

Theme Session on Connecting Physical-Biological Interactions to Recruitment Variability, Ecosystem Dynamics, and the Management of Exploited Stocks (O)

ICES CM 2005/O:01

Linking larval transport and fisheries demographic models to investigate the influence of environmental variability and larval behavior on oyster population growth and dispersal

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Annual variations in freshwater flow and wind may influence the dispersal of oyster larvae (by affecting circulation patterns and salinity) and the survival of adults (by influencing salinity-dependent disease mortality) in Chesapeake Bay, a region whose oyster fishery has greatly declined. This suggests that environmental variability has important implications for rehabilitation efforts that involve native broodstock enhancement or introduction of a new species. We tested this hypothesis for two oyster species, *Crassostrea virginica* (native to Chesapeake Bay) and *C. ariakensis* (a non-native species proposed for introduction to the Bay), using linked larval transport and fisheries demographic models. Physical conditions in the transport and demographic models were based on predictions from 3D hydrodynamic models forced with observed freshwater flow and winds during 1995–1999. The larval transport model was used to predict the spatial patterns in recruitment using a particle tracking model parameterized with larval behaviours discerned in preliminary analysis of ongoing laboratory studies. The demographic model incorporated estimates of stock-recruitment relationships, growth, natural mortality, disease mortality, fishing mortality, and the effect of extreme events such as freshets. Larval transport model results indicated that spatial patterns in settlement success were influenced by environmental conditions and larval behavior. The implications of these findings for population growth and dispersal were assessed with the demographic model, as was uncertainty in model predictions. Our linked model has utility for assessing the risks associated with introducing species and for guiding oyster management activities such as locating brood stock sanctuaries and managing harvest in response to climate variability.

Keywords: biological-physical interactions, modelling, larval transport, demographic model, oysters.

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ICES CM 2005/O:02

Environmentally caused variability in the fluctuations of the European lobster, *Homarus gammarus*, fishery in Scottish coasts

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Variability in the fluctuations of two Scottish lobster populations, the Hebrides and Southeast, was investigated from available long data series of fishery and environmental variables. In a multivariate context, relationships between selected environmental variables and the fishery data were studied at different spatial and temporal (annual, spring and autumn) scales and from individual and overall sampled fleet. Multivariate techniques such as cross correlation function (CCF), principal components analysis (PCA) and redundancy analysis (RDA) confirmed that the capture of lobsters was strongly influenced by sea surface temperature (SST), wind speed (WS), and sea level pressure (SLP) throughout the year, and this dependence affected the duration of the fishery. In the Hebrides, the total variation (42%) of the interaction fishery-environmental variables for the spring and autumn fisheries could be attributed to the environmental variables in an 89%. For the Southeast, the spring fishery was more affected by changes in the environment, with a total variation of 34%, from which 85% could be explained by the environmental variables tested, than the autumn fishery where density-dependent processes were more important. From the analyses, it is deduced that the Hebrides lobster population is strongly influenced by density-independence processes at large and small spatial scales. Density-dependent processes at all spatial scales mainly drive the Southeast lobster population and environmental variables are important in spring.

Keywords: *Homarus gammarus* fisheries, redundancy analysis, environmental factors.

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ICES CM 2005/O:03

Abundance of Northeast Arctic haddock year classes and its governing factors

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In 1950–1997, on the basis of analysis of both biotic and abiotic factors it was ascertained that mean annual water temperature at the first and second years of life of Northeast Arctic haddock cohorts exerts maximal influence on their abundance. Abundant year classes were registered only in normal and warm years. In periods of evident cooling of the Barents Sea all year classes were poor independently on the spawning stock condition, food supply and other factors. Year-to-year variations of water temperature profoundly affect the abundance of year classes as well.

Abundance of year classes very largely depends on a size and structure of the spawning stock. In years, when biomass of mature individuals was at a high level and based on fish of older age classes, even unfavourable environmental conditions not always led to appearance of poor year classes. In the period of drastic decrease of a size of spawning stock and its rejuvenation, the abundant and middle in number year classes appeared only in warm and anomaly warm years or in periods of abrupt warming up of the sea. Mature individuals at the age of 6–8 spawning two and more times made maximal impact on the abundance of haddock year classes.

Abundance of year classes was determined to a great extent by a size of immature part of the stock. At a high density of the population the abundant classes were observed much more seldom than at the low abundance of immature individuals. A link between abundance of year classes and density of population was especially pronounced in favourable for survival warm years, when a role of abiotic conditions decreased.

