performance was excellent. In particular, the *E. superba* catch,

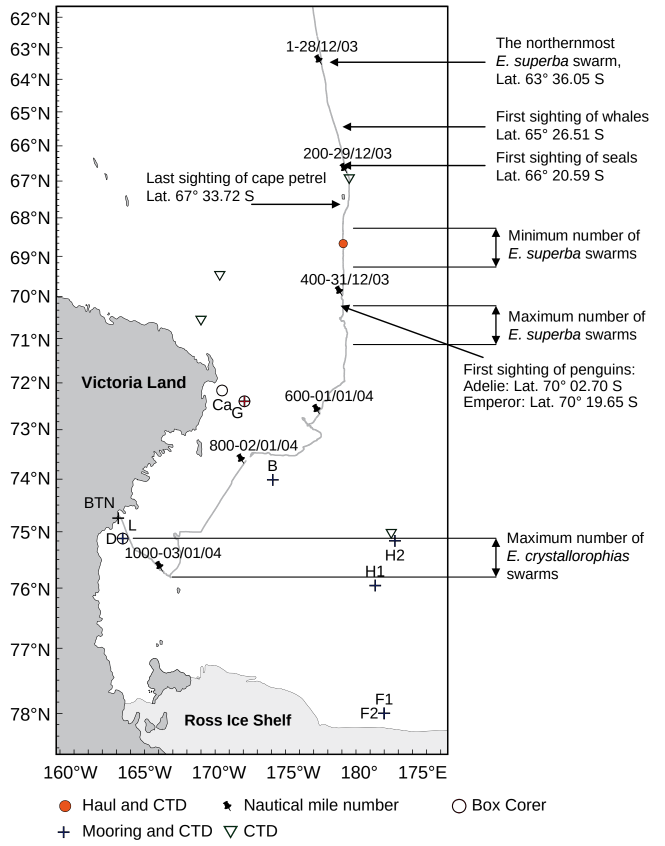

Figure 1. Transects of the acoustic sampling in the first phase of the research (28/12/2003 – 04/01/2004).

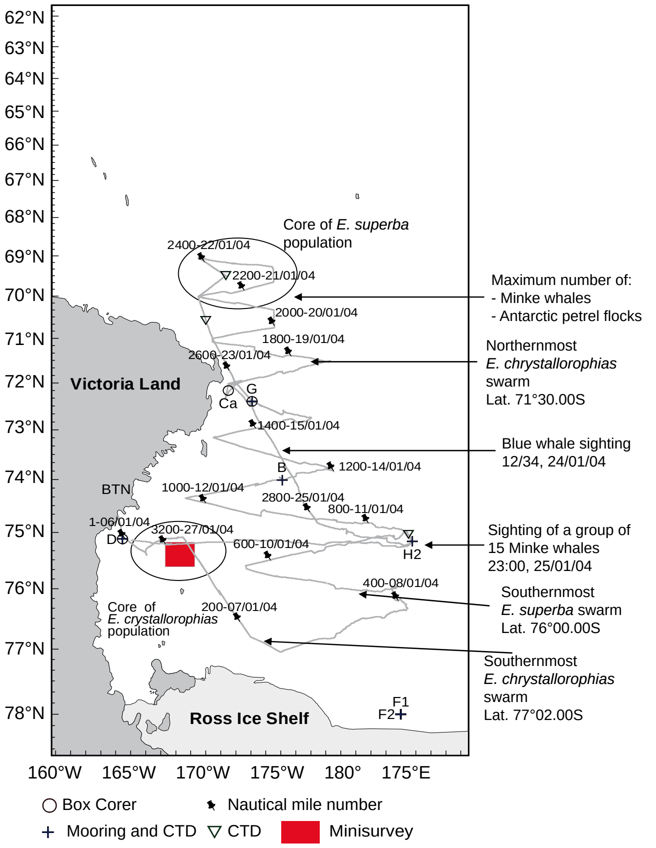

Figure 2. Transects of acoustic monitoring during the second, third and fourth phase of the research (06/01/2004 – 31/01/2004).

was higher than for previous expeditions. The water masses were sampled with a CTD and XBT when weather conditions allowed. Krill predators were also sampled at the same time, therefore we can say that four synoptic surveys were made.

