S4.1 Impacts on lower trophic levels

22 May, 09:15 (S4.1-4619) Plenary

Shrinking snowcaps and rising productivity: response of the Arabian Sea ecosystem to recent climate change

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Over the past eight years, the ecosystem of the Arabian Sea has been showing signs of rapid and profound changes. First seen in satellite images of chlorophyll *a* (Chl) as a year-on-year increase in summer-time phytoplankton Chl, this unusual escalation (>350%) in phytoplankton biomass was found to be the result of atypical strengthening of the southwest monsoon (SWM) winds and an intensification of wind-driven upwelling off the coasts of Somalia, Oman and Yemen. Our studies show that the changes taking place are not occurring in isolation, but are part of a sequence of events, whose origins can be traced to the warming trend over Eurasia and the decline in winter and spring-time snow over the Himalayan-Tibetan Plateau region. In recent studies we have been able to observe that the warming trend is undermining convective mixing responsible for nutrient enrichment during the boreal winter component of the monsoon cycle. Consistent with the weakening trend of winter convective mixing, winter-time concentrations of phytoplankton have been on the decline in the eastern Arabian Sea. In the western Arabian Sea however, Chl concentrations have been on the rise. We present data to show that this unusual increase in phytoplankton biomass seen in the ocean colour data is being caused by unprecedented blooms of *Noctiluca miliaris*, whose emergence appears to be tied to the uplift of subsurface, nutrient-rich and oxygen-poor waters off the coast of Oman.

22 May, 10:35 (S4.1-4576) Invited

Temperature rules the oceans biota

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Many ecological theories and rules try to explain the effects of temperature on the structure and functioning of populations and communities. Temperature sets the pace of many physiological processes, it therefore has direct effects on the rates at which marine organisms influence biogeochemical processes. The community structure and species diversity of marine communities is also related to temperature. Amongst others, these theories include the Metabolic Theory of Ecology, the temperature-size rule or macroecological explanations for the latitudinal diversity gradients. I will review some of these rules and the existing evidence from marine planktonic ecosystems to support them. I will also use these theories and empirical evidence to envision how possible scenarios of global warming would affect the structure and functioning of marine planktonic ecosystems and discuss the relative importance of these temperature driven changes within the complex changes envisioned in marine ecosystems with global climate change.

22 May, 11:00 (S4.1-4624) Invited

Anyway the wind blows… scenario from climate to the lower trophic levels in the western North Pacific

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Retrospective studies have reported significant correlations between various climatic indices and variation of the lower trophic level marine ecosystems world wide. There is a global demand to understand the regionally specific processes linking climate-oceanography-ecosystems to provide a better scenario of on-going and future marine ecosystem changes. Information embedded in zooplankton specimens can be a useful clue to indicate the past changes in oceanographic condition and primary productivity. We started the project under as part of a collaboration between several research institutes and universities in 2003 on detailed analyses of the historical zooplankton samples of the Odate Collection, collected in the western North Pacific during 1960s-2000. This presentation summarises the major findings of the Odate Project. Quasi-monthly time series of copepods species composition, and copepodite stage composition and stable isotope ratio ($\delta^{15}N$) of the dominant species (three *Neocalanus* spp. and *Eucalanus bungii*) were analysed together with climatic indices, seasonal hydrographic and Chl *a* data sets. We detected the two pathways of climatic influence on the lower trophic levels: 1) phenology controlled by decadal variation of wintertime wind stress, and 2) a biogeographical shift of the zooplankton community induced by dynamics of Kuroshio-Oyashio currents. The results suggested that the bottom-up control of the plankton productivity: phytoplankton phenology and subsequent match-mismatch were the plausible mechanisms of the zooplankton decline during the cool, windy 1980s and its recovery during the warm 1990s. Pan-Pacific to hemispheric comparison of mechanisms of long-term zooplankton variation will also be discussed.

22 May, 11:25 (S4.1-4843)

Effects of increasing UV radiation on arctic bacterioplankton community structure and activity

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Environmental ultraviolet radiation (UVR) has been recognised for many years as a potential stressor of organisms in a variety of environments. Several studies have shown that marine bacterioplankton and phytoplankton are sensitive to solar radiation, especially to the shortest wavelength fraction of UVR. Ozone depletion and ice cover reduction due to global warming might lead to increasing levels of UVR reaching the Arctic Ocean's surface, and therefore somehow affect planktonic communities. UV radiation causes damage to nucleic acids, proteins and lipids, and may lead to mutations, cell inactivation and death. It may also induce changes in dissolved organic matter composition and consequently modify the availability of nutrients for planktonic communities. As marine heterotrophic bacteria are considered to be too small to have developed efficient photoprotection systems, and as their genetic material involves a significant proportion of their cellular volume, it is thought that bacteria may be among the plankton groups more susceptible to sunlight damage. Our current work is focused on the study of potential changes in microbial diversity and biogeochemical activity when exposing samples to different light quality treatments. We used microautoradiography combined with fluorescence *in situ* hybridisation (MAR-FISH) in summer Arctic Ocean samples to test the effect of different irradiance spectrum conditions on heterotrophic bacterial community composition and activity at the single cell level. We show that UVR partially inhibited leucine and dimethylsulfoniopropionate (DMSP) assimilation by bacteria, so that light quality was affecting both carbon and sulfur cycling.

22 May, 11:40 (S4.1-4524)

Ocean's least productive waters are expanding

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A 9-year time series of SeaWiFS remotely-sensed ocean colour data is used to examine temporal trends in the ocean's most oligotrophic waters, those with surface chlorophyll not exceeding 0.07 mg chl/m^3. In the North and South Pacific, North and South Atlantic, and South Indian Oceans, outside the equatorial zone, the areas of low surface chlorophyll waters have expanded at average annual rates from 0.79 to 4.40%/yr and replaced about 0.8 million km^2/yr of higher surface chlorophyll habitat with low surface chlorophyll water. From 1998 through 2006 it is estimated that the low surface chlorophyll areas in these oceans combined have expanded by 6.6 million km^2 or by about 15.0%. In both hemispheres there is evidence of a more rapid expansion of the low surface chlorophyll waters during the winter. It is the North Atlantic with the smallest oligotrophic gyre that is expanding most rapidly both annually at 4.71%/yr and seasonally, in the first quarter at 6.96%/yr. The expansion of the low chlorophyll waters are consistent with global warming scenarios due to increased vertical stratification in the mid-latitudes but the rates of expansion we observe already greatly exceed recent model predictions.

22 May, 11:55 (S4.1-4836)

Role of microzooplankton grazing in the DMS cycle: laboratory and field studies

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Dimethylsulphide (DMS) is a volatile molecule that is found all over the world's oceans. Its biochemical precursor dimethylsulphoniopropionate (DMSP) is produced by some phytoplankton taxa. Upon diffusion into the atmosphere DMS gets oxidized and can form cloud condensation nuclei. In 1987 the hypothesis was proposed that marine plankton play an important role in climate regulation through DMS emission. A few published studies have shown that microzooplankton grazing on DMSP-containing phytoplankton species leads to DMS production. Nonetheless, microzooplankton are thought also to assimilate part of the prey's DMSP and divert it from being transformed into DMS, although this assimilation has never been directly observed and measured. We carried out two different types of experiments: (a) A monthly series of dilution grazing experiments over a year in the coastal NW Mediterranean, where the microzooplankton grazing rates on both the whole phytoplankton community and the subcommunity of the DMSP producers were quantified along with DMS production. (b) A lab experiment where the heterotrophic dinoflagellate *Oxyrrhis marina* was fed with a monospecific culture of the diatom *Thalassiosira pseudonana*, which had been previously radiolabelled with ^{35}S-DMSP. One third of the ingested ^{35}S-DMSP was assimilated by the grazer. The results of these experiments confirm the important role of microzooplankton in controlling DMS production, and should be very useful in developing models of the DMS cycle.

22 May, 12:10 (S4.1-4654)

Shifts in phytoplankton ecosystem composition and large scale indices of climate variability

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Biogeochemistry of the ocean is strongly linked with ecosystem composition and more particularly with the phytoplankton. Proper knowledge and prediction of many essential biogeochemical cycles strongly depends on the nature of the phytoplankton ecosystem. It is thus of great importance to improve our knowledge about phytoplanktonic ecosystem composition responses due to climate variability at the large scale, especially in the context of global climate change. New remote sensing observations now give us the opportunity to acquire original information on this important topic. Thus, an algorithm has been developed to detect some dominant phytoplankton functional types (PFTs) from marine signal anomalies acquired by classic ocean colour satellites.

Groups detected are diatoms, haptophytes, *Prochlorococcus*, cyanobacteria and *Phaeocystis*. This method, named PHYSAT, was applied to process daily global SeaWiFS data between 1997 and 2006. These original observations were used to study links between the distribution of dominant phytoplankton groups and some large scale indices of climate variability (respectively the NAO in the North Atlantic Ocean, the SOI in the Pacific Equatorial and the SAM in the Austral Ocean). A first comparison between temporal variability of those indices and the temporal and spatial variability of dominant phytoplankton groups has highlighted strong links between shifts in dominant phytoplankton groups and indices anomalies. These shifts are more particularly associated with an increase of surface wind speed during positive phase of the indices, especially at high latitudes.

22 May, 12:25 (S4.1-4590)

Propagation of an atmospheric climate signal to local phytoplankton in a small marine basin

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The long term response of phytoplankton to climate change needs to be recognised as a multiyear trend embedded in a strong repeating annual cycle. Seasonal forcing and response return approximately to their initial states at the beginning of each annual cycle, thus any long term signal must be discerned as departures from the annual average state. In the Bedford Basin (Canada), seasonal vertical stratification of the water column is determined primarily by temperature, but a multiyear change in the annual deseasonalised average stratification is induced by salinity which is linked to precipitation and river discharge. Stratification anomalies explain significant amounts of variability in the anomalies of nutrients and total phytoplankton biomass including that contributed by diatoms, but not the biomass of nanophytoplankton and picophytoplankton. Instead, the responses of the small phytoplankton groups seem more complex, apparently related to temperature and incident solar radiation but not mediated through vertical mixing. The adjustment of phytoplankton to environmental change over time appears consistent with patterns established from comparative analysis of widely-spaced ecosystems, but the proximal mechanisms have not been identified. Multiyear change is also evident in bacterioplankton and seston, indicating possible propagation of phytoplankton effects to other parts of the ecosystem. Observations from environmental monitoring provide a pragmatic evidential basis for prediction when both the climate driver and the ecological response undergo a coherent change away from their normal state.

22 May, 12:40 (S4.1-4682)

Ocean warming and phytoplankton size

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Consistent associations between temperature and marine phytoplankton stocks have been recently documented. Although warming has been shown to result in a decline of total phytoplankton biomass, we lack a theoretical explanation for the unexpected parallel increase in absolute cell abundance, and we also lack knowledge of the specific effects of temperature on the picoplanktonic size fraction (<2 μm). Picophytoplankton (*Prochlorococcus* and *Synechococcus* cyanobacteria and small eukaryotic algae) are photosynthetic unicellular organisms found throughout the world's oceans that make a large contribution to global carbon fixation. We show that a combination of general ecological theories, namely the temperature-size rule and the allometric size-scaling of population abundance, yields the phytoplankton temperature-abundance relationship. Using this theoretical framework we predict that an increase in temperature will increase the importance of picophytoplankton in relation to the bulk of phytoplankton. To test this hypothesis we merged two time series data sets (n=154) obtained in the eastern and western temperate North Atlantic Ocean across a diverse range of environmental conditions, which show a remarkably consistent pattern of increasing picophytoplankton biomass over the -0.6 to 22ºC temperature range. Furthermore, the relative contribution of small cells to total phytoplankton biomass displayed a strong positive temperature dependence. Temperature alone explained 73% of the variance of this contribution regardless of differences in trophic status or inorganic nutrient loading. Our analysis predicts a gradual shift towards smaller primary producers in a warmer ocean, providing a basis for assessing how phytoplankton communities might change in the future.

22 May, 12:55 (S4.1-4856)

Decadal changes in North Atlantic phytoplankton blooms

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Changes in the timing, intensity and spatial distribution of seasonal phytoplankton blooms have consequences for biogeochemical cycling and ecosystem dynamics. The current ten year record of SeaWiFS ocean colour data allows interannual variability in bloom characteristics and spatial extent to be investigated for the North Atlantic. Four distinct biomes are identified, ranging latitudinally from early blooming sub-tropical conditions, to late starting, highly productive sub-polar regimes. The consequences of interannual variability in bloom timing and biome extent for subsequent bloom intensity are discussed. The same analyses are applied to output from a coupled biogeochemical model (MOM4-TOPAZ). The model reproduces the biomes and timing of the bloom well, allowing changes in phytoplankton phenology from 1959-2006 to be addressed. Understanding the changes in underlying physical processes that contribute to interannual to decadal variability will provide insight into the response of lower trophic levels to future climate change.

22 May, 14:30 (S4.1-4685)

The future of shelf seas: projections and observations of changes in the thermal structure and consequences for primary production and water quality

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Phytoplankton are the base of the marine food web and in the temperate shelf seas, stratification is a key factor in controlling the timing, location and nature of the growth of phytoplankton. Our simulation suggests that in a few decades from now summer stratification in areas of the North and Celtic Seas could last up to 40 days longer. This presentation will present model simulations of the likely stratification under future climate scenarios (using a 3D hydrodynamic model, POM), coupled to the ecological significance of such events for particularly sensitive areas. Observations taken in 2003 - which was very warm and potentially indicative of the future climate - show very low oxygen values in the bottom waters in the Oyster Grounds region of the North Sea. These data and more recent high frequency observations are presented along with model results (using a 1DV ecosystem model, POM-ERSEM). The implications of these processes are discussed with direct application to the North Sea but the issues of changing primary production and low oxygen are applicable to other shelf seas.

22 May, 14:45 (S4.1-4857)

A mechanistic perspective on ecosystem response to climate variability: the California Current Ecosystem LTER site

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Building on nearly 6 decades of interdisciplinary ocean observations from the CalCOFI region, the NSF-supported California Current Ecosystem (CCE) Long-Term Ecological Research (LTER) site is addressing the mechanisms leading to ecosystem change in a coastal pelagic upwelling ecosystem. Previous work at the site has demonstrated 20th century ocean warming that was unprecedented in the previous 1400 years, illustrated nonlinear ecological responses to linear physical forcing, and identified low frequency changes in zooplankton assemblages related to the Pacific Decadal Oscillation or the North Pacific Gyre Oscillation. Here we explore the primary mechanisms underlying such low frequency ecosystem variations: (1) *in situ* changes in water column stratification and nutrient supply, (2) variations in along-shore or cross-shore advection, and (3) altered predation pressure. These mechanisms are being addressed with a research programme integrating *in situ* Lagrangian experiments; time series measurements including autonomous ocean gliders, satellite remote sensing, quarterly shipboard measurements, and high-

frequency near-shore measurements; and a vigorous modelling programme that includes ROMs, allometrically-scaled, NPZD, and control volume property flux models. An innovative information management system (centred around DataZoo) is being developed that facilitates data access and communication among different programme elements. Results will illustrate advances in our coupled measurement/modelling programme.

22 May, 15:00 (S4.1-4903)

How does climate change impact the biodiversity of marine phytoplankton communities in the North Atlantic Ocean?