The revealed complex influence of the thermal condition of the sea, spawning stock biomass and structure and density of haddock population on the abundance of its year classes permit to use these parameters at prediction of year class strength and stock management.

Keywords: density of population, haddock, prediction of year class abundance, spawning stock, stock dynamics, year class abundance, water temperature.

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ICES CM 2005/O:04

Modeling the growth of sandeel larvae as a function of temperature and zooplankton concentration: "Do larvae eat temperature?"

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The larval stages of marine fishes are characterized by high mortality rates and it is therefore generally acknowledged that rapid growth through the larval period enhances survival. Larval growth is often modeled as a function of seawater temperature, which is used as a proxy for overall environmental variability since in general temperature displays a similar pattern to seasonal productivity in the sea. However this approach is often criticized by the fact that fish do not feed on temperature; and the effect of food availability on growth should be modeled explicitly. In the present study, we used particle tracking methodology to estimate the temperature and food history of North Sea sandeel larvae of given length and age sampled in the years 1992, 1993, 2000, 2001 and 2002. Year-specific monthly temperature fields were assembled from a GAM analysis of field observations and year-specific monthly fields of zooplankton concentration were modeled from Continuous Plankton Recorder data using a GAM with a smooth function of location (latitude, longitude) and long term trend (year). The results showed that there was a strong correlation between temperature and zooplankton

concentration. A model with explicit temperature and food terms explained only slightly more variability in the data than simpler models with single food or temperature terms.

Keywords: Sandeel, North Sea, particle tracking, GAM, otoliths, smooth function, growth model, fish larvae, environmental modeling, zooplankton concentration, food history, life history.

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ICES CM 2004/O:05

Combining otolith microstructure analysis and hydrodynamic modeling: an approach to link Baltic sprat larval and juvenile growth to variability of the physical environment

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To identify potential nursery grounds of Baltic sprat for sprat originating from different spawning grounds, we used collected data on spawning location, vertical distribution and timing of spawning as input to a Lagrangian particle tracking model. From long-term model runs (1979–2002), the initial distinct horizontal distribution patterns of eggs and larvae as well as the seasonal variability of the circulation patterns provide mechanisms facilitating regionally self-sustaining populations of eastern Baltic sprat, with regions of mixed recruitment in the Arkona Basin and in the Gdansk Deep. The horizontal distribution pattern of young-of-the-year (YoY) sprat observed in October 2002 indicated that most of the survived individuals were born the Bornholm Basin in summer. Otolith microstructure analysis and hydrodynamic modeling were combined to study the growth patterns in relation to environmental histories of the YoY sprat. Daily mean temperatures, experienced across the entire YoY-population, derived from Lagrangian particle simulations as well as daily resolved wind speed data were correlated to age-detrended otolith growth rates. The results showed that abrupt changes in the physical environment can be detected in the backcalculated seasonal pattern of otolith growth, and that higher temperatures led to significantly faster growth throughout the entire age-range of YoY-sprat.

Keywords: Baltic sprat, otolith microstructure analysis, young-of-the-year, hydrodynamic modelling.

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ICES CM 2005/O:06 - Withdrawn

Buoyancy and vertical distribution of haddock (*Melanogrammus aeglefinus*) eggs

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In this study, the buoyancy of haddock (*Melanogrammus aeglefinus*) eggs from different females was studied from fertilization to hatching. Knowledge about the vertical distribution of eggs is important for understanding their transport from spawning areas to nursery areas and one of the most important factors regulating vertical distribution is buoyancy of the eggs. Little information exist about the buoyancy of haddock eggs and this is one of the first studies where this is investigated on northeast Atlantic haddock. Eggs were collected from wild caught fish kept in tanks (one female and one male in each tank), and inserted into a density gradient column where buoyancy was measured. The haddock eggs were relatively light with a salinity of neutral buoyancy ranging between 28.5 and 31 from different females. The buoyancy changed with the development of the eggs. First there was a slight decrease in buoyancy followed by an increase until day 8. After that the buoyancy decreased again until hatching. The results from the buoyancy measurements were used to model the vertical distribution of the eggs and the effect of this on transport is discussed.

Keywords: Egg buoyancy, haddock, vertical distribution, drift.