The survey was divided into four phases, firstly focusing on the passage from the Pacific to the Ross Sea (Fig. 1), the second phase was where the maximum density of the two krill species were found, the third phase focused on completing the description of krill distribution in the Ross Sea and the final phase focused on a detailed survey of krill distribution in a small rectangular area. In total 5394 nautical miles were covered of which 530 were in the Pacific Ocean (Fig. 2).

The preliminary results of this survey, together with historical surveys in the Ross Sea, seem to indicate that the two krill species move with different spatial and temporal scales and tend to occupy different places. The northern end of the Ross Sea seems particularly suitable for the *E. superba* population, the southern end for *E. crystallorophias* population, while in the central area of the Ross Sea there is a combination of the two species.

The central core of the *E. superba* population moves significantly over the years (hundreds of nautical miles, from 75°50'S (1994) to 70°30'S (2004)) whilst the central core of the *E. crystallorophias* population seems more stable (74-77°N). The central core of the *E. superba* population has always been found a few degrees further north than the *E. crystallorophias* core and it seems that the two krill populations tend to segregate their habitats from each other. It was also found that the sightings of whales tend to peak around the nucleus of the *E. superba* population.

Future works will focus on using the data from this survey as well as the historical data to ascertain the physical and biological factors that govern the formation and movements of the patterns of the two krill species and their relationship with different predators. In particular the thermal and salinity data, measured for the first time in this survey, will allow to investigators to study how patterns (both horizontal and vertical) and biological characteristics of *E. superba* and *E. chrystallorophias* can be influenced by differences in water masses.

Acknowledgments

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Non linear forecast of anchovy (*Engraulis ringens*) catches in northern Chile: A multivariate approach

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The Humboldt current system is one of the most productive ecosystems of the planet, due to the horizontal advection of nutrients, and the large scale coastal upwelling induced by winds blowing predominantly towards the equator (Bernal *et al.*, 1983). The average Chilean fish landings in the past ten years is about 5.5 million tons per year and the pelagic fishery of northern Chile (mainly anchovy and sardine) represent about 42% (SERNAPESCA, 1951-2005).

The anchovy fishery is closely associated with fishing effort changes and environmental fluctuations such as cold-warm regime shifts (interdecadal fluctuations), *El Niño* events (interannual fluctuations), and coastal trapped waves (intra-seasonal fluctuations) (Yáñez *et al.*, 2005). It collapses during the *El Niño* event in 1972-73 while a remarkable increase in sardine landings is observed (warm period); after 1985 (cold period), the anchovy fishery present a notorious recovery as the sardine landings decreases (Yáñez *et al.*, 2003).

A problem associated with ecosystemic information is the complexity and non-linear behaviour, the variability of species, composition and abundance, affected directly by environmental changes, and also affected by the presence of predators, competitors and parasites. In ecology, the application of artificial neural networks (ANN's) for modelling starts at early 1990s, when data rarely meet parametric statistical assumptions and where non- linear relationships are prevalent, they perform better than linear models and generalize well to new data inputs (Özesmi *et al.*, 2006)

A first approach to the pelagic fisheries non-linear modelling was presented by Gutiérrez-Estrada *et al.* (2007) using a univariate ANN model considering anchovy catches of the previous six months. In this study the performance of artificial neural networks monthly forecast models for anchovy catches in northern Chile (18°21'S-24°S) considering twelve environmental variables, the fishing effort and the anchovy catches in the period between 1963 and 2005, was evaluated.

In order to discard the "noise" in the input layer a previous analysis of the data was carried out, using principal components analysis and a non-linear cross correlation technique. The model used is a feed forward multi layer perceptron architecture, trained with the Levenberg-Marquardt algorithm.

The results involved an ANN model (M1) with the sea surface temperature (SST) in Antofagasta (with 6, 7 and 8 months lag) and the SST in the Niño3+4 region (with 3, 4 and 5 months lag), and anchovy catches (of the 6 previous months) as inputs. Another ANN model (M2) considers both the same SST (and the same lagged months), anchovy catches (of the previous 3 months), and fishing effort (without lag) as inputs. The Antofagasta SST lag seemed to be related to the anchovy recruitment process that occur at age 5-6 months (Castillo *et al.*, 2002). While the Niño3+4 region lag seemed to be related to the equatorial coastal trapped waves remote effects that take place in the north of Chile approximately with a 120 days lag (Hormazabal *et al.*, 2002), affecting the anchovy availability.