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The structure of marine phytoplankton communities plays an important role in regulating global biogeochemical cycles. How these communities respond to changing global climate is unclear. We are investigating the impact of environmental change associated with the North Atlantic Oscillation (NAO) and climate warming on phytoplankton community structure in a model of the North Atlantic Ocean. We employ the MIT ocean circulation model configured in an idealised basin of North Atlantic dimensions. The ocean model is forced with idealised wind stress and heat flux patterns consistent with negative and positive NAO phases and climate warming conditions. The physical model is overlain by a biogeochemistry model with four potentially limiting nutrients (nitrogen, phosphorus, iron, and silica) and an ecosystem model in which many tens of phytoplankton types are initialised with stochastically determined physiologies, drawn from reasonable ranges of traits. Ecosystem community structure "self-organises" according to the relative fitness of the initialised physiologies, and modelled community structure and biodiversity are emergent, rather than prescribed. Using this framework, we assess the climate-driven changes to phytoplankton community structure in the North Atlantic Ocean, focusing on the biodiversity of phytoplankton and the biogeography of key phytoplankton functional types. We analyse the biogeochemical impact of these ecological transitions by estimating the change in export of carbon from the euphotic zone in different climate states. Though idealised, the model suggests testable hypotheses for climate-induced structural shifts in marine ecosystems and their regional impact on biogeochemical cycles.

22 May, 15:15 (S4.1-4649)

Ecosystem consequences of decadal changes in energy and carbon flows due to climate-induced changes in Baltic zooplankton

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Climate-induced changes in hydrography, i.e. temperature and salinity, have significantly reorganised the central Baltic ecosystem. One of the most pronounced changes occurred in the zooplankton, namely a dominance change from *Pseudocalanus acuspes* to *Acartia* spp. and *Temora longicornis*. This climate-induced change in the zooplankton was a major driver for an ecosystem regime shift in the early 1990s. Along with the changes in ecosystem structure, trophic interactions in the food web and hence carbon and energy flows have potentially been significantly altered. These may have important consequences for the energy and matter transfer to higher trophic levels, mainly commercially important fish populations. Additionally the potential for carbon export out of the food web, i.e. for the efficacy of the biological pump may have changed. Here we combine analyses on long-term data on zooplankton and hydro-climatic variables with a network analysis of the Baltic food web. By this we first investigate long-term energy and carbon trends in Baltic copepod and cladoceran populations in relation to climate-induced changes in hydrography. Secondly, we construct mass-balance food web models for pre- and post regime shift periods to evaluate changes in ecosystem structure and function, as well as energy and carbon flows. Our study shows a significant change in the energy transport to higher trophic levels, especially affecting growth of the major planktivore, herring (*Clupea harengus*). We further demonstrate how the change in the zooplankton, especially the increase in *Acartia* spp., resulted in a major unused food resource and hence a potential export out of the system.

22 May, 15:30 (S4.1-4533)

Microplankton response to climatic variability in the English Channel and western Mediterranean Sea

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The composition of the micro-phytoplankton was investigated at a fixed station in the NW Mediterranean Sea (1998-1999) and two stations in the northeastern English Channel (1997-2005). A warming event in September 1999 was associated with the unusual presence of the dinoflagellate *Asterodinium* in the Tyrrhenian and Ligurian Seas. This was considered as a first phytoplankton indicator of warming in the Mediterranean Sea. In the NE English Channel, the extreme August 2003 heat-wave was associated with an exceptional peak of abundance of the dinoflagellates *Akashiwo sanguinea* and *Ceratium fusus*. Since 2003 and especially in 2005, the diatoms *Eucampia cornuta* and *Chaetoceros peruvianus* were detected for the first time, indicators of the northward spreading of subtropical species. The climatic conditions in 2005 were strongly anomalous. The spring bloom of the flagellate *Phaeocystis* was absent for the first time in recent decades. An unusual assemblage of large rhizosolenioid diatoms dominated in autumn. The meteorological events that favoured this unusual phytoplankton composition in 2005 and the influence on higher trophic levels are discussed.

22 May, 15:45 (S4.1-4664)

Surface warming, decreasing upwelling intensity and plankton off Galicia (NW Spain)

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Plankton biomass and composition is expected to reflect changes in nutrient inputs and water column stratification. The mean intensity of the north-eastern Atlantic upwelling system at its northern limit (Galicia, NW Spain) decreased during the last 40 years while surface waters become warmer. In this regard, plankton biomass and species abundance data, both at regional and local scales were examined and related to upwelling intensity. Regional data were from the Continuous Plankton Recorder (since 1958) and local data came from the Spanish Atlantic Time series programme (since 1990). Phytoplankton biomass did not show significant trends but there was a significant decrease in diatom abundance at regional scales and also of large species at local scales. In contrast, zooplankton abundance (mainly copepods) significantly decreased offshore but increased near the coast, particularly due to the abundance of small-sized species (e.g. *Acartia*). *Temora stylifera*, a warm-water species became increasingly abundant at both regional and local scales in recent years. These results suggest that during the last 40 years local factors were able to modulate the effects of large scale environmental trends on the plankton.

22 May, 16:00 (S4.1-4881)

The jellyfish joyride: can we stop oceans sliding down the slippery slope to slimy stingers?

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The most obvious human impacts on marine ecosystems have probably been on coral reefs, where our activities have precipitated a slide down a "slippery slope to slime", with large hard corals being replaced by bacterial mats and seaweeds. Here we present evidence that pelagic ecosystems may also be on a trajectory that ends in noxious states, dominated by jellyfish. Rapid climate change may favour opportunistic rapidly-responding

"generalist" species such as jellyfish over more "specialist" higher trophic level species that we have traditionally valued. Impacts of climate change act synergistically with eutrophication, overfishing, habitat modification and species translocation to flip pelagic ecosystems from being dominated by fish to a less desirable state dominated by jellyfish. Jellyfish possess a suite of highly successful attributes that reinforce outbreaks: they have no feeding satiation, when starved they shrink rather than die, under unfavourable conditions they undergo encystment from which they can re-emerge years later, and they have faster growth rates and lower energy requirements than almost any other metazoan. This alternate jellyfish stable state has dramatic and potentially lasting ecological, economic and social consequences. We must address the impacts of climate change in concert with other human stresses which act synergistically to alter ecosystem state. The battle plan needed to stop such changes requires both short-term coping strategies and longer-term strategic responses. Previous lessons teach us, however, that prevention is far easier than cure and more cost-effective, so directed and concerted early action is required to avert large-scale disruptions to pelagic ecosystems.

22 May, 16:15 (S4.1-4653)

Effects of North Atlantic climate variations on the Irish marine ecosystem

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Changes in the North Atlantic heat budgets may trigger consequences in global ocean circulation, with effects on regional climate systems and ecosystem dynamics. Ireland is in a geographically privileged position to monitor such changes, and has established a Marine Climate Change Research programme to investigate trends on decadal time series of both physical and biological 'essential ocean climate variables' (temperature, salinity, phytoplankton biomass), as well as other parameters (fish population dynamics). Subsurface temperature anomalies, monitored at a permanent observation station on the northern coast of Ireland, show a generally positive trend (+0.85°C) over the last 50 years, with repetitions of exceptionally warm years over the last decade. These regional results generally agree with basin-scale (North Atlantic) trends, and appear to be correlated to the main global temperature anomalies. From a biological perspective, considering twenty years of observations, the phytoplankton blooming season appears to have lengthened. Analyses of microalgal abundance and community structure are in progress, with the additional aim of identifying sentinel species for climate change. At higher trophic levels, the North Atlantic catch of salmon has decreased dramatically since the 1970s, in spite of severe exploitation regulation; sea-trout counts fell from 1000-3300 individuals (years 1970-1985) to consistently less than 500 after 1988. We hypothesize that climate variability and change in the North Atlantic affects the physical mechanisms controlling the dynamics of the lower trophic levels of the Irish Atlantic marine system, and question whether, and through which mechanisms, higher trophic-level dynamics correlate to these changes.

22 May, 16:30 (S4.1-4848)

Impacts of global warming on lower-trophic level ecosystems projected by a 3-D high-resolution ecosystem model

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In order to clarify the impact of global warming on marine ecosystems, we developed a 3-D high-resolution ecosystem model with an off-line calculation method which can directly use predicted results of climate models as a physical field of the ecosystem model. Our model, COCO-NEMURO which has a horizontal resolution of 1/4 by 1/6 degrees, consists of PICES NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography) coupled with COCO (CCSR Ocean Component Model). We applied this model to the western North Pacific, and conducted a global warming experiment using predicted physical fields by a high-resolution climate model (the CCSR/NIES/FRCGC climate model which contributed to the IPCC-AR4). The experiment was conducted with an idealised scenario in which an atmospheric CO_2 concentration increases by 1% per year.

Under the global warming condition, our model projected a significant decrease in the maximum phytoplankton biomass by 25% during the spring bloom in the subarctic-subtropical transition region. This result supports the projection of Hashioka and Yamanaka (2007) with a medium resolution version of COCO-NEMURO (1 by 1 degrees). However, it is interesting that the predicted maximum biomass in spring in the subarctic region increases by 20% in the new experiment with the high-resolution model, while there is a decrease in the annually averaged biomass. These results suggest that the impact of global warming would significantly appear in specific seasons and regions. We show the reason for these changes based on changes in the environmental factors associated with global warming (e.g. temperature, nutrient and light conditions).

22 May, 16:45 (S4.1-4760)

SCOR WG125 "Global comparison of zooplankton time series": a summary of results

SCOR WG125 Members, Associate Members, Data Collaborators and David **Mackas**[1]

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The short life span (weeks to a year) of mesozooplankton allows their population size to respond strongly and rapidly to interannual environmental change. This, plus the fact that there is no direct fishery mortality, makes long zooplankton time series a valuable resource for understanding ocean climate impacts on marine ecosystem structure and productivity. SCOR Working Group 125 recently compiled zooplankton time series from a number of regions worldwide, and converted them to intercomparable time series of annual anomalies. This report is a brief summary of what we learned (more detailed results reported in Workshop W1 presentations). Strong and ecologically important modes of low frequency zooplankton variability include changes of total biomass/biovolume/abundance (3-30x), changes of community composition (amount within individual species or species assemblages, 10-100x), changes of seasonal timing of within year maxima (weeks to months), and changes in size, condition, and chemical composition. All of the longer time series show very strong low frequency variability at multiple time scales ('ENSO', decadal regime, and overall trend). Decadal variability is spatially coherent within current systems (correlation length scale ~1000 km), but is usually weakly correlated or uncorrelated between hemispheres. Responses to ENSO events are ~synchronous but stronger in the Pacific than in the Atlantic. Log-scale anomalies of individual species and species assemblages are usually larger (by 2-3x) than the anomalies of total biomass, and show evidence of strong poleward displacement of zoogeographic boundaries in time intervals when temperature and stratification anomalies are positive.

S4.1 Posters

Poster S4.1-4059

Effect of climate changes on the aquatic ecosystem of the Black Sea: from planktonic communities to fish recruitment

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Dramatic changes which have occurred during the last three decades in the Black Sea are connected to a combination of two factors: anthropogenic influence and climate impact. Which factor is more important: anthropogenic forcing or climate impact has been debated in many recent papers. Opportunities to undertake retrospective analyses are provided after extensive studies by a number of large international projects in the Black Sea (such as NATO TU Black Sea) and new knowledge has been obtained about the reasons for long-term variability in the Black Sea ecosystem. Due to this, there are now opportunities for inter-ecosystem comparisons. In the present paper an empirical model is presented which shows that the changes of the European climate modify the long-term dynamics of the Black Sea ecosystem. The result of the present work is a schematic representation of the effect of climate impact on the cascade interactions of ecosystem levels due to the influence of natural and human factors: atmospheric circulation, water structure and circulation, anthropogenic influence, biodiversity, population changes, modification of planktonic and fish diet, outbreaks of alien species, food accessibility, fish recruitment and ecosystem balance.

Poster S4.1-4534

Phytoplankton invasive species: comments on the validity of the non-indigenous dinoflagellates and diatoms in the European Seas

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Climate change is expected to alter the species composition of the local planktonic communities as well as their invasion by exotic species. The validity of categorising the diatoms and dinoflagellates reported in the literature as non-indigenous phytoplankton in the European Seas is investigated. Synonyms are often included as separate species (*Gessnerium mochimaensis = Alexandrium monilatum, Gymnodinium nagasakiense = Karenia mikimotoi, Pleurosigma simonsenii = P. planctonicum*). Other species names are synonyms of cosmopolitan taxa (*Prorocentrum redfieldii = P. triestinum, Pseliodinium vaubanii = Gyrodinium falcatum, Gonyaulax grindleyi = Protoceratium reticulatum, Asterionella japonica = Asterionellopsis glacialis*). Epithets of an exotic etymology (i.e. *japonica, sinensis, indica*) result in the consideration of cosmopolitan species as non-indigenous. Several taxa are even considered as non-indigenous in the type locality (*Alexandrium tamarense* and *A. peudogoniaulax*). The records of *Alexandrium monilatum, A. leei* and *Corethron criophilum* are doubtful. Cold or warm-water species expand their geographical ranges or increase their abundances to detectable levels during cooling (*Coscinodiscus wailesii, Thalassiosira punctigera*) or warming periods (*Chaetoceros coarctatus, Proboscia indica, Pyrodinium bahamense*). These are examples of a marginal dispersal associated with climatic events instead of species introductions from remote areas. The number of non-indigenous phytoplankton species in European Seas has been greatly over-estimated.

Poster S4.1-4565

The long-term dynamics of coccolithophorids in the Black Sea with respect to environmental trends

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Coccolithophorids now are the subject of special interest due to their ability to produce a calcite cell wall which eventually increases deposition of carbon to bottom sediments. Satellite images show that blooms of these algae may occupy up to 20-60% of the total sea area in May-June. The goal of this study was to detect whether a long-term trend in coccolithophorid abundance exists or not? For this purpose the database on phytoplankton of the Black Sea was used. It includes data from 930 stations and 2600 samples collected from 1968 to 2007. Three evident time periods with different level of coccolithophorid abundance were revealed for May-June. Before the 1980s the role of coccolithophorids in the phytoplankton community was not substantial. Average wet biomass for the upper mixed layer was 8 $\mu g\ l^{-1}$ while their share of the total phytoplankton biomass was 3%. In the 1980s average biomass increased up to 106 $\mu g\ l^{-1}$. From the 1990s to the present coccolithophorids dominate the structure of the phytoplankton community, with an average biomass of 227 $\mu g\ l^{-1}$ and percentage of the total phytoplankton biomass of 42%. They replaced dinoflagellates in the phytoplankton community. Forty years of coccolithophorid dynamics was compared with long-term trends of abiotic and biotic parameters. It was shown that during recent years the high concentrations of coccolithophorids were recorded after cold winters with subsequent relatively high phosphate concentration in the upper water layer and low nitrogen/phosphorus ratio. This pattern is in good concurrence with experimental results, which show an evident phosphate limitation of coccolithophorid growth in May-June.

Poster S4.1-4575

Biological cycle of *Sphaeroma serratum* (Isopoda) in the Thau lagoon: Impact of global change from 1972 to 2006

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In the context of global change, rising temperatures cause an evaporative increase in salinity, particularly in lagoons where responses to variations are faster than in the open sea. In the Thau lagoon, the impact of these changes has been investigated by studying the biological cycle of the isopod crustacean *Sphaeroma serratum*. The objective was to compare the resulting 2006-2007 data with those collected in 1972-1973 in the same lagoon. In 2006-2007, the average water temperature was 17.9°C versus 15.4°C in 1972-1973. The mean salinity also increased from 32‰ to 37.5‰. Important differences affecting the biological cycle were noted in 2006-2007 compared to 1972-1973. (i) Hatching occurred one month earlier, in May 2007 instead of June in 1973. (ii) Some females reproduced twice a year in 2006-2007 instead of once. The increase of temperature may thus improve the reproductive potential of females. (iii) In males, the 2006-2007 lifespan was shorter by 3 months compared to 1972-1973, maybe due to a decrease in osmoregulatory capacity of the pubescent adult males. The higher salinity resulting from increased temperatures may thus decrease the life duration of the male *S. serratum* perhaps by triggering an earlier senescence phase preceding death.