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ICES CM 2005/O:07

Growth differences in juvenile Norwegian spring spawning herring (*Clupea harengus* L.) related to temperature conditions in the nursery areas

Åse Husebø, Aril Slotte, and Arild Folkvord

The hatched larvae of Norwegian spring spawning herring are transported to nursery areas in fjords along the coast and to the Barents Sea from 58°-80°N. Consequently there is a wide range of temperature and ecological regimes experienced by the juveniles which may be reflected in differences in growth patterns throughout their geographic range. In the present study we demonstrate differences in juvenile growth between nurseries on a latitudinal scale using data collected on research surveys during 1989-2004. The possible effects of temperature on geographical and inter-annual differences in juvenile growth are tested.

Keywords: herring, growth, nursery area, latitude, temperature.

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ICES CM 2005/O:08

Size selective mortality in Norwegian spring spawning herring juveniles?

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The growth-mortality hypothesis, where survival during the larval stage is positively related to size, is tested for Norwegian spring spawning herring (*Clupea harengus* L.). The daily increment width in the otoliths is compared between larvae sampled in May-June along the Norwegian shelf and the surviving population of 0-group juveniles sampled in fjords and inlets along the coast and in the Barents Sea in autumn (August-December). In order to select juveniles from the same cohort as the larvae sampled on the Norwegian shelf (May-June), a numerical model was used to simulate the drift of larvae from the shelf areas to the nursery areas where 0-group juveniles had been sampled. Samples from years with low high recruitment and from different areas are compared. The results are discussed in relation to variations in environmental conditions.

Keywords: Size selective mortality, otolith microstructure, Norwegian spring spawning herring, larvae drift.

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ICES CM 2005/O:09

Small scale variation on mackerel egg mortality over a high density patch

Enrique Portilla, Doug Beare, Eddie McKenzie, I. Gibbs, F. Burns, and Dave Reid

Ideally, mortality is estimated over a single population observed for enough time to see them all die. Unfortunately such observation resolution is not possible in the field. Mortality is generally estimated on data combined in time and space. In order to enhance mortality rates over a population, during the 2004 mackerel egg survey, sampling took place over 24 hours in one location at high rate following the same strategy as the one used to estimate Total Annual Egg production on the standard survey. Using these data it was possible to quantify mortality rates more accurately with average values for mackerel of 1.12 d⁻¹. Mortality rates showed significant diel variation within the 24h period possibly related to sunlight forcing. Finally, conclusions about diel behaviour have to be approached with precaution because of the change on location during the sampling period.

Keywords: Mackerel eggs, mortality estimation, Birth death models, intensive sampling.

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ICES CM 2005/O:10

A method to represent vertical migration of Zooplankton in 3D-Eulerian Models

Thomas Neumann and Wolfgang Fennel

To understand the vertical distribution of zooplankton, the swimming behavior of the animals in response to physical processes, food conditions etc., has to be taken into account. The active, vertical migration of copepods can be considered as a reaction to external and internal stimuli. The reaction patterns can be covered by a set of behavioral rules.

In this paper, we introduce a method based on so-called evaluation functions that assess the local habitats of the copepods at each grid point of the model, and to quantify the probability of their possible reactions in terms of up- or downward migration. The method is tested for the case of the Baltic Sea. Known observational facts of the main mesozooplankton groups are used to define the evaluation functions for two aggregated groups of model copepods, which occupy different habitats. The copepod groups are divided into five developmental stages.

Several simulations were carried out with the aid of one- and dimensional Eulerian models to constrain the involved set of parameters. It can be shown that a plausible characterization of the behavioral features of copepods, as generally known from observations, mimics the migration patterns of the model copepods in an excellent agreement with the typical behavioral pattern of the main mesozooplankton in the Baltic Sea.

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ICES CM 2005/O:11 - Withdrawn

Hake habitat in the California Current System: distribution, dynamics and implications for management.

V. N. Agostini, R. C. Francis, A. N. Hendrix, A. B. Hollowed, and J. E. Little, S. Pierce, and C. Wilson.

The California Current (CC) system is a highly dynamic environment, where physical and biological processes interact at a number of spatial and temporal scales. Climate variability has been known to impact production of a number of CC species. Studies have often attempted to link climate forcing directly with production variability, aggregating impacts across large spatial scales and range of species. The focus has been on directly linking climate with fish abundance metrics, often overlooking a more detailed analysis of how climate forcing impacts the ocean habitat of fish.

Recent studies suggest that changes in ocean forcing may alter the dimension and location of ocean habitats, which in turn may alter the distribution and density of marine populations. This study examines Pacific hake habitat using acoustic data on fish abundance and flow along the west coast of North America. We use a modeling approach to quantify coastal ocean habitat of Pacific hake. I will argue that while physical processes may not directly affect hake production, they may be the link between large scale ocean-atmosphere variability and hake distribution along the west coast. Implications for both single species and ecosystem based fishery management will be briefly discussed.