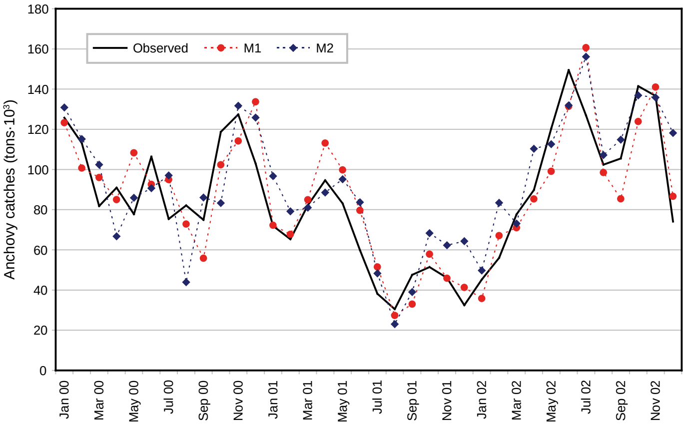

Figure 1. Observed and estimated anchovy catches in the external validation phase (2000-2002) for M1 (in red) and M2 (in blue) models.

The external validation process shows an explained variance of 78% and 69% respectively, the standard error of prediction (SEP, %) was lower than 23% in both models. The strong correlation among the estimated and observed anchovy catches in the external validation phases (Fig. 1) suggested that calibrated models (M1 and M2) captured the general trend of the historical data and therefore these models could be used to carry out an accuracy forecast.

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Large contribution of the north Atlantic Ocean climate on the variability of plankton communities in the northwestern Mediterranean

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Identifying marine ecosystem responses under climate change is currently a challenging endeavour in marine sciences. In southern Europe, one of the most exposed areas to global warming is likely the Mediterranean basin, which undergoes multiple external pressures that include anthropogenic and climatic processes. The potential impact climate change may have on its functioning is therefore a matter for current concern. This note introduces new results on the sensitivity of the northwestern Mediterranean pelagic ecosystem to climate variations in the North Atlantic Ocean. Plankton communities in the northwestern Mediterranean showed marked changes since the middle 1980s and it has been suggested that local atmospheric variability has had a role in such events. However the magnitude of changes and the contribution of global climate drivers so far have not been quantified.

To date some of the most profound consequences of climate change in marine ecosystems have been identified in high latitudes and productive temperate seas where underlying mechanisms linking climate and oceanographic patterns have been recognised (Hare and Mantua 2000; Beaugrand and Reid 2002; Edwards *et al.*, 2002). In northern Europe regional-wide marine ecosystem changes (Alheit *et al.*, 2005) appear to be related to significant modifications in the North Atlantic ocean-atmosphere circulation noticed particularly since the early 1980s. As the North Atlantic Ocean climate strongly affects atmospheric conditions in the western Mediterranean, similar forcing is expected to act on the northwestern Mediterranean marine ecosystem. Accordingly couplings between the North Atlantic climate and the marine ecosystem of the northwestern Mediterranean are plausible, and may be tracked when using appropriate chronological records and statistical techniques. In fact, downscaling assessments of climate – ocean interactions have revealed close connections between some copepods and jellyfish species in the western Mediterranean and the North Atlantic climate variability (Molinero *et al.*, 2005a, b). The results introduced here extend previous findings and strengthened evidence on the large contribution of the North Atlantic climate on the long-term changes of pelagic communities in the northwestern Mediterranean.

Data analysed cover the period 1967-1993 and constitute one of the longest data sets for the Mediterranean basin. During the period investigated, plankton was consistently sampled and counted, which makes these records valuable to investigate links between climate and plankton variability (details on sampling are given in Molinero *et al.*, 2005a, 2008). The zooplankton groups analysed were copepods, chaetognaths and jellyfish. These groups play a key role in the pelagic food web for which tracking their long-term variability may reveal modifications in the functioning of the pelagic ecosystem in the northwestern Mediterranean.

Figure 1 displays the results from the Pearson product moment correlations between first principal components (PC1) of North Atlantic climate, local hydroclimatic conditions and zooplankton (a detailed description of analysis is given in Molinero *et al.*, 2008). The close connection between the pairs: North Atlantic climate (PC1 47%) – local hydroclimate (PC1 61%) (Fig. 1a), North Atlantic climate (PC1) – zooplankton (PC1 33%) (Fig. 1b), and local hydroclimate (PC1) – zooplankton (PC1) (Figs. 1c), is illustrated by the density distribution of correlation coefficients obtained after bootstrap resampling. Kernel smoothing techniques were used to estimate the density distribution. This illustrates the tight coupling between the North Atlantic climate, local hydroclimate and the zooplankton variations over the period 1967-1993.