Poster S4.1-4608

Hydrographic changes and their connection to the phytoplankton spring bloom in the German Bight

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Algal counts from the Helgoland Roads time series (German Bight, North Sea) showed a step-like delay for the phytoplankton spring bloom starting in 1978. This may be evidence for a regime shift in the North Sea at the bottom of the food web. To investigate if a hydrographic regime shift could be responsible for the delay in the phytoplankton bloom, transport patterns in the German Bight were analysed and a sudden increase of the mean flushing rates was found in 1978 (by about 30%, from 31.000 m³/s to 42.000 m³/s). As the hydrodynamics control Secchi disk depth, salinity, temperature and nutrients, which influence phytoplankton, also these variables have been taken into account. For salinity and nutrient concentrations clear change points in 1978 and 1995 were found. Secchi disk depth and temperature change in about 1988. Regime shifts in the late 1970s, 1988 and the late 1990s are discussed in the literature. While the period 1978-1995 is clearly visible in the salinity data, nutrient concentrations and transport patterns of our study, it was not possible to identify any hydrodynamic shift in 1988. We conclude that such a shift in about 1988 most probably would have to be explained by factors other than the hydrodynamic flow patterns (e.g. temperature, Secchi disk depth).

Poster S4.1-4634

To what extent do coastal zooplankton reflect Mediterranean climate variability?

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Coastal areas are complex ecosystems characterised by high spatial and temporal variability of their physical and chemical factors, and by consequently remarkable variability in their pelagic populations. Moreover, the dynamics of coastal environments are continuously affected by anthropogenic activities, which tightly interplay with natural forcing and events. All these elements make it quite difficult to disentangle the various components of system variability and to clearly discern proximate from remote sources. At the same time, coastal areas are easily accessible and therefore the sites of the most numerous long-term studies are useful for monitoring the responses of the pelagic system to climate change. In coastal regions of the Mediterranean Sea, a semi-enclosed basin sensitive to climate variability, only a few investigations are regularly carried out to investigate zooplankton responses. A long-term time series is being conducted in the Gulf of Naples (western Mediterranean Sea) since 1984 to track the dynamics of the coastal mesozooplankton along with environmental variability. The samples are collected biweekly until 1990 and weekly sincy 1995, with a major interruption from 1991 to 1994. Various structural aspects of these pelagic communities are under investigation, from total dry biomass to species composition and abundance, with the aim of discerning recurrences and trends in different organisational levels and at different temporal scales. Some results are presented here that indicate how patterns that might be related to climate forcing can be better perceived in species rather than in bulk properties.

Poster S4.1-4650

Coccolithophore response to abrupt and short-term climate changes in the Gulf of Lions (western Mediterranean) for the last 25,000 years

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Cores PRGL-1 (310 m long) and MD99-2348 (21.5 m long) were recovered in the Gulf of Lions (42.690°N; 03.838°E) at 298.48 m water depth, during the PROMESS 1 campaign (SRV *Bavenit* drilling vessel) and IMAGES V (RV *Marion Dufresne*, Calypso piston core), respectively. The high sedimentation rates estimated by robust ^{14}C

dating have given us an excellent opportunity to perform high resolution analyses on these materials. In this study we present data from the last 25 kys. The retrieved sediments consist of silty-clay terrigenous material mixed with a small amount of calcareous microfossils. Quantitative analyses of coccolithophore assemblages allow us to identify significant changes in sea surface temperature in this period. Cold peaks are marked by increases in the proportion of *Gephyrocapsa muellerae* and large morphotypes of *Emiliania huxleyi* (>5 μm); some of the most significant can be correlated with Heinrich events. The high sedimentation rates observed during most of the interval studied also allow us to identify an overprinted multicentennial scale pattern related to Dansgaard-Oeschger cycles. The combined analyses of coccolithophores and planktonic foraminifers enables a sea surface temperature (SST) record to be made in which sharp fluctuations of around 4ºC in amplitude have been detected. These abrupt changes in SST are also linked to changes in surface productivity and in the deep and intermediate water dynamics, probably related with variations in the atmospheric pattern (NAO-like oscillations).

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Poster S4.1-4651

Study of potential effects of climatic forcing on the ecosystems of the western Mediterranean Sea

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In this work we study the effect of climatic forcing on sea surface chlorophyll. We explore the relationships between atmospheric variables (wind stress and heat fluxes) and ocean colour images (SeaWiFS chlorophyll). The atmospheric data set was obtained in the framework of the HIPOCAS project through a dynamical downscaling (1/2°x1/2°) from the NCEP/NCAR global reanalysis using the atmospheric limited area model REMO. The chlorophyll is estimated through the MedOC4 regional algorithm. SeaWiFS images are analysed using Data Interpolating Empirical Orthogonal Functions (DINEOF), providing both EOFs and the interpolated weekly time series, with a spatial resolution of 1/16°. We focus on the western Mediterranean by considering different subareas and we obtained the EOFs for all the selected variables. To relate the atmospheric variables with chlorophyll we used a genetic algorithm. The genetic algorithm gives the transfer function of each couple of variables and its functional dependencies. With this method we can assess and quantify the ecosystem response to the atmospheric forcing and to the climate change.

Poster S4.1-4656

How will the ocean warming affect the planktonic diversity?

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Past oscillations in climate have been followed by abrupt changes in species diversity. Unfortunately the fossil record of planktonic organisms is restricted to a few groups with hard shells and skeletons (e.g. foraminifers and coccolithophorids), but they have been used in the study of biodiversity and extinction as far as the Cambrian (543 million years ago). In general, foraminifers increase in species richness and diversity when temperatures increase and *vice versa*. The same pattern seems to be valid by coccolithophorids. However, as they do not fossilize, little is known about the response of copepods (the most abundant class in the mesozooplankton) under past climate changes. In the present scenario of global warming, this lack of knowledge is being substituted by a subjective perception that the diversity of copepods is increasing, which is the opposite of that which is occurring with other invertebrates (e.g. insects, molluscs, echinoderms, etc.). In this paper we review data from published literature to compare the trends in copepod biodiversity at a global scale, in the biogeography domains and in some specific regional seas, during the last 50 years and we speculate about the expected trends if the warming is maintained in the next 100 years.

Poster S4.1-4672

Impact of climate change on the marine pelagic ecosystems off Galicia (NW Spain). I: Water characteristics and plankton

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Changes in atmospheric temperature and pressure fields at global and multidecadal scales have measurable effects on the characteristics of the upper ocean and, in turn on pelagic ecosystems. However, the direction of changes at these scales may be different at regional and local scales. To ascertain the significance of changes in relevant oceanographic and pelagic ecosystem variables in relation to climate change at the northern limit (Galicia, NW Spain) of the north-eastern Atlantic upwelling system, a multidisciplinary study was initiated in this region. The objectives were directed to determine patterns of change in: 1) marine climate and oceanographic properties, 2) diversity and composition of biological communities and 3) biological production, including fisheries and aquaculture. In this poster we highlight some of the results obtained for the two first objectives. Coastal surface waters in south Galicia warmed at a mean rate of 0.27±0.03°C every 10 years, but large variations were found at local scales. In addition, there was a measurable decrease in the mean intensity of the upwelling caused by a reduction in the duration and intensity of upwelling-favourable winds during the last 40 years. The impacts of such changes on plankton were difficult to assess because of the magnitude of high-frequency variability. However, zooplankton abundance in the last 40 years reduced offshore but increased near the coast. These results stress the importance of local factors modulating the impact of large scale environmental trends on the ecosystem.

Poster S4.1-4677

The effect of the North Sea regime shift on the distribution of plankton functional groups and biomass

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One of the main concerns when trying to assess the effects of climate change on a given ecosystem is the occurrence of abrupt changes in the biological component in response to a gradual change in the environmental conditions. For instance, a gradual change in temperature might have little effect until a threshold is reached at which a large shift occurs. A regime shift in several biological compartments has been reported for the North Sea in the late 1980s and its causes and consequences have generated an extensive literature. In this study, we aim for better understanding of this phenomenon by using a new modelling approach to the CPR database. By using a modified non-parametric regression technique (threshold GAM) we investigate both when and where the plankton community experienced the most dramatic changes. To do this, we focus on broad biological descriptors (i.e. biomass of functional groups) while previous works were more focused on changes at a finer scale (i.e. species composition). Substantial changes were observed in the northern North Sea, not only during the late 1980s but also in other periods.

Poster S4.1-4679

Unusual mucilage event along Italian coasts in the northern Adriatic Sea

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The presence of mucilaginous masses in the Adriatic Sea has been known for a long time: the first records in Gulf of Trieste were noted in 1729. The phenomenon appeared along both the western Italian and eastern Slovenian-Croatian coastlines, causing serious problems for the tourism and fishing industries. The occurrence of mucilage masses is strongly related to the meteo-climatic and seawater conditions, calm sea, high temperatures, thermo-saline stratification of the water-column and nutrients. Mucilage masses usually appear during the summer, but they surprisingly occurred also in the winter of 2006/07 years. This anomalous event was probably linked to the climatic conditions, as both higher air and sea temperatures were observed.

Poster S4.1-4689

Interannual variability in the size-abundance relationship of nano- and micro-phytoplankton in a coastal marine ecosystem

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The size scaling theory has been shown to be a useful tool in modelling phytoplankton community structure. The aim of the present study was to determine the interannual variability in the relationship between abundance and cell size in nano- and micro-phytoplankton in a coastal marine ecosystem and to relate this variability to changes in climatological and hydrographical variables. Size-abundance spectra were determined monthly at 5 depths at a station located off A Coruña (NW Spain) during the period 1991-2002. The resulting slopes and the additional variables were studied using time series analysis techniques. Despite the high productivity of the ecosystem studied and the variability observed over a variety of time-scales, we found that a significant, inverse relationship between abundance and cell size was persistent throughout the study. Also, over the time period analysed there was a marked trend towards less negative slopes in the size-abundance relationship, indicating a greater relative importance of larger species. We evaluate the possible influence of different variables such as temperature, salinity, nutrients, upwelling and the North Atlanic Oscillation on the observed trends.

Poster S4.1-4694

Temporal variability of 10-year global SeaWiFS time series of phytoplankton chlorophyll *a* concentration

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The SeaWiFS global data set now offers a 10-year time series of consistent, well calibrated, ocean colour record that is suitable for temporal analysis. First, the chlorophyll *a* (Chl *a*) signal is broken down into seasonal, irregular and trend components using an additive decomposition method and considering a linear description of the trend. This yields a classification of the biogeographic provinces of the ocean on the basis of their temporal variability. The variance associated with the seasonal signal represents about 90% of the total variance of Chl *a* monthly series for the mid-latitude regions, from the subtropical gyres to the subpolar waters. This seasonal contribution decreases for tropical and upwelling regions as well as for some marginal seas and coastal waters, where the component of irregular (interannual) variability can dominate. A general decline of Chl *a* is detected in the North Atlantic Drift province as well as in the gyres of northern and southern Pacific. Conversely, a significant increase of Chl *a* is observed, for instance, in the Arabian or Tasman Seas. For some provinces, this simple decomposition approach, assuming a fixed seasonal cycle and a linear trend, does not capture the essential temporal dynamics inherent to the system. A time series decomposition technique based on Census X-11 approach, that allows a varying seasonal amplitude, appears more suitable to describe systems exhibiting strong interannual variations such as the equatorial Pacific where the non-linear long-term evolution related, for instance, to ENSO explains 65% of the total variance.

Poster S4.1-4782

Effects of iron on spatial and temporal phytoplankton distribution using a global 3-D ecosystem model (NEMURO)

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Interannual to interdecadal scale oscillations in atmosphere-ocean systems affect marine ecosystems by altering nutrient supply across the thermocline and horizontal advection. Trace metals such as iron, supplied by atmospheric dust and other sources, are important for limiting primary production. To investigate effects of iron on marine

ecosystems, we used NEMURO (North Pacific Ecosystem Model for Understanding Regional Oceanography); developed by the MODEL Task Team of PICES (North Pacific Marine Science Organization) embedded into a global three-dimensional physical-biogeochemical coupled model, '3D-NEMURO'. We simulated changes in the lower trophic level of the ecosystem caused by climate variability, using a monthly climatological average of the National Centers for Environmental Prediction (NCEP) 6-hourly data set as a surface forcing to drive the coupled model. The dust flux data used in the model is from the daily output of a global aerosol transport-radiation model, SPRINTARS (Spectral Radiation-Transport Model for Aerosol Species). We compare the standard version of NEMURO to our newly developed version including the iron cycle, focusing on the effect of iron on primary production and distribution of phytoplankton. We will also present preliminary results of decadal scale comparisons of historical simulations with each respective version.

Poster S4.1-4788

Phytoplankton assemblages in the Gulf of Trieste (northern Adriatic Sea): are there signals of climate change? A twenty-year case study

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In the Gulf of Trieste (northern Adriatic Sea) at a coastal site (18 m depth) the microphytoplankton community has been studied since the early 1980s as part of larger projects on plankton dynamics and food web structure and efficiency. From March 1986 to September 2005, quali-quantitative analyses of microphytoplankton species composition were performed on the basis of monthly or fortnightly sampling using Niskin bottles. To analyse the data set we have used a statistical approach based on clustering and degrees of membership, in order to identify phytoplankton assemblages during the two decades. The assemblages were identified using the Indicator Value and eight clusters were highlighted with specific species assemblages. Seven of these groups were represented by colonial diatoms, while only one was represented by autotrophic dinoflagellates. An annual pattern with different assemblages following one another during the seasons was observed. Within these general dynamics several changes were observed during the two decades; the analyses showed: 1) the disappearance of the late spring-summer assemblage (represented by autotrophic dinoflagellates) and of the early spring one (represented by the diatoms *Skeletonema costatum* and *Pseudo-nitzschia* spp.) towards the middle of 1990s; 2) the appearance of another late spring-summer assemblage (represented by the diatom *Cyclotella* spp. and the autotrophic dinoflagellate *Prorocentrum minimum*) towards the beginning of the 2000s. This evidence might suggest important modifications in the ecological niches probably due to both human impacts and climate change.

Poster S4.1-4790

Seasonal and interannual variation of the marine ecosystem in the western subarctic Pacific simulated by a 3D marine ecosystem model

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Spatiotemporal variations of the lower trophic level marine ecosystem in the western subarctic Pacific were investigated using a 3D marine ecosystem model, for understanding mechanisms of the variations and developing prediction of ecosystem responses to climate change. The marine ecosystem model was a plankton functional types model (e-NEMURO with 3N-4P-4Z-4D), which was coupled with an eddy-resolving physical model (C-HOPE,

grid size: 1/16º) assimilated to satellite altimetry (TOPEX/POSEIDON and Jason-1 data). The model was driven by atmospheric surface forcing (heat flux: NCEP/NCAR reanalysis data, wind stress: QuikSCAT data) for three years from 2003 to 2006. The model successfully reproduced the seasonal and interannual variations of plankton dynamics observed along a repeated monitoring line (A-line: from 42.8ºN, 144.8ºE to 38.0ºN, 147.3ºE, including the Oyashio (cold current) region and the Kuroshio (warm current)-Oyashio transition region). Especially the timing of the spring diatom bloom and the maximum chlorophyll *a* concentration of the bloom were quite similar to the observations. Both seasonal and interannual variations of the chlorophyll *a* concentration and zooplankton biomass in the Oyashio region were much larger than those in the Kuroshio-Oyashio transition region. The chlorophyll *a* concentrations in these regions were frequently influenced by the effects of mesoscale eddies, while the zooplankton biomass changed smoothly compared with the chlorophyll *a* concentrations.