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ICES CM 2005/O:12

Common trends in two populations of the European lobster, *Homarus gammarus*, in Scottish waters

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Dynamic factor analysis (DFA), a multivariate time series analysis technique recently applied to fisheries data for the first time, is used to explore common trends, and the effects of sea surface temperature (SST) and wind speed (WS) on short non-stationary multivariate time series of catch rates of the European lobster in Scottish fisheries. Catch rates of undersized and legal lobsters at three locations in the Hebrides and two locations in the Southeast of Scotland, were generally highest in autumn (August-October) with strong seasonal trends during the period 1990-1997, and therefore, de-seasonalised time series were analysed. From the DFA analysis, significant relationships between catch rates (undersized lobsters in one location and legal lobsters in two locations) and SST were observed for the Hebrides. At all locations in the Southeast, catch rates (both undersized and legal size lobsters) were related to SST. The results suggest that (i) catch rates in the Hebrides have been steadily decreasing, (ii) those in the Southeast have been increasing during the studied period. DFA identified two common trends not revealed by traditional approaches, and proved to be a robust technique in the study of multivariate time series for the European lobster fishery.

Keywords: Dynamic factor analysis, common trends, catch rates.

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ICES CM 2005/O:13

Environmental changes and varying conditions shape reproduction limits and interactions in the Baltic fish community

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The Baltic Sea is a shallow (mean depth 55–60 m) brackish water sea. The number of fish species is rather low, however, compared to the small water volume the fish production is high. The total annual fish catch has varied between 580 000 and 970 000 tonnes per the total water volume of around 21 000 cubic km. The magnitude of the catch is not mainly based on fast growth but instead effective reproduction that sometimes varies considerably for some species.

The Baltic is characterized by extreme conditions that test the adaptability of fish stocks, causing changes into the annual survival of 0+ individuals of many species. Both marine and freshwater fish species try to cope e.g., with temporal and spatial salinity variations (from 0 to 34, being on the whole < 12). This study aims e.g. to evaluate different limiting factors such as temperature and salinity on some early stages of fish. Reasons for reproduction and growth failures are not always direct but complicated interactions in the food chain are involved. One example presented here is the increased eutrophication that may favour cyprinids at herrings expense in overlapping juvenile feeding areas. Overall, environmental conditions and overlaps in reproduction areas play a decisive role in structuring the fish community.

Keywords: reproduction areas, interactions, variability, larvae, juveniles, limiting factors.

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ICES CM 2005/O:14

Transport and survival processes of eggs and larvae of jack mackerel in the East China Sea

Akihide Kasai and Kousei Komatsu

The jackmackerel is of ecological and commercial importance in the East Asia. Recent surveys have found that the essential spawning ground of jack mackerel is located in the north of Taiwan (NT), where the Kuroshio flows northeastward. The eggs and larvae spawned in the region are likely to be transported to Japanese coastal area, where is the important nursery grounds and is also known as the other local spawning area. However, the precise mechanisms of the transport and recruitment of eggs and larvae of jackmackerel and the relative importance of each group to support the population have not clarified yet. Therefore, we examined the transport and survival processes of eggs and larvae from the spawning area to the nurseries by a numerical model. The results show that 1) the simulated distributions of larvae by the model were well correlated with those by the field survey. 2) The jackmackerel's stock in the Sea of Japan is composed of both larvae from NT and those from western coast of Japanese Islands. It takes a few months for the former to reach the Sea of Japan, while within two months for the latter. 3) A part of the eggs and larvae spawned in NT is transported rapidly by the Kuroshio Current, and the other slowly to the east or northeast along the continental slope in the East China Sea. The main contributor of jack mackerel around Japan would be the latter, since the survival rate of the latter is better than the former.

Keywords: eggs and larvae, jack mackerel, numerical model, recruitment, transport.