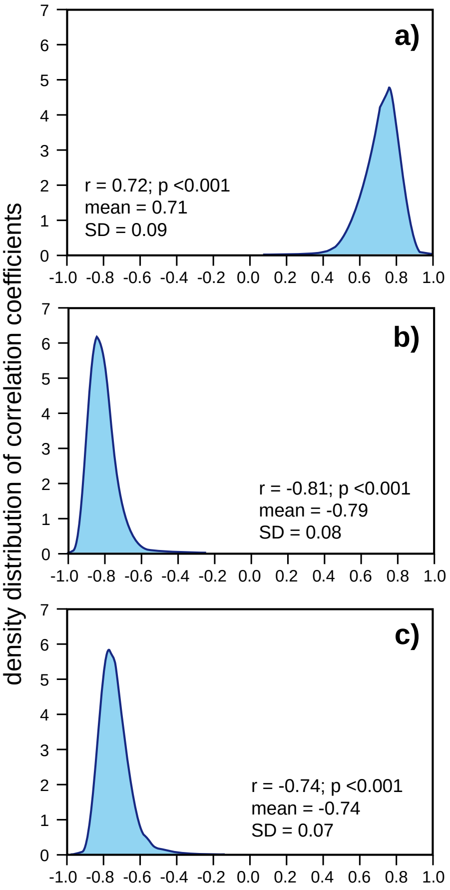

Figure 1. Density distribution of correlation coefficients of the links between zooplankton and climate signals operating at large and local scales. (a) PC1 North Atlantic climate and PC1 local hydroclimate; (b) PC1 North Atlantic climate and PC1 zooplankton; and (c) PC1 local hydroclimate and PC1 zooplankton. Density distribution was estimated by Kernel smoothing techniques, and quantifies the distribution of the correlation coefficients after bootstrap resampling of the pairs above indicated. Each time series was resampled 10,000 times. Detailed description of methods is given in Molinero et al., 2008. PC1: Principal component. Figure modified from Molinero et al., 2008.

Synchronous and opposite interannual changes in the North Atlantic climate and the northwestern Mediterranean pelagic ecosystem are shown in Figure 2 (top panel). The impact of the North Atlantic climate was further detected in the anomalous events (outbursts, drops) of copepods, chaetognaths and jellyfish particularly in the 1980s. It is revealed that during the period late 1960s – early 1990s the modifications in the North Atlantic climate have altered the pelagic ecosystem of the northwestern Mediterranean through changes in the dynamics of water masses, i.e. mesoscale hydrographic patterns (Vignudelli *et al.*, 1999),