Poster S4.1-4796

A statistical analysis of climate variability and ecosystem response in the German Bight

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We compiled homogeneous long-term time series of data with 39 variables representing the German Bight and for the period 1975-2004. A diverse set of variables was selected to cover multiple trophic levels and different environmental forcing. Previous studies have hypothesised the presence of regime shifts in observations extending over the entire North Sea. Focusing on a smaller spatial scale, and closer to the coast, we investigated the major modes of variability in the compiled time series using Principal Component Analysis. The results obtained confirm a previously identified regime shift in the North Sea in 1987/88 and suggest that the German Bight is dominantly characterised by long-term modes of variability. We conclude that the shift of 1987/88 was driven by climate forcing (through temperature, Gulf Stream Index, frost days and Secchi depth). Phosphate and ammonium showed highly negative correlations with the documented long-term mode of variability. Diatoms and *Calanus helgolandicus* did not show evidence of changes in relation to this mode. The results also underline the need for ecosystem modelling and the importance of maintaining long-term monitoring programmes.

Poster S4.1-4835

The influence of northern hemisphere climate patterns on the Adriatic Sea pelagic ecosystem

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We investigated northern hemisphere climate effects on the long term variability of the marine ecosystem in the middle Adriatic Sea during the period 1961-2005. Air temperature, precipitation, evaporation, air-sea fluxes and the North Atlantic Oscillation index covary with the patterns observed in temperature and salinity data. The use of a sequential algorithm for regime shift detection (SARS) applied to the primary production and sardine/anchovy ratio revealed three periods with significantly different mean levels of productivity: 1961-1979, 1980-1996 and 1997-2002. Moreover, the years 1980 to 1996, with the highest primary production, showed contrasting periods of productivity. While the years 1980-1986 showed an increasing trend, the years 1987-1996 were characterised by an inverse pattern. Such opposite patterns appeared to be linked to modifications in thermohaline circulation related to the Eastern Mediterranean Transient (EMT) whose effects prevented warm and nutrient rich water mass intrusions into the Adriatic and reduced productivity. Weak ventilation in the Adriatic was also evident in the lower than normal sea temperature and oxygen concentrations below the thermocline. These results provide evidence on connections between shifts in primary production in the middle-Adriatic with the northern hemisphere climate system via changes in regional atmospheric conditions, and highlight the role atmospheric variability may play as a triggering factor for ecosystem-wide changes.

Poster S4.1-4838

Impact of inorganic and organic nutrient inputs on bacterioplankton community composition along a latitudinal transect in the Atlantic Ocean

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Oceans have a major role in the global carbon cycle, and consequently might influence and regulate climate change through feedback mechanisms. A predictable consequence of alterations in soil use and of hydrologic and global biogeochemical cycles is the modification of the amount and nature of continental and atmospheric matter inputs into the world's oceans, which in turn will likely affect microplanktonic structure and functioning. Bacterioplankton are responsible for a large fraction of the respiration and DOM remineralisation in the ocean; therefore, potential changes in their taxonomic composition due to changes in nutrient inputs may have important biogeochemical implications. We hypothesize the impact of nutrient loading depends on the type of input, the kind of the initial microbial community, and the interactions between microbial components. To test our hypothesis we conducted a set of microcosm experiments along a latitudinal transect in the Atlantic Ocean (26ºN-29ºS). We simulated changes in nutrient fluxes to surface waters by means of a series of addition treatments. We studied the effects of inorganic (nitrate, phosphate and silica) and organic (glucose and amino acids) inputs separately as well as their joint effect on the bacterioplankton community composition. Changes in the relative abundance of important bacterial groups (*Roseobacter*, SAR11, *Gammaproteobacteria*, *Bacteroidetes*) were followed using CARD-FISH (catalysed reporter deposition-fluorescence *in situ* hybridization). We observed that distinct groups responded differently to nutrient additions, and that the bacterial response varied depending on the initial microbial community composition. Our results further suggest that changes in bacterioplankton community structure are related to changes in bacterial carbon use.

Poster S4.1-4842

Response of open ocean microbial communities to inorganic and organic inputs: a microcosm approach along a latitudinal transect in the Atlantic Ocean

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The magnitude of the inputs of inorganic and organic matter into the open oceans as well as the ratio between these components are expected to change as a result of desertification processes and changes in wind stress related to climate change. Variations in frequency, strength and quality of these inputs will likely affect the structure and functioning of planktonic microbial communities in the world oceans. To test this hypothesis, we conducted a set of microcosm experiments along a latitudinal transect in the Atlantic Ocean (from 26ºN to 29ºS). In these experiments, we simulated quantitative and qualitative changes in nutrient fluxes to surface waters by means of a series of addition treatments. We studied the effects of inorganic (nitrate, phosphate and silica) and organic (glucose and amino acids) inputs separately as well as the joint effect of both components on microplankton community structure and metabolism, as determined from photosyntethic efficiency and rates of primary production, bacterial production and community respiration. The observed responses were highly variable and dependent on the initial communities sampled along the latitudinal transect. These results suggest that microplankton community structure should be considered in order to understand the effect of climate-driven changes in the inputs of matter into the oceans on the microbial ecology of the euphotic marine ecosystem.

Poster S4.1-4865

Recent trends in the North Pacific chlorophyll and their controlling factor in relation to climatic forcing using satellite remote sensing

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The North Pacific is well known as one of the most biologically productive regions in the world ocean. High primary productivity and strong air-sea interactions characterise the carbon cycle of this region. Understanding the role of the biological pump in the ocean and monitoring variability of the chlorophyll *a* (chl *a*) and primary productivity is very important to clarify the geochemical cycles. Ocean colour remote sensing is a useful new tool for continuously monitoring the temporal and spatial variability of chl *a* concentration, and now over 10-year ocean colour remotely sensed data sets are available. In this study, we will describe seasonal and inter-annual variability of chl *a* concentrations and examine recent trends in chl *a* variability focused on the North Pacific using an ocean colour sensor (SeaWiFS) during 1997-2007. To clarify the factors controlling phytoplankton variability, we utilised a combination of satellite remote sensing data from AVHRR (sea surface temperature), SeaWiFS (photosynthetically active radiation, wind speed, as well as climatology data). Finally we will discuss the distribution patterns of chl *a* and their controlling factor in the North Pacific in relation to climatic forcing such as ENSO and/or monsoonal wind.

Poster S4.1-4868

ICES Working Group on Zooplankton Ecology

Roger **Harris** and WGZE

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The ICES Working Group on Zooplankton Ecology (WGZE) was established as a Study Group by the ICES Council in 1990. In 1994, ICES changed the status of the group into a Working Group, giving it a more permanent position within the ICES structure. Since then the group has met annually to discuss research activities and technical issues on micro-, meso-, and macroplankton, as well as benthic meroplanktonic larvae and icthyoplankton. The group is the only single disciplinary international group working on zooplankton in the world, giving it a special position within the community of marine researchers. The products of its work include Laboratory and Sea-going Workshops, Taxonomic Workshops, The Zooplankton Methodology Manual, The Annual Plankton Status Report, ICES Zooplankton Taxonomic ID Sheets and advice to other ICES expert groups. The products have wide use both within and outside the ICES community. The poster is intended to advertise some of the activities of WGZE, and to encourage participation and collaboration.

Poster S4.1-4869

BASIN: Basin-scale Analysis, Synthesis, and Integration: resolving the impact of climatic processes on ecosystems of the North Atlantic basin and shelf seas

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BASIN is an initiative to develop a joint EU/North American research programme in the field of ocean ecosystems in support of the Global Earth Observation System of Systems (GEOSS) initiative. The focus of this initiative is the integration and synthesis of data sets for coupling with modelling studies at the basin-scale to elucidate the mechanisms underlying observed changes in physical and biological changes in the North Atlantic Ocean and to predict consequences of climate and environmental change. The first BASIN meeting took place in Iceland in March 2005 and provided the basis upon which further programme development has taken place (Wiebe *et al.* (Eds.). 2007. BASIN. Basin-scale Analysis, Synthesis, and INtegration. GLOBEC Report 23/US GLOBEC Report 20, 56pp.). Two subsequent science workshops have been held to identify key issues and strategies for

the development the BASIN programme. The first was held in Hamburg from 23-25 of January 2007 and the second was held in Chapel Hill, NC, from 1-3 of May 2007. These meetings identified and documented the state of the art of climate-related ecosystem research in the North Atlantic basin and associated shelf seas, and produced broad based objectives that are designed to foster the development of an understanding of the links between climate and the marine ecosystems of the North Atlantic Basin and the services these ecosystems provide including exploited marine resources. The key next step is to produce a science/implementation plan where by joint research initiatives involving the EU, USA, and Canada can be developed and funded.

Poster S4.1-4870

METAOCEANS: training in advanced meta-analysis and comparative analysis techniques applied to marine ecosystems

Roger **Harris** and METAOCEANS students

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Major international programmes and parallel technological developments have resulted in large amounts of information on biogeochemistry, and the functioning and structure of marine ecosystems. The resulting data represents a key resource to explore patterns and carry out comparative ecosystem analyses. Many of these large data sets remain largely unexploited, as these data have been used in a local context and few attempts have yet 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- and comparative analyses. The METAOCEANS project, funded by the European Union, recognises this problem and provides an early stage training programme dedicated to train young scientists in advanced meta-analyses and comparative analyses techniques applied to marine ecosystems. The project combines the development of expertise on all relevant ecosystem functions, with emphasis on new approaches and analytical techniques. Twelve PhD students are currently working on subjects applying meta-analyses and comparative analyses techniques to the following topics: ecosystem metabolism, microbial food webs, planktonic processes, trophic links and human impacts. Research projects are carried out at six European institutes (AZTI, Spain; CNRS, France; CSIC, Spain; DIFRES, Denmark; PML, UK and UoB, Norway) with students spending time in other partner institutes as part of their training. The poster presents a synthesis of the current work accomplished within the METAOCEANS project.

Poster S4.1-4873

The occurrence of potentially harmful algal blooms (HAB) in the Gulf of Oman in relation to environmental changes.

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The diversity of harmful algal blooms (HABs) and their impacts present a significant challenge to those responsible for the management of coastal water resources. The abundance and distribution of HABs in coastal waters of Oman has been poorly investigated. We examined the occurrence of potential HAB species over a 2-year (2004-2005) period in the coastal waters of the Gulf of Oman that have been subject to ecologically significant events which have been related to HABs. The results of our study reveal a significant presence of more than three species of phytoplankton that have been shown to be toxic in other regions of the world. In addition the abundance of these species appears to have been associated with changes in environmental conditions over the last 2 years. It may be hypothesized that changes in environmental conditions driven by large scale events such as mesoscale eddies contributed to these biological changes. The significance of these results is discussed within the context of the ecological changes in the coastal waters of Oman.

Poster S4.1-4874

Effects of ice meltwater on Arctic bacterioplankton

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Climate change is causing a rapid melting of Arctic ice containing nutrients and contaminants accumulated during recent decades. We have evaluated the effects of ice meltwater on the bacterioplankton communities of the Arctic Ocean in two microcosm experiments. One-metre ice cores were sampled from two locations at the ice-edge in the Fram Strait (Arctic Ocean). Sections of the ice core were melted and 100 mL meltwater were added to 900 mL of < 0.8 μm filtered seawater. The bottles were incubated in the dark during 4 days. After the incubation, bacterial abundance, production and the activity of eight ectoenzymes and the utilization of 31 carbon sources were determined. Addition of meltwater resulted in an increase in bacterial abundance and production in all cases. Among the activities and carbon sources studied, meltwater generally caused an increase of chitinolytic and proteolytic activity and the utilisation of N-acetyl-glucosamine, all containing nitrogen. These results indicate that the addition of meltwater enhanced the use of organic nitrogen compounds which could be incorporated into the marine planktonic food web through their consumption by bacteria.

Poster S4.1-4876

Interactions among climate, circulation, and plankton distribution in the Black Sea

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Based on long-term investigations in the NE Black Sea, four main water circulation regimes and four corresponding types of cross- and long shore distribution of plankton have been distinguished. 1) The narrow fast Rim current flowing close to the continental slope causes the biomass increase over the slope and its dramatic decrease offshore. Intensification of long-shore transport and restriction of cross-shelf exchange favour the propagation of neritic species along the basin shelf and prevent their export offshore. 2) Vortical regime with nearshore eddy formation leads to a biomass increase over the shelf and at the frontal zones of the eddy. Revolute translational movement of eddies causes both cross- and along shelf transport of plankton. 3) Formation of long-lasting large eddies in the open sea causes the significant increase of plankton biomass in the eddy area especially at the periphery. Neritic species, benthic and fish larvae are trapped with the eddies and transported in the open sea. 4) Relaxation and meandering of the Rim current is accompanied with "smoothed" plankton distribution where the biomass and structure of the plankton community are similar nearshore and offshore. Substantial cross-shelf exchange causes "washout" of neritic species and larvae beyond the boundaries of their habitat. Every regime can exist at timescale up to seasonal. The interannual alterations of the prevailing circulation regime are related to the variable long-term thermohaline and wind forcings which, in turn, are affected by climate change. We show that the surface temperature and wind regime depend on the large scale atmospheric circulation and particularly on the North Atlantic Oscillation.

Poster S4.1-4914

Comparing microphytoplankton seasonality after 50 years at a coastal site in the northwest Mediterranean

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We followed the temporal succession of the phytoplankton community at monthly intervals off the coastal town of Blanes (Catalunya, Spain). Microphytoplankton as well as some components of smaller size classes, reveal a marked seasonal variation. Diatom abundances peak in February/March and contribute the bulk biomass of the annual chlorophyll maximum. Assemblages change from year to year and resemble temperate spring bloom assemblages. Concentrations of the dinoflagellate genus *Ceratium* increase in late spring. Other microplanktonic

dinoflagellates display a slight increase in summer. Microphytoplankton seasonality off Blanes is similar to other more eutrophic coastal systems with a spring bloom of diatoms and a summer biomass increase of microplanktonic dinoflagellates. Our observations reveal remarkable similarities to microphytoplankton annual dynamics observed off Blanes half a century earlier by Ramon Margalef during two time series carried out for 17 years. These concurrences indicate that microplanktonic population dynamics in Blanes probably have not changed significantly over many years.

Poster S4.1-4926

Recent variability of coccolithophore blooms in the eastern Bering Sea shelf

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During the late-summer of 1997, for the first time ever recorded, most of the continental shelf of the eastern Bering Sea was covered by aquamarine waters, resulting from massive bloom of coccolithophores *Emiliania huxleyi*. Since then, coccolithophores blooms are not unusual but common in the eastern Bering Sea. Objectives of this study are, to examine recent temporal and spatial variability of coccolithophore blooms in eastern Bering Sea, and to evaluate the causes maintaining the blooms. Since 1997, coccolithophore blooms have been monitored using satellite ocean colour SeaWiFS and MODIS data and recently the peak of the bloom tended to occur in September.

Poster S4.1-4927

COPEPOD: a climate studies resource for historical plankton data

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The Coastal & Oceanic Plankton Ecology, Production & Observation Database (COPEPOD) is an online database of historical zooplankton and phytoplankton abundance, biomass, and composition data. COPEPOD offers easy, online searching and access to over one hundred thousand plankton tows from hundreds of cruises collected by a variety of monitoring programmes, surveys, and projects from around the world. Individual data sets can be downloaded in a variety of formats, or the user can select from an assortment of pre-made regional (e.g. "Antarctic", "North Atlantic") or taxonomic (e.g. "diatoms", "copepods") data compilations. COPEPOD also features an interactive map describing over forty zooplankton time series from around the world. Each mapped point provides a standardised content summary of the featured time series, as well as a contact person for the data. This poster summarises the COPEPOD interface and the content and data products available online now at: http://www.st.nmfs.noaa.gov/plankton

Poster S4.1-4931

Seasonal and interannual variability of primary production in the scallop forming area in the Okhotsk Sea in relation to climate change

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The Okhotsk Sea is one of the most biologically productive regions in the world, and it supports high fisheries production. It is well known as one of the southern most seasonal sea ice zones in the northern hemisphere. Seasonal change of sea ice in this area has large interannual variations and has been considered to play an important role in the high production at the ice edge. The coastal region of the Sea of Okhotsk, Hokkaido, is an ideal habitat for the Japanese scallop *Mizuhopecten yessoensis*, and has supported important fisheries for this

species since the early 1900s. Understanding dynamics of ice formation and phytoplankton bloom development is important in management of this benthic community. The objectives of this study are to clarify the interannual variability of primary production in the scallop farming area in the Okhotsk Sea using satellite remote sensing and GIS. Prolonged high primary production after termination of the spring bloom is supported by the development of the frontal area along the Soya Warm Current in summer and of the East Sakhalin Current in autumn. Even at the weakening of one process, this area is sustained by other processes. Clarifying the effects of these physical processes is important to understand effects of future climate change and formulation of rational management plans in the scallop farming area.