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ICES CM 2005/O:15

Effects of turbulence on the ingestion rate and survival rate of bluefin tuna, *Thunnus thynnus*, larvae

Yoshiki Kato and Shingo Kimura

Rearing experiments were conducted to study effects of oceanic turbulence on the survival and the ingestion rates of initial feeding larvae of bluefin tuna. The energy dissipation rate (ϵ) of optimal turbulence intensity for the best growth was determined. Several levels of turbulence intensity were provided by changing flow rate of water from the out flow pipe equipped on the bottom of the tanks containing bluefin tuna larvae. The results showed that there was an optimal turbulence intensity for initial feeding larvae that enhances larval ingestion and survival rates. The turbulence intensity was equivalent to approximately $4.0 \times 10^{-8} \text{ m}^2 \text{ s}^{-3}$ as a turbulence energy dissipation rate. High turbulence intensity greater than this optimal intensity had a negative effect. Larvae in the higher turbulence tanks could not ingest any rotifers and could not survive until 4 days after hatching. Compared to turbulent intensities under natural conditions, which correspond to the obtained turbulence energy dissipation rate in laboratory, larvae of bluefin tuna have to be exposed to turbulence caused by wind speed of more than 7 m s^{-1} . Thus condition greater than 15 m s^{-1} associated with typhoon approaching makes the survival rate worse. Optimal turbulence intensity of bluefin tuna was slightly higher than that of yellowfin tuna. This similarity suggests that range of $3.0\text{--}4.0 \times 10^{-8} \text{ m}^2 \text{ s}^{-3}$ of turbulence energy dissipation rate was a feature common to the tunas, *Thunnus*, spawning at open sea.

Keywords: turbulence, bluefin tuna, initial feeding larvae.

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ICES CM 2005/O:16

Variability in the abundance of the Argentine squid *Illex argentinus* in relation to environmental conditions on the high seas of the Patagonian Shelf

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The Argentine shortfin squid *Illex argentinus* is the most important commercial squid species in the South West Atlantic and one of the target species for Spanish demersal trawlers operating on the high seas of the Patagonian Shelf, i.e., on the edge of shelf and slope of $45\text{--}47^\circ \text{ S}$ and $41\text{--}42^\circ \text{ S}$ outside the Argentine EEZ. Catch data showed a very high level of biomass in 1999 and the collapse of the fishery in 2002 and 2004. We examine whether these fluctuations can be attributed to environmental variation. Analysis of fishery catch data collected by scientific observers aboard commercial vessels was

made to assess relationships between abundance variability of the slope-oceanic winter spawning group of *Illex argentinus* (CPUE) and environmental parameters. GIS and remote sensing data were used to study the influence of anomalies in sea-surface temperature (ASST) and oceanic circulation. Preliminary results show that relationship between sea surface temperature and abundance is non linear being the highest CPUE found at temperatures between 7 to 15°C. Sky, moon and sea state parameters explain a very low proportion of variation in the *Illex* abundance.

Keywords: abundance, squid, SW Atlantic, environment, ASST.

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ICES CM 2005/O:17

Detection and historical reconstruction of mesoscale hydrographic features: an application to the Bay of Biscay continental shelf

Benjamin Planque, Pascal Lazure, Marc Segond, Cyril Fonlupt, and Denis Robillard

Long-term indices of ocean climate are generally based on large scale features (such as atmospheric circulation (e.g. NAO) oceanic circulation (e.g., Gulf Stream index), changes in SST, and so on). Although such indices provide some indication of large scale changes in the ocean, they often provide limited insight on the possible response of pelagic fish because the scale of the physical processes described is far greater than the scale at which fish behaviour (at individual, school or population levels) is generally understood. Process understanding of fish response to the environment is generally more obvious at the meso-scale (10–100 km, days-weeks) where oceanographic features such as fronts, plumes, upwelling or eddies occur. An understanding of fish response to climate compatible with process understanding requires that meso-scale oceanic features be detected and tracked over long period of times.

Here, we present 3 techniques for the automatic detection of mesoscale hydrographic features such as thermal fronts, vortex-like structures, and spring hydrological landscapes. The three methods are applied to realistic hindcasts of the bay of Biscay shelf hydrography during the past 40 years in order to provide time series of long term changes in meso scale hydrographic features in the region.

Keywords: mesoscale, thermal fronts, river plumes, vortices, hindcasts, hydrography.

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ICES CM 2005/O:18

Simulating the influence of climate variability on larval fish survival: An example using sprat (*Sprattus sprattus*) in the southern North Sea