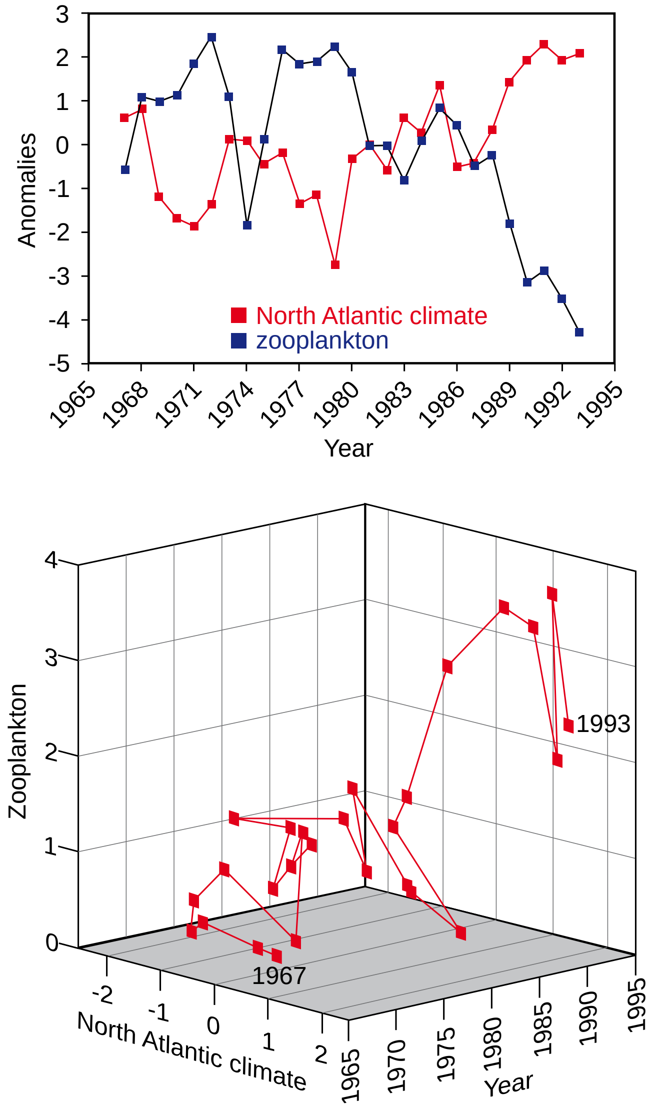

Figure 2. Top panel: Synchronous and opposite changes in the interannual variability of the PC1 North Atlantic climate and PC1 zooplankton abundance, which account for 47% and 33% of the total variance, respectively. PC1: Principal component. Bottom panel: Magnitude and timing of the step-like change of zooplankton variability in the plane of time – North Atlantic climate variations. The zooplankton time series corresponds to the absolute values of the standardised zooplankton abundances. Two major periods are highlighted by the variability of zooplankton, the former (1967-1987) characterised by low anomalies, and the latter (1988-1993) by high anomalies leading to a step-like change in zooplankton abundance. Figure modified from Molinero et al., 2008.

water column stability and temperature (Molinero *et al.*, 2005a). These changes in turn have affected some of the main functional groups in the pelagic food web, i.e. copepods (Molinero *et al.*, 2005b), salps (Licandro *et al.*, 2006), gelatinous carnivores (Molinero *et al.*, 2005a; Molinero *et al.*, 2008) and probably the pelagic food web dynamics through changes in biological interactions, competition and predation, leading to anomalous events manifested as outbursts or collapses in zooplankton populations, and consequently to a major change *ca.* 1987 (Fig. 2 (bottom panel); Molinero *et al.*, 2008). These results are therefore indicators of the sensitivity of the northwestern Mediterranean pelagic ecosystem to the North Atlantic climate, and particularly stress the possibility of a more regeneration-dominated system in this area as a result of the climate induced environmental changes (see also Molinero *et al.*, 2005a).

There is now no question that the North Atlantic climate variability has a large contribution to the long-term variability of pelagic communities in the northwestern Mediterranean, and likely on the functioning of its ecosystem. The marked stepwise change in the variability of zooplankton reflects the magnitude of alterations the pelagic ecosystem experienced during the 1980s under the increasingly stressful North Atlantic climate forcing. Moreover, it is worth noting that the step-like change shown here occurred during a period of important modifications in the North Atlantic ecosystems and adjacent seas (Dippner *et al.*, 2001; Reid *et al.*, 2001; Beaugrand and Reid, 2003; Alheit *et al.*, 2005; Weijerman *et al.*, 2005), which deserve attention to investigate possible common regional drivers of alterations in the pelagic ecosystems of European Seas.

These results stress the sensitivity of the western Mediterranean pelagic ecosystem to changes in the North Atlantic Ocean climate, and may constitute a baseline in future attempts to assess climate impacts on Mediterranean pelagic ecosystems.

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Trend analysis of sea surface temperature around the coast of Donostia-San Sebastián (Northern Spain)

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This contribution presents the results of the trend analysis of sea surface temperature measured at two locations around the coast of Donostia-San Sebastián (southeastern corner of the Bay of Biscay, northern Spain): the Aquarium (43°19'N, 02°00'W) and the entrance of Pasaia harbour (43°20'N, 01°55' W). The Aquarium time-series extends from 2 July 1946 to 10 June 2007; representing almost 61 years of daily data (22,259 days) recorded at 10 am manually. The time-series presents gaps in the data, especially between 1967 and 1975; consequently, up to 23% of the total data (5,121 days) are missing. Nevertheless, it has been proved that the distribution of gaps is sufficiently homogeneous as not to distort the annual mean values. In order to remove fluctuations due to time-scales smaller than a year (such as seasonal variability), a running annual mean has been calculated, taking into account missing data within the original time-series. Subsequently, a trend analysis has been performed with annual data.