Poster S4.1-4940

Shifts in the Black Sea plankton communities: phenological response to climate forcing or nutrient alterations

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Our study disclosed temporal patterns (seasonal, interannual, and decadal) of dominant phytoplankton and mesozooplankton species in the period 1960-2005 trying to disentangle the combined effect of rising temperatures and changing nutrient supply on the coastal ecosystem of the western Black Sea. For assessment of plankton community dominance we also discuss long-term dynamics of key taxonomic groups. We used seasonal decomposition techniques to reveal seasonality and trend of key plankton species. Statistical analyses were applied to disclose the extent of correlations between species and climate indices. Appearance/disappearance, replacement and numerical abundance of cold and warm-water species were used as an indication of shifts in the plankton communities (phenological response). At a species level we revealed temporal fluctuations of *Emiliania huxleyi, Prorocentrum minimum, Skeletonema costatum* as the most typical bloom producing species. The copepods *Acartia clausi* and *Calanus euxinus* and the cladocerans *Penilia avirostris* and *Oikopleura dioica* (Appendicularia) were focused on. The results suggest reduced amplitude of seasonal oscillations and year to year variations, a decrease of phytoplankton blooms and their critical levels attained especially in summer, an increase in the dominance of diatoms, along with an elevated increased portion of taxa "other" than the habitual for the Black Sea basin species pool, chrysophytes, microflagellates and cryptophytes, and a shift of the seasonal succession of phyto and zooplankton species. The ecosystem shifted towards more harmonised seasonal dynamic-reduced amplitude of seasonal oscillations and year to year variations. The increased dominance of heterotrophic dinoflagellates and elevated presence of "other" concurrent species that alter the cross-phylletic balance of the assemblages along with the reported deviations in the succession are signatures correlated to hydrometeorological, anthropogenic forcing and *Mnemiopsis* pressure in the Black Sea, an integrated phenological response to the altered environment. The decoupling of phenological relationships in the lower food chain might have important ramifications for trophic interactions, altering the energy flow and ecosystem-level changes.

Poster S4.1-4945

Reaction of dominant copepods to climatic changes in the Barents Sea

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Specific years typical of different climatic periods were taken as examples to show the peculiarities of the Barents Sea plankton community's structure and distribution in time and space. The dynamics of sea ice in summer was analysed as the major factor influencing the plankton's condition. The numbers, reproduction times and stage structures of *Calanus finmarchicus* and *C. glacialis* in the Arctic and mixed waters in August-September were studied. It was found that aggregations of the former are influenced by the rates of ice retreat, intensity of the local population's reproduction and transport of early stages from the southern spawning sites. Slow ice retreat causes the plankton to accumulate along the ice edge and rapid ice retreat in the areas with higher horizontal gradients of water temperature results in significant population increases (1987, 1989, 2002, and 2005). Also, in colder years distribution is limited by 77ºN while in the warm years by 80-82ºN. In 2004 when the ice edge in

July was more dynamic, and also in 2006 when in August the Barents Sea was ice-free, the distribution area of *C. finmarchicus* was small and its number was low. The formation of *C. glacialis* aggregations mostly depends on the amount of ice and its melting which causes high numbers and broad distribution of this species (including early developmental stages) in some years (1989, 2004). In 2006 due to the absence of ice *C. glacialis* were very sparse in the north except for in the north-east where ice remained for the longest period. In the years under study in the northern areas in August-September reproduction of *C. finmarchicus* and *C. glacialis* was observed but in 2006 it was weak; also unlike other warm years where the populations of the both species had few early developmental stages.

S4.2 Impacts on higher trophic levels

19 May, 10:00 (S4.2-4564) Plenary

Forecasts of population trends for two species of tuna under an IPCC scenario

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The spatial ecosystem and population dynamics model SEAPODYM includes a definition of habitat indices, movement, and accessibility of tuna predators to their forage at different vertical layers. The model was improved by implementing data assimilation techniques, and parameterisation was optimised by maximum likelihood estimation using historical fishing data (1985-2000). First optimised parameters were obtained for Pacific skipjack and bigeye, two tuna species with very different biological characteristics. Based on estimated parameters, hindcast simulations back to the early 1960s, i.e. the beginning of the industrial fishing period, predicted catch and tuna population abundance is in agreement with observation and stock assessment studies. We employed this model to forecast the future of skipjack and bigeye in the world's oceans under the A2 IPCC scenario. The simulation is driven by bio-physical fields predicted from a global Earth system simulation coupling atmospheric, land surface, sea ice, physical and biogeochemical marine components. A preliminary simulation demonstrated the capacity of the model to predict plausible responses at global scale. However, due to overly coarse spatial resolution of the atmospheric model, the climate simulation produced a temperature cold anomaly in high latitudes. Given the key effects of temperature in the dynamics of both mid-trophic components and tuna populations, further simulations were conducted after the temperature fields were processed to remove this bias. Potential future changes in distribution and abundance of skipjack and bigeye under the IPCC scenario are presented. Populations' responses to the environmental changes are complex and differ between oceans. Though on average, the effect due to climate change is on the same order as the fishing effect, the combination of both effects result in spatially heterogeneous distributions.

19 May, 11:20 (S4.2-4699) Invited

Predicting impacts of climate change on fisheries production

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Predictions of terrestrial crop and forestry production under climate change are made with medium confidence in the 2007 IPCC report, based on extensive experimental and comparative field studies of a small number of important species. Some relatively trivial predictions concerning fisheries are made with high confidence (distribution shifts; extinctions at the edges of ranges), but we have very low confidence in predictions of future fisheries production globally, regionally or for individual species. The reasons why we are less able to predict aquatic than terrestrial systems are fairly obvious and will be reviewed. We can improve our ability to predict future aquatic production by research and management which includes:

- Experiments and comparative field studies to investigate the effects of changes in temperature, oxygen, pH, ammonium, salinity etc. on individual species.
- Modelling of net primary production (all scales) with improved nutrient dynamics and temperature sensitivity.
- Regional and smaller scale models of coupled physical and biological systems which capture important local processes (e.g. declining salinity of the Baltic Sea).
- Analysis and models which aggregate and simplify fish community structure and production.
- Better understanding and representation of trophic dynamics.
- Management based on more active control of production systems.

These topics will be briefly introduced and some relevant research questions proposed.

A key limitation in our ability to predict future fisheries production arises because the response of marine ecosystems to changes in physical or biological forcing can be nonlinear, e.g. when a threshold value is exceeded and a major change in species composition, production, and dynamics takes place. Seasonal and extreme patterns of forcing variables must also be taken into account, since changes in mean values may fail to capture important processes. Aquatic food production is increasingly based on controlled systems (aquaculture, ranching etc.) and can be regarded as undergoing a transformation similar to that which has occurred in terrestrial food production and land use throughout human history. It may be time to acknowledge this trend and to review the basis of fisheries and marine ecosystem management from this perspective.

19 May, 11:45 (S4.2-4596) Invited

What will happen on the stock of chum salmon, walleye pollack, and common squid in the Northern Pacific?

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What will happen to the stocks of commercial fishes in the Northern Pacific under global warming? We forecast the future status of fish stocks based on the outputs from a global atmosphere–ocean-terrestrial coupled model with an A3 scenario. Hokkaido stock of chum salmon will disappear by 2100, although chum salmon in Bering Sea will remain. Honshu stock of walleye pollack will collapse in 2050 and Hokkaido stock will decrease dramatically by 2100. The spawning season of Japanese common squid will move 1-2 months ahead of the present season. Using NEMURO and NEMURO.FISH, developed by PICES MODEL Task Team, Hashioka *et al.* (2007) predicted the change of lower trophic biomasses in global warming case. A bio-energetic model of common squid in the Japan Sea shows a difference of growth as well as the possible change of its migration route under climate change. We will discuss the future possibility of NEMURO applications on the forecast of ecological states.

19 May, 12:10 (S4.2-4719)

Marine fish and fisheries in a changing climate

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Based on first principles, we develop a framework for the integrated study of the response of fish populations to climate change. We summarise available literature on processes operating at the physiological, population and ecosystem level to interpret observed changes distribution and abundance in relation to changes in climate and predict possible changes in response to IPCC climate scenarios. Our study covered the eastern North Atlantic region between Iberian and Arctic waters. Major conclusions from this exercise are: (i) early life-history stages will be more sensitive to climate change due to their narrower temperature tolerance and lower body reserves, (ii) fish species of higher latitudes will be more sensitive due to their narrower tolerance range and the predicted larger increase in temperature, (iii) climate driven changes in spawning and nursery habitats are likely to be more important than changes in the adult habitat, (iv) the effect of climate on fish populations is local and will hence deviate from general predictions due to local differences in the availability of suitable habitat for successive life history stages and connectivity among these, (v) in temperate ecosystems fish stocks are likely affected by changes in their food base primary and secondary production in combination with bio-energetic and population dynamic processes, while in high latitude ecosystem processes, climate induced changes in predation will prevail, (vi) climate impact will interact with the effects of fishing and may change ecosystem control from top-down to bottom-up and *vice versa*.

19 May, 12:25 (S4.2-4763)

Impacts of climate shifts in the late 20th century on zooplankton and fishery resources in the Japan Sea

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The Japan Sea environments are determined by the monsoon regime, and in particular they depend on the strength of the Siberian High in winter and the Hawaiian High in summer. The winds from any direction cool the sea surface, although the summer monsoon supports a positive heat flux into the sea due to the strengthening of the warm northward currents. Indeed, weakening of the Siberian High caused winter warming in the Japan Sea surface waters since the late 1980s, and weakening of the Hawaiian High was the reason for the summer warming since the late 1990s. The winter sea surface temperature is an important factor in the intermediate water formation, so the temperature in the intermediate layer became higher in the late 1980s, but the sea surface temperature shift in the late 1990s had no significant effect on this layer. Large-sized cold-water copepods, became more abundant in the 1990s, because the warming favoured their maturation. Fluctuations of mass subtropic fishes and squids were coherent with the zooplankton abundance changes: jack mackerel, Pacific saury, and Japanese common squid bloomed in the highly-productive conditions of the 1990s. This appeared as increased catches of these species, with time-lags corresponding to their age at recruitment. The stocks of mass boreal fishes depend directly on thermal conditions or on both the environment and zooplankton abundance. Japanese sardine was a special case: its fluctuations depend directly on changes of neither abiotic nor biotic parameters, but they have an influence on zooplankton abundance. Cushing's match/mismatch hypothesis is discussed for this species.

19 May, 12:40 (S4.2-4960)

Effect of climate change on estuarine fish production in Queensland, Australia

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The speculation that climate change may impact on sustainable fish production suggests a need to understand how these effects influence fish catch on a broad scale. Many commercially important fish species use estuarine habitats such as mangroves, tidal flats and seagrass beds as nurseries or breeding grounds and have lifecycles correlated to rainfall and temperature patterns. Correlation of catches of mullet (e.g. *Mugil cephalus*) and barramundi (*Lates calcarifer*) with rainfall suggests that fisheries may be sensitive to effects of climate change. A conceptual model demonstrates ecological and biophysical links of estuarine habitats that influence capture fisheries production. The difficulty involved in explaining the effect of climate change on fisheries arising from the lack of ecological knowledge may be overcome by relating climate parameters with long-term fish catch data. Catch per unit effort, rainfall, the Southern Oscillation Index, temperature and catch time series for specific combinations of climate seasons and regions have been explored. The major fluctuations in Queensland's capture fisheries were contemporaneous with *El Niño* and *La Niña* events and reduced rainfall. Furthermore, results indicate that up to 30% of Queensland's total fish catch and up to 80% of the barramundi catch variation for specific regions can be explained by rainfall often with a lagged response to rainfall events. Monthly air temperature and monthly mullet, flathead (*Platycephalus fuscus*) and whiting (*Sillago* spp.) catch showed negative relationships in south-east Queensland and in the central east coast whereas barramundi catch was positive related to average air temperature in the central east coast. Our approach allows an evaluation of the economic consequences of climate parameters on estuarine fisheries, thus highlighting the need to develop forecast models and manage estuaries for future climate change impact by adjusting the quota for climate change sensitive species.

19 May, 12:55 (S4.2-4897)

Larval fish physiology and individual-based models: exploring climate impacts on early life stages of key species

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Individual-based models (IBMs) are popular tools used to investigate how abiotic and biotic factors influence the vital rates of early life stages of marine fishes. A variety of approaches have been used to represent the feeding and growth of marine fish larvae within IBM's, from simple/holistic descriptions with no prey fields to complex/mechanistic depictions using modelled prey fields. Here, we discuss aspects of larval physiology underpinning such models by reviewing the state of knowledge regarding how key environmental factors (e.g. temperature, prey availability) impact larval fish growth physiology. The review includes an analysis of laboratory data collected on a variety of species and aims to reveal both specific (within-species) and general (between-species) patterns. Since the choice of how to represent prey fields can be critical to IBM-based projections of larval fish growth and survival, we also comment on the utility and pitfalls associated with using model-derived prey fields. Next, we provide an example of results obtained from a coupled bio-physical IBM developed for sprat (*Sprattus sprattus*) and Atlantic cod (*Gadus morhua*). The coupled model system projected marked differences in the survival and growth of these species in the North Sea driven by species-specific differences in the spatial- and temporal extent of match/mismatch situations between first feeding larvae and their prey. Employing coupled models that utilise more generic fish early life stage IBMs seems warranted and would allow us to explore climate-driven processes (e.g. match/mis-match) in a wider variety of marine fish species.

19 May, 14:30 (S4.2-4806)

Temperature, light and food mediated growth for larval cod (*Gadus morhua*) at latitudinal extremes: a comparative study between the NW Atlantic and Norwegian Sea ecosystems

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Atlantic cod (*Gadus morhua*) is a widespread species distributed across the North Atlantic shelves of latitudinal range from Georges Bank (42°N) to Spitsbergen (80°N). Environmental constraints, such as temperature, light and prey availability, vary greatly both between and across the cod nursery grounds. These variations have strong impact on growth, feeding conditions, and survival for larval cod between years and habitats. We applied an individual based model for larval cod for environmental conditions at the latitudinal extremes of the Georges Bank (42°N) and Lofoten (68°N). The model contains modules for mechanistic feeding, ingestion, assimilation, gut content, metabolism, and growth. It is forced with light, observed temperature profiles distributed across the respective habitats, and a range of prey concentrations for several years. The calculated growth rates quantify the requirements for food in order to grow at rates close to their size- and temperature-dependent capacity for the two habitats, both within and between years. These theoretical explorations combined with the observations on growth and abundance of year classes, open up our understanding of how larval fish may be affected by future climate changes. The observatons of the ecological effects of the natural multidecadal climate oscillations of the 20th century give some indications. However, the projected amplitude of the temperature change by the mid 21st century exceeds by far the natural variability of the past century. Therefore, comparative studies covering the latitudinal extremes are one important way to improve our understanding of climate change beyond natural variation.