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Within many coastal marine regions, changes in factors affecting hydrography (e.g., river input, tidal mixing, and atmospheric conditions such as solar radiation and wind) lead to spatial and temporal variability in factors impacting the transport and vital rates of fish larvae (e.g., water currents, turbulence, temperatures and prey fields). To investigate the impact of changing environmental conditions in the southern North Sea on the transport, growth and survival of larval sprat (*Sprattus sprattus*), we employed four inter-linked models: 1) a hydrodynamic model (HAMSOM) provided 3D fields of hydrographical properties, 2) a NPZD model prescribed local sprat prey fields (ECOSMO), 3) a Lagrangian transport model simulated temporal changes in cohort distribution, and 4) an individual-based model (IBM) depicted foraging, growth and survival of early life stages of sprat. The NPZD model (ECOSMO), which provides the spatially and temporally variable prey field, includes 3 nutrient cycles, two phytoplankton groups (diatoms, flagellates) and two classes of zooplankton (omnivorous and herbivorous). The IBM includes eggs, yolk sac larvae and foraging and growth subroutines for post-

yolksac larvae. To estimate the influence of varying climatic conditions on vital rates of young life stages of sprat, scenario tests were performed by running the models for anomalously warm (1992) and cold (1986) years as well as within a year with average temperature conditions (1993). The simulation results were compared to *in situ* estimates of distribution and condition of larval sprat in the southern German Bight in 1992 and 1993.

Keywords: biophysical models, individual-based models, life cycle modeling.

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ICES CM 2005/O:19

A comparison of larval cod (*Gadus morhua*) growth models applied to the Georges Bank and Norwegian Sea regions

A collaboration between US GLOBEC and NORWAY GLOBEC was initiated with the main objective to compare and improve individual-based models of larval cod developed on both sides of the Atlantic. Extensive data sets from the Northwest Atlantic and Norwegian field programs are available to study how physical variables (e.g., temperature and photoperiod), larval behavior (e.g., foraging abilities), and prey abundance, type and distribution affect the growth, development, and recruitment process of larval cod. Specific relationships between larval growth and the environment are based on extensive time series of data collected from process cruises, as well as model-based representations of these processes generated in the laboratory. The available field and laboratory data open a wide range of opportunities for model inter-calibration and to explore the factors affecting larval growth and distribution in the two systems which are at the extremes of the geographic distribution of Atlantic cod.

Keywords: Atlantic cod, larva growth, recruitment, Individual based model.

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ICES CM 2005/O:20

Multiple grid-scale model for egg production, larval transport, recruitment and fishery production for lobsters in the Gulf of Maine

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We discuss a synthesis of data and approaches to understanding the spatial relationships between larval production (at time of hatch), recruitment to the benthos (settlement) and subsequent fishery production for lobsters (*Homarus americanus*) in the western Gulf of Maine. In addition to some of the difficult vital rate estimations (for example, larval mortality), a population model in this region is especially challenged by the migratory behavior of adult female lobsters prior to hatching of the attached eggs, by the extremely convoluted shape of the coastline where flows are not resolved, and by the need to integrate very fine-scale observational data (for example, observations of settlement on various substrate types) with practical limitations of modeling at the scale of the Gulf of Maine system. We have approached this by blending spatially explicit and non-explicit models at two grid-scales. One is the 4 km resolution of the circulation model (for egg production and larval drift, mortality and dispersion) and the other is at a larger grid scale (Lobster Management Zones) for settlement and post-settlement population dynamics. A high-resolution coastal model of limited geographical extent is nested within the larger coupled model and used to examine dispersion from egg hatching along a complex shoreline, and its contribution to the fishery “downstream.” An advantage to running the population model at the larger (management zone) scale is that it averages over spatial uncertainties in the higher-resolution model, and it provides fishery estimates at a scale useful to management and the fishing industry.

Keywords: circulation, egg production, larval transport, settlement, recruitment, fishery production, modeling.

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ICES CM 2005/O:21

Which time and spatial scales should be used to model anchovy seasonal distribution in the Bay of Biscay according to physical and biological conditions?

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Relating adult stages dynamics of small pelagic species with environmental conditions is challenging, as adult movements are relatively independent from water masses transport. By studying the individual growth pattern of the anchovy population in the Bay of Biscay, we aim at enhancing our understanding of these interactions. In the Bay of Biscay, adult anchovy are concentrated in the south-east in spring during the spawning season and in the north in late summer. Our hypothesis to explain this spatial pattern is that the growth conditions in late spring become limiting in the south-east. This present work looks at the possibility to assess such a growth limitation thanks to ecological modelling. An anchovy growth model is built according to the Dynamic Energy Budget theory and applied to immobile individuals distributed all over the continental shelf. The physical and biological environmental conditions are given by a coupled 3D hydrodynamic-biogeochemical model of the primary production over the French Atlantic shelf. The theoretical growth curves obtained at various locations are compared with an optimal growth curve. The use of the time and spatial scale of the biophysical model for a fish displacement model is discussed regarding the results of the present study.

Keywords: Bay of Biscay, anchovy, growth conditions, DEB model, observation scale.