Globally, a very small cooling trend (-0.002°C/year) can be observed for the whole time-series. However, a change in tendency is observed for the last period of the series, 1991-2007, with a warming trend around 0.050°C/year (Fig. 1). This positive tendency can be detected even if extreme hot periods, like summer 2003 and the second half of 2006, are removed from the analysis. From August 2001 to present, the Aquarium data have been complemented by those acquired by an oceano-meteorological station located at the entrance of Pasaia harbour. This station, one of six stations located along the coast of the Basque Country, provides real-time measurements (http://www.azti.es) with a sampling rate of 10' at several depths (0, 5, 10, 15 and 20 m). The station will provide information, for an accurate evaluation in a medium and long-term, of the evolution of atmospheric and marine variables and their relationships (Fig. 2).

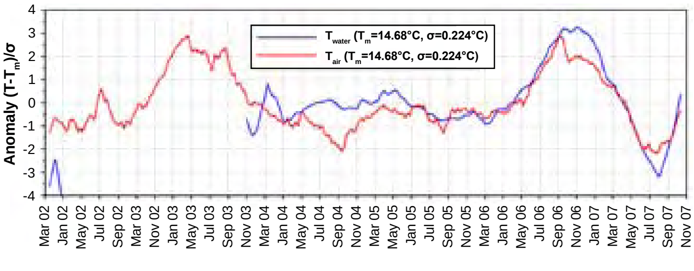

Figure 2. Anomaly evolution of the air temperature and the sea surface temperature registered at the Pasaia station.

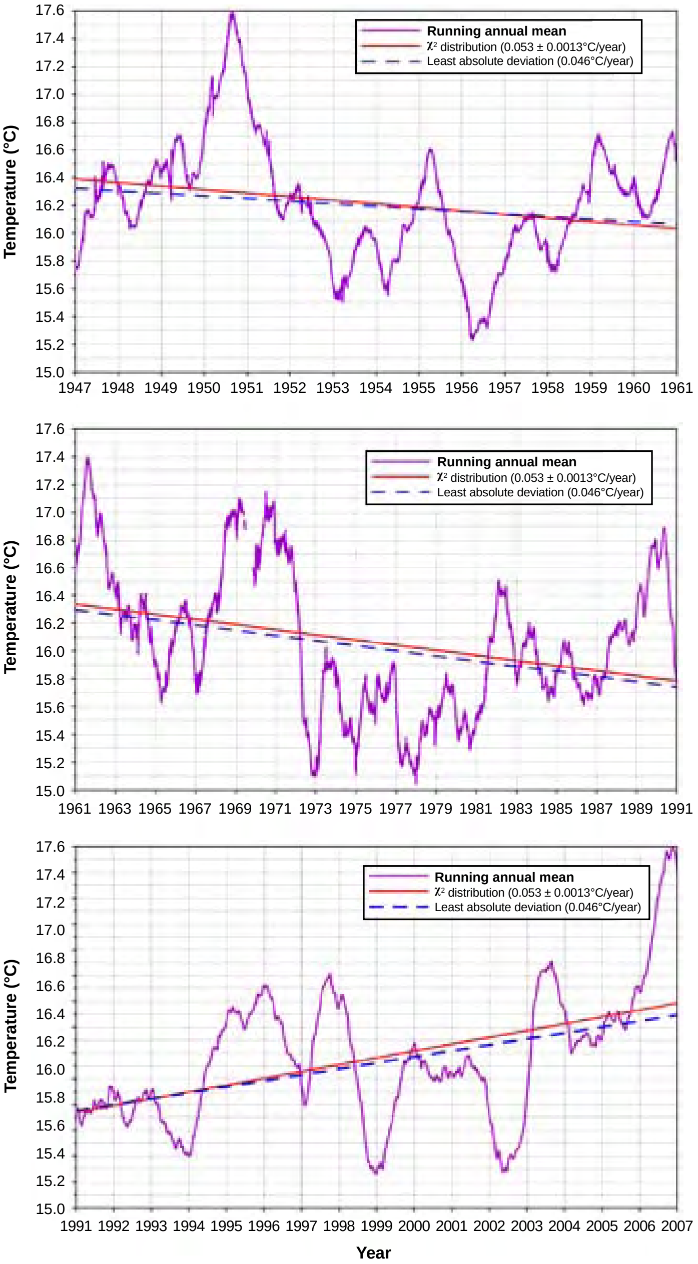

Figure 1. Running annual mean of the SST registered at the Aquarium, and its trend following the χ^2 distribution and the least absolute deviation methods for three periods: 1947-1961, 1961-1991, and 1991-2007.

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