19 May, 14:45 (S4.2-4646)

Variability in environmental factors affecting the recruitment of fish species in the North East Atlantic

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Inter-annual variations in recruitment may be due to processes operating during specific life history stages: eggs and larvae, juveniles and adults. In order to better understand the recruitment mechanisms it is important to focus on the conditions that fish actually experience in the spawning area, nursery area and adult feeding grounds. Using spatially explicit data we analysed how potentially relevant environmental variables affected recruitment variation using additive modelling. The environmental data were a combination of measured, satellite and modelled sources. The analyses show that the recruitment of cod (*Gadus morhua*) in ICES area VIa is affected by the temperature in the spawning areas during the spawning period and the availability of important prey organisms. The recruitment of North Sea plaice (*Pleuronectes platessa* L.) is correlated with the NAO-winter index the year prior to spawning, and affected by the bottom temperature during the feeding period and the bottom temperature in the spawning period. The recruitment of North Sea autumn spawning herring (*Clupea harengus*) is affected by the spawning stock biomass and the salinity in the spawning area around the Orkney Islands. To assess if the above models could be used for predictions or management purposes they are compared to basic stock-recruitment relationships, such as Beverton-Holt (with or without including environmental factors), to determine if the inclusion of extrinsic environmental factors improves predictions of recruitment.

19 May, 15:00 (S4.2-4920)

Impact of climate variability on small pelagic fishes in the Atlantic and Pacific: a comparison

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Populations of small pelagic fishes such as sardine, anchovy, sardinella, herring and sprat respond dramatically and quickly to changes in ocean climate because of their characteristic life history traits: short life spans, high fecundity and short, plankton-based food chains. Consequently, they are excellent indicators of the impact of climate variability and regime shifts in ecosystems as they exhibit drastic variations in population size during short periods. Numerous examples for the response (changes in abundance, distribution and phenology) to climate variability have been demonstrated for the rather small clupeoid populations in the NE Atlantic whereby the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) seem to be the external drivers. Interestingly, whereas open water populations of sardines and anchovies seem to react preferentially to the AMO, sprat and sardinellas in semi-enclosed basins respond primarily to the NAO. Although the large clupeoid populations in the eastern and western boundary currents of the Pacific have exhibited drastic fluctuations in abundance, their response to climate variability is not as clear-cut as in the Atlantic. The impact of the Pacific Decadal Oscillation (PDO) does not seem to be as overriding as the AMO and NAO in the Atlantic. Effects of different climate phenomena on small pelagic populations and the mechanisms by which they are brought about will be compared. Potentially climatically-induced teleconnection patterns will be investigated, including the Arctic Oscillation which affects both oceans.

19 May, 15:15 (S4.2-4626)

Mechanisms of population dynamics of Japanese sardine and Japanese common squid in the Kuroshio/Oyashio current system, with a speculation on their future

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In the Kuroshio/Oyashio current system, Japanese sardine *Sardinopus melanostictus* was the most dominant commercial pelagic fish during the 1980s. The Japanese common squid *Todarodes pacificus* is also a commercially important species whose catch increased during the 1990s, in contrast to the Japanese sardine. Based on the existing information, we constructed conceptual mechanistic models of the population dynamics of these two species including linkages to ocean/climate changes. Stronger Aleutian Low activities favour Japanese sardine through intensified Oyashio (spin-up), lower sea surface temperature (SST) in the Kuroshio Extension Current, and depression of the common squid population, one of the major predators. In turn, weaker Aleutian Low and *El Niño* (negative SOI) favour common squid through warming of SST in their spawning ground (the East China Sea) and shorter Kuroshio path (spin-down). Productivity of the Oyashio will be enhanced by a moderate SST rise, through more available light (stratification in surface layer), but will deteriorate with an extreme SST rise due to more stratification that reduces vertical supply of nutrients to sea surface during winter. Under global warming, the Aleutian Low will be intensified and thereby spin-up the Oyashio and Kuroshio. These conceptual models suggest effects of global warming on sardine and common squid are complex, because intensification of the Aleutian Low and SST rise have opposite effects on the population dynamics of these two species, and a SST rise in the Japan Sea will delay the spawning period of common squid, thus it may subsequently cause a mismatch with blooming of phytoplankton and subsequent availability of zooplankton.

19 May, 15:30 (S4.2-4612)

Shifting warm-water to cold-water conditions and food web dynamics of juvenile Pacific salmon in the eastern Bering Sea ecosystem

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The Eastern Bering Sea (EBS) ecosystem is an important feeding ground for juvenile Pacific salmon. Shifts in the relative strength of Pacific Decadal Oscillation and Arctic Oscillation, and associated shifts in thermal regimes in the EBS have been suggested to have major implications for energy flow along food web and trophic interactions among forage fish and juvenile salmon. The EBS shifted from a warm-water condition during 2002-2005 to a relatively cold-water condition during 2006-2007. This shift seems to be linked to dramatic shifts in the abundance of the major forage fish species, the most common diet of juvenile Pacific salmon species. We evaluate if the reversal of ocean thermal regimes cause significant shifts in food web dynamics and trophic interactions among the juveniles of salmon species, ontogenetic niche shifts as a function of size within species, and diet overlaps among species. To test our objectives, we used N and C stable isotope signatures of over 10,000 samples of juvenile salmon, forage fish and zooplankton collected during six years along north-south and east-west transects of the EBS. We present results showing how the change from warm to cold years are associated with significant contrasts in diet overlaps and trophic interactions among salmon species, and onshore-offshore variability in trophic shifts within Pacific salmon species as a function of body size, and discuss the implications of the observed variability for growth, survival and productivity of Pacific salmon.

19 May, 15:45 (S4.2-4551)

Potential effect of rising temperature on growth performance and its influence on chum salmon

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The body sizes of animals often decrease with increasing temperature (Bergmann's rule). Therefore, global warming may reduce asymptotic size (L_∞). Empirical evidence suggests that ectotherms reared at higher temperatures grow to a smaller final size, the optimal temperature for the growth of ectotherms decreases with increasing body size, and larger fish prefer colder waters than smaller fish. Therefore, it has been hypothesized that the negative effects of rising temperature would be more severe for *large* fish. During 1973-2007, the sea surface temperature (SST) in the Bering Sea increased significantly. During the same period, the condition factor of large chum salmon decreased significantly, whereas that of small chum salmon did not. The condition factor of large chum salmon was negatively correlated with SST, indicating that global warming is already affecting the growth of large fish. To predict how chum salmon populations will respond to reducing the growth of large fish, we simulated the change in age and size at maturity, and spawning stock biomass (SSB) in response to decreasing L_∞ using a size-structured model with age- and size-specific maturation rates. This showed that a 5% decrease in L_∞ led to a 4% decrease in size at maturity, a 6% increase in age at maturity, and a 15% decrease in SSB.

19 May, 16:30 (S4.2-4625)

Latitudinal gradients in growth and spawning of sea bass: effect of temperature and photoperiod

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0-group Sea bass, *Dicentrarchus labrax* (L.) were captured in four estuarine nursery areas along the Portuguese coast, during the spring and summer of 2005. This coast has a north-south orientation which means that these estuaries are located at approximately the same longitude but present a latitudinal orientation: the Ria de Aveiro at 40º34'N, the Mondego estuary at 40º06'N, the Tagus estuary at 38º45'N and the Mira estuary at 37º37'N. Growth and hatch dates were estimated through otolith daily increment analysis. A clear latitudinal gradient was detected in the growth rates, from north to south, sea bass from the Ria de Aveiro presented growth rates of 0.48 $mm.d^{-1}$, while at the Mondego estuary it was 0.51 $mm.d^{-1}$, in the Tagus estuary, 0.56 $mm.d^{-1}$ and at the Mira estuary, 0.61 $mm.d^{-1}$. The estimated spawning periods also presented a north-south gradient with spawning starting earlier (December) in the Mira estuary and later (February) in the Ria de Aveiro. Analysis of SST data from the adjacent coastal waters shows that spawning is not solely triggered by an increase in temperature, like argued in other coastal areas. The important role of photoperiod is discussed. The impact of a future climate change scenario in the observed patterns is also discussed.

19 May, 16:45 (S4.2-4815)

Fish population response to future climate drivers: a next step forward

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The development of the analytical tools to implement forecasts of commercially exploited fish populations represents a critical first step towards integrated ecosystem assessment. We present an analytical approach to projecting climate change effects on groundfish and salmon in Alaskan waters. We use climate model simulations

carried out for the Intergovernmental Panel on Climate Change Fourth Assessment Report and our knowledge of processes underlying recruitment of managed fisheries to project the impacts of climate change on selected fish species. Climatologists screen models based on their ability to replicate the observed climate variability of the North Pacific in the hindcasts for the 20th century. The subset of better models provides a basis for projections through the first half of the 21st century. The ranges of realisations from an ensemble of forecasts provide measures of natural variability and uncertainties in the variables of interest. We will utilise these scenarios to predict the impact of climate change on ocean variables that influence recruitment success of our fish species. Time series of key oceanographic factors will be produced through analysis of the direct model output, and where necessary, through empirical downscaling. We demonstrate how time series of fish production can be estimated by incorporating the projected time trend in ocean variables to a stock recruit relationship to track population fluctuations under different harvest control rules and climate change scenarios. We report on an international effort to apply this approach to species throughout the Pacific Rim through the coordination of PICES and ICES.

19 May, 17:00 (S4.2-4743)

What drives tuna captures between 1525 and 1756 in southern Europe?

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The almadraba catch series on tuna species from 1525 to 1756 showed strong oscillations with a clear decreasing trend. The objective of this work is to test the potential influence of climatic factors in the bluefin tuna catches obtained between years 1525-1756 from Medina *Sidonia almadraba*. The spectrum analysis on the capture series showed the presence of short and medium term periodic cycles. The short-term periodicity (6-9 years) is probably associated with tuna density-dependent dynamics, and it is coincident with the highest cross-correlation coefficient between sea surface temperature and the captures (6 year lag). We used a generalised linear model to relate the tuna captures to climatic parameters. We carried out variance-partitioning analysis of tuna captures to assess the relative contribution of climate from temporal autocorrelation. The results indicated that climate accounts for 11.6% of the total variance, the temporal autocorrelation accounts for 12.9% of the total variance, and 35.1% of captures is accounted for by the joint effect of the two latter components. The temporal component indicates the role of population dynamics in tuna capture series. The significant variance accounted for by climate (specifically, greenhouse gases) suggests that the low temperatures during the Maunder minimum (the so called "The Little Ice Age", years 1640-1715) may have reduced both recruitment and tuna abundance in the North Atlantic and Mediterranean Sea. Our findings suggest that both environmental and population dynamic components played an important role in the Medina *Sidonia almadraba*.

19 May, 17:15 (S4.2-4739)

Effects of ocean climate variation on production, maturation, and recruitment of snow crab (*Chionoecetes opilio*) on the Newfoundland-Labrador shelf

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The snow crab (*Chionoecetes opilio*) is a highly stenothermal species. Males undergo their final molt across a broad size range such that some males fail to achieve the minimum legal size and recruit to the male-only fishery. This terminal molt is associated with sexual maturation in females, whereas in males (already sexually mature adolescents) it corresponds to achievement of adulthood, as reflected by the development of enlarged chelae. We found that size at maturity or adulthood was directly related to bottom water temperatures between 0 and 4°C. This suggests that in both sexes the terminal molt is delayed at high temperatures. Our study also showed that effects of ocean climate variation differ throughout the life cycle. Cold conditions in early life favour survival while in later life they promote early terminal molt, thereby reducing the proportion that will recruit to the fishery. Snow crab commercial catch rates are positively related to area of ice coverage and inversely related to bottom temperature, at lags of 6-10 years, suggesting that the positive effects on recruitment of cold conditions early in

the life history are stronger than the negative effects in later life. We find that the evidence for predator control of snow crab abundance is not convincing and we conclude that recruitment trends are more strongly associated with variability in the ocean climate and (by inference) production. This implies important consequences of future climate change to snow crab production and fisheries.

19 May, 17:30 (S4.2-4605)

The future of Baltic cod - modelling interactions between climate, food web dynamics and fisheries

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Atlantic cod (*Gadus morhua*) is among the commercially most important fish species in the North Atlantic and has been subjected to excessive fishing pressure for many years. Additionally climate variability influence cod stocks, principally through effects on recruitment and growth. However, food web processes may additionally influence fish stock dynamics by producing feedback loops that determine the ultimate response of populations to climate change. Integrating these forces in models are therefore of great concern in developing a sustainable EBFM approach for Atlantic cod. By statistically fitting a generalised Lotka-Volterra 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 dynamics in the face of climate change. Based on the findings of the Assessment of climate change for the Baltic Sea Basin (BACC), we simulated plausible climate scenarios for the 21st century by generating a number of "red-shifted" climate time series. Using these scenarios as inputs, we forced our food web model bottom-up, exploring the impact of climate change on the future dynamics of Baltic cod. Further, by including management scenarios for all three species of the Baltic food web, we elaborated on the role of commercial fishing in developing a sustainable exploitation strategy. 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.

19 May, 17:45 (S4.2-4628)

Climate-mediated changes in prey quality affect the production of wild Pacific salmon

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The marine survival of salmon has been observed to covary with climate and ocean conditions at small and large spatial scales. Several competing hypotheses have been proposed to explain these patterns. Although the specific mechanisms affecting the marine survival of salmon differ among these hypotheses, all generally agree that lower marine survival of Pacific salmon is associated with lower marine growth during their first year at sea. In this study, we examined the effects of ocean conditions on the growth and survival of Pacific salmon and developed forecasting models for the marine survival of Pacific salmon. Our work shows that, while plankton productivity and temperatures tend to be higher in the northern California Current Ecosystem, salmon are generally larger and fatter, and have higher growth in the Alaska Coastal Current Ecosystem. The poorer growth and condition of salmon in the northern California Currents Ecosystem appears to be related to a calorie-deficient diet rather than to lower rates of food consumption or to higher metabolic rates. This indicates that ocean conditions affect salmon production through changes in prey community composition and quality, which in turn are induced by the effects of climate on ocean circulation, and on the local success of different zooplankton life history strategies (year round activity *vs* seasonal dormancy and lipid accumulation).

19 May, 18:00 (S4.2-4728)

The effect of environmental changes in the NE Atlantic sardine (*Sardina pilchardus*) fishery

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The Iberian sardine (*Sardina pilchardus*, Walb.) is distributed along the whole shelf of the Iberian Peninsula. Highest catches of the stock are taken from the southern part of the Galician waters (NW corner of the Iberian Peninsula) and northern Portugal. Landings comprised mainly young fish (0 and 1 yr old), which reflects the proximity of the main recruitment area of the stock to the fishing grounds. The fishery is dependant on the strength of the recruitment in this area and recruitment processes seem to be driven by oceanographic (local) and climatic (global) events. This study explored where the variability observed in the environmental variables at large (NAO-winter, Gulf Stream and AMO) and local scale (upwelling and poleward current) could explain the variability observed in the recruitment (and thus landings) in the area from 1940 to 2005. The fitted model matched quite well the predicted recruitment during the 1980s but when the whole time series was considered the performance of the model was poor. There appears to be a shift in the general trend of the environmental variables in 1995 which coincided with a consecutive series of poor recruitments at the end of the nineties.

S4.2 Posters

Poster S4.2-4525

Cyclic climate changes and fish productivity in the past and at present

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Long-term time series of various climatic indices and variation of commercial fish populations in the most productive areas of the Pacific and Atlantic are analysed. Comparison of climate index fluctuations and populations of a number commercial species for the last 1500 years indicates a coherent character of climate fluctuations and fish production dynamics. A simple stochastic model is suggested that makes it possible to predict trends of basic climatic indices and populations of some commercial fish species for several decades ahead. The approach based on the cyclic character of both climate and marine biota changes makes it possible to improve harvesting of commercial fish stocks depending on the phase (ascending or descending) of the long-term cycle of the fish population. In addition, this approach is helpful for making decisions on long-term investments in fishing fleet, enterprises, installations, etc. The results also elucidate the old discussion: which factor is more influential on the long-term fluctuations of major commercial stocks, climate or commercial fisheries.