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Inter-annual variability of sprat abundance at early ontogenetic stages in the Gdansk Deep of the Baltic Sea: retention contribution into high density aggregation formation.

E. M. Karasiova and A. S. Zezera

Ichthyoplankton data on sprat eggs and larvae in the Gdansk Deep in the Baltic Sea for May 1992–2004 were considered. The lack of significant correlation between eggs and larvae abundance was noted. The occurrence of high density patches of sprat larvae were observed in 1992, 1994, 1995, 2004. In 2004 the relationship between eggs and larvae distribution and hydrodynamic characteristics of the environment was analysed. There were two types of the geostrophic circulation in the layer from the surface to the halocline in 2004: cyclonic on the northwestern slope of the Deep and anticyclonic on the southeastern slope. The main egg concentrations were located in the cyclonic circulation area with peak abundance in the eastern periphery. Abundant aggregations of larvae were associated mainly with the eastern and partly with the southern periphery of the cyclonic circulation. Presumably, the extremely high accumulation of sprat larvae during some years (up to 700 sp./m²) was caused by the vicinity of the local zones of water upwelling and downwelling induced by the northerlies and easterlies. On the basis of long-term data the relationship between density of larvae aggregations and vertical gradients of the basic hydrographic parameters in the thermocline and halocline was considered. It was supposed the diurnal vertical distribution pattern of sprat larvae can promote the retention under specific hydrodynamic conditions. The importance of retention and dispersion processes for sprat offspring survival at the early ontogenetic stages was discussed.

Keywords: sprat eggs and larvae, distribution patchiness, cyclonic and anticyclonic circulation, retention.

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ICES CM 2005/O:23

Modelling fish habitat suitability in the Eastern English Channel

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Valuable marine habitats and living resources can be found in the Eastern English Channel and in 2003, a Franco-British Interreg IIIA project, 'Eastern Channel Habitat Atlas for Marine Resource Management' (CHARM), was initiated to support decision-making for the management of essential fish habitats. Fish habitat corresponds to geographical areas within which ranges of environmental factors define the abundance of a particular species. Habitat Suitability (HS) modelling was used to relate fish spatial distribution to environmental factors, hence delineating their optimum habitat. This study was based on data obtained from 1988–2004 IFREMER's Channel Ground Fish Survey and 1989–2004 CEFAS' Beam Trawl Survey, including both species abundance and environmental data. A generic methodology allowing for the modelling of several fish species was developed including measures of fit and model validation techniques. In brief, habitat suitability modelling based on non-parametric multi-linear quantile regressions was used to relate species abundance to depth, temperature, salinity, seabed stress and sediment type. Backward selection resulted in HS models that described species affinity with a subset of significant environmental variables and that were used to map fish optimum habitats using GIS. Models were validated by comparing predicted abundances against abundance data that were not used in the modelling process. This work will help elaborating guidelines for the conservation and protection of natural habitats of marine living resources in the face of climate change and anthropogenic disturbances.

Keywords: Eastern English Channel, CHARM, Fish Suitable Habitat, GIS.

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ICES CM 2005/O:24

The effects of environment and fishing on the abundance and condition of Iceland scallop in Breidifjörður

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Sea temperature is one of the primary factors limiting the overall geographical range of most marine species, including the Icelandic scallop. In Iceland, the sub-arctic Icelandic scallop resides at its southern limits. As a result, it is likely to be especially vulnerable to changes in the immediate environment. During the last 5 years, the stock size of Iceland scallop in Breidifjörður on the West coast of Iceland has undergone a dramatic decline. This period has been characterized by steady increase in summer sea temperature and in 2003 the temperature had reached a historical maximum of the last century. As well, since 1998, there have been fluctuations in chl-a level, with the lowest values observed in 1999 and 2000. At the same time, muscle weight has declined and a minimum weight was attained in 2001–2002. In the following years, natural mortality of scallops in Breidifjörður increased significantly. The mortality was however quite localized within the main fishing area in the southern part of Breidifjörður. At the same time two *Coccidia* parasites have been described in Iceland scallop from Breidifjörður. These parasites may have influenced the survival of the scallops. Recruitment into the fishable stock in Breidifjörður was highly variable during the 1993–2003, with low recruitment towards the end of the 1990s. Due to high total fishing mortality during 1990–2000, the fishery depended on relatively few year classes. Therefore the fragile status of the stock did not endure the medium-high exploitation rates in conjunction with several years of poor recruitment.

Keywords: Iceland scallop, *Chlamys islandica*, recruitment, mortality, environment, temperature.