Poster S4.2-4595

Long-term changes in the abundance and population structure of yellowtail *Seriola quinqueradiata* in the Japanese waters and its relation to sea surface temperature over the last century

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The yellowtail *Seriola quinqueradiata* is one of the most important, large-predatory fishes in Japanese waters. It is traditionally caught by set-net traditionally and the catch is largely affected by oceanographic conditions. Using the historical catch data of yellowtail and a sea surface temperature (SST) data set for the waters around Japan over the last century, the long-term variability in the abundance of yellowtail and its relation with SST was examined. The total catch of yellowtail increased from 14,446 tons in 1894 to 77,462 tons in 2000 with an evident increasing trend over the last century. However, the trend is not linear but decadal with significant shifts occurring around in 1912, 1932, 1957, 1974 and 1990, strongly suggesting an effect of water temperature. Analysis between the catch by fisheries regions and SSTs showed that the catch trend was approximately in accordance with SSTs. In particular, the catch from the Japan Sea, where the yellowtail is mainly caught by set-net, was significantly and positively correlated with winter SST in the northern Japan Sea, indicated the increasing water temperature in the Tsushima Current region has a positive effect on the migration and recruitment of yellowtail to the Japan Sea. On the other hand, the catch from the set-net during the 1990s was lower than that in the 1950s, the lower catch since 1990 was a result of increasing fishing effort of purse seine on yellowtail. The total catch of large size adult yellowtail was still at a lower level compared with before 1950, suggesting that fishing may have an impact on the changing population structure.

Poster S4.2-4613

The influence of water temperature on abundance of walleye pollock and northeast arctic cod

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The solar activity, atmospheric circulation, seawater temperature, and chlorophyll *a* may be used as integrated factors affecting the existence conditions of biota in the ocean. The interannual variability of seawater temperature impacts essentially on success of fish reproduction, duration of early stages, food availability, and rate of metabolic processes. The analysis of relationship between the solar activity and concentrations of chlorophyll *a* in the southeastern Bering Sea in 1963-1994 showed a positive correlation (r=0.6). The relationship between concentrations of chlorophyll *a* and sea surface temperature was direct also but the correlation coefficient was lower (r=0.4). The correlation between the solar activity and sea surface temperature in the eastern Bering Sea during the 1970-1998 period was relatively weak (r=0.38). To answer a question regarding the existence of statistically significant relationship between the year-class abundance of walleye pollock (*Seriola quinqueradiata*) and that of Atlantic cod (*Gadus morhua*) a linear regression analysis was carried out. The results showed the absence of significant correlation between the year-class abundance of walleye pollock and near-surface water temperature (r=0.06) and near-bottom water temperature (r= -0.23). The highest correlation coefficients were obtained from the analysis of year-class abundance of pollock in the eastern Bering Sea at age of 1 and 5 years and the average seawater temperature in the 0-100 m layer a year ahead of spawning (r=0.77 and r=0.72, respectively). When comparing chlorophyll *a* concentrations and walleye pollock abundance at age of 1 year for the 1970-1994 period, the correlation coefficient was low (r=0.11). The relationship between the abundance of northeast Arctic cod (age 3+) and mean water temperature in the Barents Sea during 1977-2002 in the 2-100 m layer was statistically significant (r=0.68).

Poster S4.2-4621

Pan-regional synthesis in the US GLOBEC programme

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The US GLOBEC programme is entering into its final phase of research with a pan-regional synthesis programme. Previous phases have included field and modelling programmes in the northwest Atlantic (Georges Bank), the northeast Pacific (northern California Current and coastal Gulf of Alaska), and the Southern Ocean (western Antarctic peninsula). The pan-regional phase seeks to make larger connections between these and other marine ecosystems. The overall synthesis and integration effort includes comparing the dynamics of closely related taxa in relation to common physical processes (e.g. stratification, upwelling and downwelling, or sea ice extent). Some examples are studies of calanoid copepods and gadoids on bank and shelf systems; copepods, euphausiids, and salmonids in the North Pacific; and euphausiids, calanoid copepods, and upper trophic level predators (e.g. seabirds, penguins, seals and cetaceans) in continental shelf waters of the Southern Ocean. Modelling of all kinds – conceptual, mathematical, numerical, and statistical – will be a major focus of the GLOBEC Pan-Regional Synthesis, having already played a central role in the regional studies. Pan-regional synthesis will examine processes controlling the population dynamics and recruitment of the target organisms as a function of system type, to ascertain how these processes would be affected by a changing climate. It will further understanding of ecosystem response to climate change, particularly in connection with other, anthropogenic forcing. Ultimately, pan-regional synthesis will provide guidance on how to assess ecosystem-level questions within the GLOBEC context, and identify implications for the management of marine resources in a changing climate.

Poster S4.2-4655

Relationship between ocean warming and catches of Atlantic salmon (*Salmo salar*) at the southern boundary of the European geographical distribution

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The northern part of the Iberian Peninsula is a transitional area between boreal and subtropical fauna and flora. This boundary may displace northward due to global warming and, under this scenario, abundance of boreal species in this area will decrease. One of these species is *Salmo salar*, an anadromous fish, whose populations in the northern Iberian rivers are the southernmost Atlantic salmon populations in their European geographical distribution. These populations are expected to be particularly vulnerable to global warming. Time series analysis of captures of *Salmo salar* from 1950 to 2006 in rivers localised in the north Iberian Peninsula show that the spatial distribution of salmon populations have progressively become more restricted to rivers localised in the central Cantabrian thus narrowing their spatial distribution range. Besides, the number of adults captured has declined significantly in the last 25 years. In this communication we discuss the plausible relationship between the compression of the distribution area and the decreasing trend of abundance of *S. salar* in the north Iberian Peninsula with trends of various environmental variables related to the effect of global warming in the North Atlantic.

Poster S4.2-4665

Impact of climate change on the marine pelagic ecosystems off Galicia (NW Spain). II: Living resources

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Trends in biological production, including fisheries and aquaculture, were analysed as part of a multidisciplinary study directed to ascertain the significance of changes in relevant oceanographic and pelagic ecosystem variables in relation to climate change off Galicia (NW Spain). Marine productivity was largely determined by the seasonal upwelling as this region is at the northern limit of the northeast Atlantic upwelling system. In this way, the decrease in upwelling intensity and warming of surface waters during the last decades may have potential impacts on productivity and selected resources. For instance, warm-water fish species became more frequent in recent years and a decreasing trend in the yields of some fisheries (e.g. sardine and octopus) was found. Long-term changes in the size and distribution of clams and in the quality of cultured mussels were also related to changes in local and regional oceanography. The patterns of change in the exploited populations, however, must be interpreted in the framework of their low frequency variability (including multidecadal oscillations), which in most cases is still poorly described.

Poster S4.2-4674

Impacts of climate variability on spatial distribution of 0-group fish in the Barents Sea

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Capelin (*Mallotus villosus* Müller, 1776), juvenile herring (*Clupea harengus* L.), cod (*Gadus morhua* L.), and haddock (*Melanogrammus aeglefinus* L.) are commercially and ecologically important fish species in the Barents Sea, representing different biogeographic groups. All these stocks have nursing areas in the Barents Sea. However, the response of the spatial distribution of the fish larvae from climate variability is not well known. For more than 20 years spatial data on fish larvae have been collected in August-September in the Barents Sea, together with hydrographic data. These spatial data span a period with a strong increasing temperature trend, from the cold 1960s-1970s to the very warm 1990s-2000s. The presented data are from the period 1980-1996. Climatic variation is represented by time series of spatial temperature fields based on observations, observed mean temperatures in

Atlantic water masses, and modelled inflow of Atlantic water masses into the area. Fish larva are presented as 0-group fish (age 0, about half year old). Geographic distributions of the 0-group are based on field observations from designated 0-group surveys. Results from the spatial analysis of variation in fish larvae distribution as affected by climatic variation are presented. Further, a study of temperature limits for the distribution areas is shown. Finally, the results are discussed with respect to expected future climate changes in the Barents Sea.

Poster S4.2-4696

Impact of climate change and variability on coastal water and fisheries resources of Bangladesh

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By 2050, flooding and droughts will increase in Bangladesh and the probability of an extreme wet year will increase seven fold and dry years will increase by 4.4 times. A 1 m rise in sea level over the next 100 years will lead to the permanent inundation of nearly 20% of the country affecting approximately 25% of the population. Many of the freshwater fish species in Bangladesh are already under great threat. Climate change will aggravate the situation further. Production of inland capture is likely to decline due to 10% loss of area. Production from floodplains, the largest contributor to inland capture fishery is likely to decline. Contributions from estuarine zones are likely to increase due to the expansion of their area and as they are biologically the most productive. Increased ocean temperature may alter coastal ocean currents. These in turn influence the residence time of water in nearshore environments, which may have negative consequences on the growth and survival of many aquatic animals. The carrying capacity of the Bay of Bengal is likely to be changed due to an increase in total chlorophyll leading to a considerable change in the distribution, migration and fishing grounds of the various pelagic fishes. Offshore fisheries may be the least affected by future climate change and sea level rise. However, there will be a profound change in the near-shore marine fisheries. The greatest impact may be on fish species which are dependent on the estuaries and creeks of the coastal zone for breeding or spawning.

Poster S4.2-4741

Impact of climate variability on the California Current ecosystem and Pacific salmon survival: linkages, ocean condition indicators, forecasting, and management perspectives

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Recently, the northeast Pacific has experienced high-frequency variability in the PDO pattern: cool phase from 1999-2002; warm phase from late 2002-2006; cool from 2006 to present. We have used this 'natural' experiment to determine how quickly marine organisms respond to strong climate variability focusing our studies on an iconic species in the North Pacific, the Pacific salmon. We use our 12 year time series of hydrography and zooplankton collected off Newport OR and our 10 year time series of hydrography, zooplankton and pelagic fish collected off Washington and Oregon to investigate the response of the pelagic marine ecosystem to recent changes in the state of the North Pacific. Ecosystem indicators have been developed from these time series as metrics to describe interannual variability in ocean conditions, and to forecast recruitment variability of salmon in Pacific northwest waters. We communicate our results through a web site; the site includes information on the status of the northern California Current ecosystem on a seasonal basis, and provides a one-year lead forecast of returns of coho salmon and a two-year lead forecast of Chinook returns, based on the "stoplight" approach. Our ability to manage fishery resources in the future will depend in part on our ability to forecast the impact of changing ocean conditions as a result of global climate change. We suggest that use of comprehensive ecosystem observations, from physics to fish, will become a requirement if we are to understand how variations in physical climate will affect fisheries and marine ecosystem productivity.

Poster S4.2-4748

Sedimentary fish abundance records over the last 1500 yrs from the western North Pacific: basin-scale link of sardine and anchovy abundance

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In the latter half of the twentieth century, catch records of sardine and anchovy revealed multidecadal-scale variations, showing synchronous and asynchronous patterns between remote regions off Japan, California, Peru, and Chile; a basin-wide link of variations in pelagic fish abundance was detected. Sedimentary reconstruction of fish abundance over the past millennia revealed centennial-scale or millennial-scale variability of anchovy and sardine abundance in the California Current system, and variability of sockeye salmon in the Gulf of Alaska. However, no sedimentary record exists for the western Pacific. Therefore, the existence of a centennial-scale and millennial-scale link between abundances of remote pelagic fish populations in the Pacific remains unclear. We first discovered sedimentary anchovy and sardine scales in a seasonally anoxic basin, Beppu Bay, of the western Seto Inland Sea of Japan. The sedimentary scale records are anticipated to be a potential source to elucidate not only long-term variations in anchovy and sardine populations in the western Pacific but also a basin-wide link of variations in pelagic fish abundance on centennial to millennial timescales. In the presentation, we will deliver the 1500-yr fish abundance records from Beppu Bay and discuss the basin-scale link of fish abundances among sardine and anchovy in the western and eastern North Pacific and Pacific salmon.

Poster S4.2-4765

Is a changing North Sea environment making sustainable exploitation of herring more difficult?

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Environmental change can affect the productivity of fish stocks. In the North Sea herring (*Clupea harengus* L.) stock, environmentally induced change is impacting sustainable exploitation. Despite simultaneously having a large stock size, relatively low exploitation and Marine Stewardship Council accreditation (implying sustainability), an unprecedented five sequential years of poor production (recruitment) have occurred. Analysis shows that over-fishing does not appear to be playing a role in this sequence of recruitment failures, as it has in the past (e.g. during the mid-1970s); instead, survey data show that recent year-class-strength is determined during the larval over-wintering period. Changes in the North Sea environment appear to be the most-probable ultimate-cause of these failures. Recent warming of the North Sea has caused numerous shifts in this ecosystem, and changes in the herring stock may have been initiated by the lately reported 2000 "regime-shift" in the plankton community. It is therefore possible that we are observing the first consequences of this change for the higher trophic levels. It is not possible to say when or whether the sequence of poor recruitment will abate: there is no indication of a recovery in recruitment in the short term. Unless fishing mortality is rapidly reduced to sustainable levels, another collapse of this stock is possible. Stock managers must recognise that in dynamic ecosystems and environments, the past does not necessarily provide a reliable indication of future productivity.

Poster S4.2-4773

Evidence of the north-east Atlantic warming and it consequences on marine fishes

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There is a scientific and social preoccupation due to the so called "climate change", even when the Earth's climate has always been changing between cold and warm periods, but this last is occurring faster than the previous historical ones. Environmental variations affect terrestrial and marine ecosystems, and the changes observed in the fish fauna distribution along the north-eastern Atlantic Ocean could be other evidence of this climatic process. To quantify the variations observed in fish fauna composition during the last sixty years, and analyse the tropicalisation process, we have considered the geographic area between 28ºN and 60ºN, that involve the FAO fishing area 27 and the north part of 34, according to the number of sites, oceanographical characteristic of this region and thermal faunistic limits. According to the last, we identified two sub-areas, the southern one extended from the Canary Islands to the NW Spain and the northern one from the Gulf of Biscay to the North Sea. We have checked the literature in order to review the number of reference of "rare/uncommon" fishes species reported by areas each year, and the number of fisheries that collapsed or declined in the lasts decades, with the objective to relate this records with changes in the environment (warming or overfishing). Our preliminary results show a relation between temperature changes and the northward fish movements, which indicate the existence of a process of tropicalisation of the northeast Atlantic. However, more exhaustive analysis should be done.

Poster S4.2-4780

Comparing Pacific and Atlantic leatherback turtle movements and oceanography using state-space modelling

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Leatherback turtles are currently critically endangered and could be on the verge of extinction within the Pacific Ocean. They are the largest species of marine turtle and conduct long pan-oceanic migrations between their nesting and foraging grounds. Over the last decade, developments in satellite telemetry have revolutionised our understanding of their movements and distribution, but satellite location data suffer from having non-Gaussian estimation errors and being recorded irregularly in time. Estimation errors are also generally large for marine animals that spend little time at the surface. State space models (SSM) provide a valuable tool for modelling movement data by simultaneously accounting for measurement error and variability in the movement dynamics. A two-mode switching SSM also enables the behavioural mode to be estimated for each location, providing an objective method for defining phases of movement. This model was applied to the satellite tracks of leatherback turtles in the Pacific Ocean, where there have been rapid population declines, and in the Atlantic Ocean, where numbers have been increasing. Comparison of their migration movements and the oceanographic conditions in the two ocean basins provides a valuable insight into their responses to environmental variability and the potential impacts of climate change. The difference between the two oceans in the time spent in the two behavioural modes, migrating versus foraging, is also assessed. The more prolonged and widely dispersed foraging phase in the Pacific suggests that food patches are less predictable and may explain the longer period between nesting seasons for these females.

Poster S4.2-4826

Associating a fish kill event with seawater temperature in the Philippines

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Water quality assessment was conducted in the Caquiputan Strait, northwestern Philippines (16º18'N, 119º55'E) in June 2007 after a massive fish kill that affected milkfish, *Chanos chanos* mariculture farms in the area. Results of the study showed that water temperature, salinity and DO were at critical levels of 34.28ºC, 34.5‰ and ≤1 mg/l, exceeding values in adjoining bays of a non-fish kill area. The limited water movement in the area due to prolonged neap tides and higher water temperatures might have induced the collapse of DO level that triggered the fish kill event. No harmful algal bloom was observed in the area during the event.

Poster S4.2-4830

Impact of climate change in the 20th century on benthos communities in Peter the Great Bay (Japan Sea)

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Water temperature changes at the standard oceanographic section in the northwestern Japan Sea are traced for 1927-2007 and compared with the changes in benthos communities of Peter the Great Bay between three surveys: in 1925, 1972-1973, and 2003. Large-scale changes of water temperature in the subsurface layer corresponded generally to the winter SST changes and were caused by winter monsoon fluctuations. The subsurface temperature followed the fluctuations of the Siberian High activity in winter and had a negative trend in 1920-1930s, positive trend in 1940-1950s, slight negative trend in 1970-1980s, and was rising fast (0.3 deg./decade) in the 1990s and the next decade. Against a background of these large-scale tendencies measured by fractions of a degree C, stronger quasi-decadal fluctuations develop with the range of about 1ºC, and local effects of deep sea-shelf exchange and vertical mixing are important for the coastal zone. In spite of the high variability of environmental conditions on the shelf, the composition of the benthos communities in Peter the Great Bay was rather stable, with cold-water species dominating. However, the large-scale changes in the thermal regime had consequences in quantitative parameters of the communities. The community of sea cucumbers, being dominant permanently in the central part of the Bay (60-120 m depth), became both more diverse and more abundant in 2003 as compared with the "cold" 1970s, and the warming was particularly favourable for the dominant species *Pentamera calcigera*. The mean spatial density of the benthos biomass over the bay was also higher in 2003 (395 g/m^2) than in 1972-1973 (209 g/m^2). Obviously, recent "warming" at the bottom in the northwestern Japan Sea shelf causes an increase in benthos biodiversity (by appearance of low-abundance subtropical species) but is still favourable for the abundant boreal species.

Poster S4.2-4833

The effect of the environmental variability on the early life stage of flounder *Platichthys flesus* in the Baltic Sea

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Flounder (*Platichthys flesus*) is a temperate marine fish that is well adapted to the brackish waters of the semi-enclosed Baltic Sea. Conditions for life in the deeper waters of the Baltic Sea are strongly influenced by inflows of highly saline and oxygenated water from the North Sea. These events, termed major Baltic inflows, have an episodic character and are the only mechanisms by which the central Baltic deep water is renewed. In the absence of such inflows, stagnation occurs and the oxygen and salinity concentrations below the halocline progressively decreased. It is generally agreed that recruitment variation in flatfish stocks is dominated by density independent factors operating at a local scale on the eggs and larvae meaning that climate and hydrodynamic circulation are key

factors in these species distribution and abundance. The aim of the present investigation is to examine whether variations in the hydrological regime can explain the fluctuations in early life stage of flounder that have occurred over the past 35 years. We evaluate the hypothesis that the spatial heterogeneity of the available reproduction area is defined as bottom area with dissolved oxygen > 1 ml/l and salinity > 10.6 psu affects the survival of flounder eggs and larvae and determines recruitment success

Poster S4.2-4851

Toward a better understanding of climate forcing on decadal changes in the Adriatic Sea ecosystem

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We analysed information gathered from multidisciplinary oceanographic monitoring since 1950 in the Adriatic Sea, in the light of changes of dominant climate indices in the northern hemisphere (e.g. NAOI, AOI, MOI). Together with the oceanographic parameters, which included temperature, salinity, and water transparency, we assessed the patterns of variability of regional atmospheric variables (i.e. zonal and meridional wind components, sea level pressure, temperature, solar radiation) and biological indicators of the ecosystem functioning like primary production, fish and other species landings. The potential link between ecosystem and climate variables with global factors like sunspots was also investigated. Fourier and sliding-correlation analyse were used to identify high and low frequency variability of the investigated time series, and the evolving relationships between them. These results provide new concepts for an integrated management of the pelagic ecosystem of the Adriatic Sea.

Poster S4.2-4858

Ichthyoplankton assemblages off northern Peru: spatio-temporal dynamics and relation to *El Niño*/Southern Oscillation

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One of the most productive pelagic ecosystems in the world is found off northern Peru – a region world famous for its fishery and the most devastating *El Niños*. During the number of years P.P. Shirshov Institute of Oceanography of Russian Academy of Sciences carried out multidisciplinary investigations of upwelling ecosystems in the northern Humboldt Current (7-8ºS). Based on extensive collections in years with drastically different environmental conditions (strong upwelling - 1974; moderate warming - *El Aguaje* 1978; pre- *El Niño* 1982; strong *El Niño* - 1987), the larval fish assemblages off northern Peru are analysed and described in terms of their abundance and composition, spatio-temporal variability, recruitment potential, and general transport patterns along the Peruvian shelf. Relatively low diversity of 75-80 larval taxa from 42-45 families was recorded during the two decades of irregular sampling. The majority of Peruvian ichthyoplankton is formed by eggs and larvae of commercial pelagic species – *Engraulis ringens* (Engraulidae), *Sardinops sagax* (Clupeidae) and *Scomber japonicus* (Scombridae). The principal non-commercial larval fish species are mesopelagic *Vinciguerria lucetia* (Phosichthyidae), *Diogenichthys laternatus* (Myctophidae), *Bathylagus nigrigenis* and *Leuroglossus urotranus* (Bathylagidae). This work will provide a broad overview of Russian ichthyoplankton studies in the area concentrating on coastal, as well as lesser known oceanic upwelling regions, and the influence of complex ocean/atmosphere interactions during the ENSO cycle on reproduction of principal pelagic fish stocks in the region.

19 May, 18:00 (S4.2-4901)

Distribution dynamics of three hake species along the NW African coast: is climate variability a key factor?

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The NW African coast supports important demersal fisheries, some of them based on three different hake species: European hake (*Merluccius merluccius*) and two black hake species (*M. senegalensis* and *M. polli*). This area is the southern distribution limit for European hake, and the black hakes are truly Africans, but along the Saharan Bank the three species overlap their distribution. According to observations and fishery data, we know about marked changes in the relative contribution to the total hake catches, suggesting different response to certain "factors". We know about strong dependence of European hake abundance with climate-environmental variability in NW Africa forced by the North Atlantic Oscillation (NAO), affecting the early life stages of this species. In order to contribute to building the multi-species approach of fisheries dynamics of hakes in NW Africa, the aim of this work was performing a comparative approach using the same environmental descriptor (NAO) over the abundance of the three hake species during the last two decades. The catch-based time series was correlated with the annual NAO index lagged by time, as a proxy of climate-environment variability. There was a an opposite response between European hake ($r= 0.77$; $p<0.0005$) and black hake ($r= -0.69$; $p<0.0001$) abundance *vs* NAO. Results suggest that during less intense upwelling years, the black hake could extend their range due to an increase in suitable conditions but it was detrimental to European hake as their northward distribution contracted. On the other hand, during highly intense upwelling years, European hake increases their distribution area because of the prevalence of the cold-season oceanographic period. This situation shows a highly dynamic structure into the same eastern boundary upwelling system.

Poster S4.2-4905

Biophysical modelling of climate impacts on larval fish: testing parameterisations at the individual level

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Coupled bio-physical individual-based models (IBMs) are frequently used to assess climate impacts on early life stages of marine fish larvae. During the last two decades, however, advances in the physics have greatly outpaced those in larval physiology. Here we present the results of laboratory experiments that were designed to test parameter estimates currently used within the IBM subroutine for larval fish foraging and growth. Measured and modelled growth rates were compared for Atlantic herring (*Clupea harengus*) larvae feeding on different size classes of copepod prey at 7 and 13°C. Model estimates of growth potential were based upon functions of prey encounter rate, prey capture success, assimilation efficiency and metabolic costs developed for herring in previous laboratory studies. The model performed well with unfed fish where modelled and predicted rates of weight loss agreed closely at both temperatures. However, the model estimates of growth in fed fish were much higher than mean values of growth observed in fed treatment groups. However, rates of growth (biochemically-based), food consumption (both prey items in guts and feeding strike frequency) and activity (pause duration, pause frequency) were quite variable among individuals. After taking into account this high inter-individual variability, modelled and observed growth agreed well. A list of recommended IBM parameter values for larval clupeid physiology is provided. Although not a direct test of "climate impacts" *per se*, such laboratory experiments are critical if we hope to produce models providing robust estimates of the influence of climate-driven processes on early life stages of key fish species.

Poster S4.2-4933

Influence of physical and biological oceanography on population fluctuations of the yellow croaker (*Larimichthys polyactis*) in the Yellow Sea/East China Sea

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Yellow croaker, *Larimichthys polyactis*, is a commercially important demersal fish in the Yellow and East China Sea. It migrates vertically and horizontally with certain rhythm. Croakers descend to the sea bottom during the daytime and ascend toward the surface at night, probably following the diurnal vertical migration of their zooplankton prey such as Euphausiids, copepoda and other crustaceans. They ontogenetically migrate from spawning to nursery, and then to their over-wintering grounds. The Yellow Sea stock migrates to spawn in the Korean western sea during the April to June period. This stock arrives earlier in the southern compared with the northern Yellow Sea. Spatially, catch levels are higher in shallow, coastal areas than offshore areas. This species migrates to the waters near Chilsan and Wi Islands in April-May, and then moves northward to the waters near Yeonpyeong Islands in June-August. Young croakers (< 2-year old individuals) dominate Korean commercial catches, which are mostly landed at Chuja and Heuksan Islands from October to the next March. We will identify physical and biological factors influencing stock fluctuation of yellow croaker to predict stock fluctuation of yellow croaker based on the age-specific catch levels and ontogenetic migration.

Poster S4.2-4944

Climate change and prospects of fisheries in the Barents Sea and adjacent Arctic seas

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The last decade is in general characterised by the stable increase of the air temperature over the area of the Barents Sea and adjacent seas. Similar processes were observed in the hydrosphere. The warming of the "ocean-atmosphere" system caused the decrease of the ice cover area in the sea. The present-day changes of climate have already had an impact on the biological resources of the Barents Sea and adjacent areas. The most noticeable changes take place in the geographical redistribution of the fishing over the sea and of new fish species traditionally dwelling in warm Atlantic waters. A consequence of changing climate in the last decade is the fact that the boundaries between the Arctic and Atlantic oceanic systems have became weaker, and the frontal zones in the Barents Sea became correspondingly fuzzier. In connection with this one can assume that the climate warming could have a certain negative impact on the abundance of such important commercial species as cod and capelin, the habitats of which are densely connected with frontal zones. Thus, even now it is necessary to switch the task of studying of implications of the climate change from theory to practice. In our opinion one of the first steps in investigating implications of global warming for fishing bioresources should be a programme studying fishing bioresources in the Kara Sea.

Poster S4.2-4956

Influence of a change in climate on the development of molluscs in marine farming (for Possyet Bay, Sea of Japan)

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The tendencies of climate change, namely global warming, are of great interest. The research in climatic changes in separate regions is especially interesting for estimation of their possible aftermaths and impact on the environment and economy. To develop scientific methods of long-term prediction of mollusk productivity, it is necessary to study the effects of hydrological parameters on Japanese scallop and the technology of its cultivation. The information used in this study was scallop observations from a sea farm at Possyet (1970-2005), a multiyear series of mean diurnal data from the Hydrometeorological Station Possyet, and the State Network of Hydrometeoservice

situated in Possyet Bay. This paper sets forth the results of statistical analysis of thermohalinic characteristics of four periods of the annual developmental cycle of the Japanese scallop. The departures from the mean values of the duration of biological periods and their thermohaline characteristics were calculated. The results show that all parameters undergo considerable interannual variability. Comparing the duration of the development of Japanese scallop for the periods 1970-1990 and 1999-2005, the mean duration itself was not changed but the maximum and minimum duration decreased. Good-harvest and low-harvest years are identified on the basis of an analysis of the distribution of harvest deviations from the trend.

Poster S4.2-4966

Is there evidence of climate change impacts on Portuguese coastal fish assemblages?

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The Portuguese coast is located in a biogeographical transition area. Due to this particular situation, fish characteristic of the Mediterranean and warm temperate regions can be found in sympatry with others typical from cool temperate and boreal latitudes. Hence, this is a good geographical area to evaluate changes in fish communities due to climate change. Although time series data on fish assemblage composition and structure is extremely scarce and fragmented, an effort was made in the present study to compile the available data, both from historical records and more recent surveys, including some collections conducted in 2007 in the Almada Atlantic front (central coast of Portugal), as a result of a joint project between Almada City Council and the Oceanographic Institute. For some coastal areas, fish assemblage composition and structure (based on functional guilds) was compared throughout the last decades, and its relationship with climatic change evaluated, especially with regard to sea surface temperature. The implications of an increase in sea surface temperature on coastal fish assemblages in this geographical area are discussed and its possible impacts foreseen.

Poster S4.2-4973

Could warmer years mean good years for cod? A pan-Atlantic meta-analytic perspective

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This study aims to identify the effect of temperature on cod (*Gadus morhua*) population dynamics by meta-analysing data across the species distributional range in the North Atlantic. Our objective is to evaluate how extreme temperature conditions in each region affects recruitment and conversely the temperature conditions experienced in years when extremely high or low recruitment is produced. For this purpose, we first compiled an extensive database consisting of updated available time series of recruitment, spawning stock and total biomass, plus time series of upper layer (0-100 m) temperature during the cod spawning season (spring), for all populations. We then applied parametric and non-parametric meta-analytical methods using standard and novel effect size metrics (e.g. response ratio between strong and weak year-classes) to evaluate potential associations between years having exceptional temperature conditions and exceptional recruitment. Stock-specific metrics were combined through random and mixed effects meta-analytic methods in order to identify patterns in effects and produce overall results regarding cod response to ocean warming, allowing for the influence of other ecosystem characteristics specific to each stock. The methods employed include hierarchical Bayesian meta-analysis, which allow us to integrate various levels of uncertainty in addition to scientific knowledge. We find that there are geographic patterns in cod response to temperature, with stocks inhabiting the colder range being favoured by warmer years. On the other hand weak year-classes are associated with the extreme high temperature for the warmer range stocks. The critical temperature appears to be *ca*. 7°C, above which negative effects prevail.

Poster S4.2-4980

Anchovy as indicator of climatic regime shifts?

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Small pelagic fish have been proposed as candidate indicator species for predicting climatic regime shifts. The relative availability of information (through fishing or surveys), relatively low time-lags in responses to environmental change (because of close linkage to primary and secondary production) and the wide geographical distribution of small pelagic fish are three characteristics making them potentially useful indicator species. Conspicuous recent changes in the North Sea zooplankton and fish communities indicate that a regime shift has occurred and in this context we use a small pelagic fish to test the above expectation. Anchovy (*Engraulis encrasicolus*) increases observed in the North Sea over the past half decade were examined to reveal whether a clear response of anchovy populations to climate via direct (temperature related) and indirect (food web related) mechanisms could be detected. The analysis is carried out in time and space and we assess whether anchovy populations could be useful predictors of climatic change in temperate waters.