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Including climate into the assessment of future fish stock recruitment using multiple regression models

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Climate variability has generally not been included in the assessment of fish stocks in the Barents Sea and Norwegian Sea. However, in recent years there has been a focus on implementing climate variability in the assessment for several stocks in both areas. A promising approach, using linear multiple regression models, has been applied for short time projections of recruitment of Northeast Arctic cod, Norwegian spring spawning herring and Barents Sea capelin. Environmental factors influence the fish throughout their life history. Time lags between climate variables and the time the fish are recruited into the fisheries can be used in combination with stock abundance at younger ages to make models with predictive power 1–3 years ahead. The presented models describe 70–85 % of the variance in the recruitment data. The choice of variables in these kinds of models will always be a trade-off between best possible fit, the presences of a time lag and the possibility of updating the regressions/prognosis as close to the appropriate ICES working groups as possible. At the same time it is important that there is a plausible cause-and-effect link between the variables. The paper also discusses how this approach can be implemented in the assessment work.

Keywords: climate, recruitment, Barents Sea, Norwegian Sea, assessment, prediction.

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Swells as a turbulence source in shallow water

J. E. Stiansen, S. Sundby, A. Jenkins, and J. E. O. Nilsen

Two field investigations to an exposed shallow area outside Lofoten, western Norway, were conducted in 1995 and 1996. Direct measurements of turbulence were conducted from an underwater tower with acoustic current meters 6 m above the bottom. The tidal energy in this area is low and the wind conditions during the experiment were mostly weak. Still the energy dissipation rate at 20–25 m depth was in the range 10⁻⁷–10⁻⁵ W/kg. The only other possible energy source was long swells of wavelength 100–200 m that rolled in from the open sea. Analysis shows that the wave motion intermittently becomes unstable, inducing strong turbulent patches in parts of the wave orbit. The mechanism behind this process is not clear, but possible explanations may be local energy concentration or interaction of waves with different frequency. In many areas and situations this energy source is equal in force to tidal and wind generated turbulence. Simultaneous measurement of vertical profiles of zooplankton and fish larvae from a nearby allows for discussing swell induced turbulence in a ecological context.

Keywords: swells, turbulence, energy dissipation rate, zooplankton, fish larvae.

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Drift and growth of larval Northeast Arctic cod emerging from behavioural rules

Øyvind Fiksen, F. Vikebø, T. Kristiansen, and S. Sundby

Northeast Arctic (NEA) cod spawn in the Lofoten area in March-April. The eggs and larvae drift in the Northeast Atlantic current or the Norwegian coastal current into the Barents Sea where they settle during autumn. The dispersal of the drifting larvae has been shown to depend on their vertical positioning - if they remain near the surface they have a larger chance of becoming entrained in the warmer Northeast Atlantic current and to be widely dispersed in the Barents Sea. If they stay deeper down in the water column they have a higher probability of ending up in the colder Coastal current and end up near the coast. Here we simulate the fate of individual larvae with various behavioural rules of depth selection, and evaluate the success of various strategies in terms of growth and probability of surviving through the larval phase. We address the potential trade-off between water-column processes (growth and predation) and the large-scale circulation pattern of the area. To what extent can larvae influence the risk of being advected into unfavourable areas by tracking certain

environmental cues such as e.g., light, temperature and salinity? Are there rules that have persistently high success independently of spawning location and hatching time?

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ICES CM 2005/O:28

Modelling zooplankton and characteristic larval feeding environments in the North Sea with an NPZD model

Corinna Schrum, Irina Alekseeva, and Michael St. John

A 3-D coupled biological-physical model ECOSMO (ECOSystem MOdel) has been developed to simulate ecosystem dynamics in the North Sea and the Baltic Sea. ECOSMO was used to study the regional and temporal variability of production in the North Sea. Validation of zooplankton distribution were performed by using observational data. It could be shown, that zooplankton distribution and biomass as well as the timing of occurrence of biomass was well described by ECOSMO. In contrast to earlier model approaches ECOSMO was able to identify frontal environments as zones of high primary productivity and the simulations characterized the dynamics of different zooplankton feeding environments with special emphasis on the role of frontal production. In order to assess historic changes in zooplankton production numerical hind-casting was performed for the period of 25 years (1980–2004). Simulated fields were used to investigate the variability of plankton biomass and production in relation to changes in atmospheric forcing. From production and biomass anomalies basic modes of variability were identified. For a couple of modes related physical forcing mechanisms were identified. Different characteristic periods could be identified to be dominated by either stratification induced variability (1980-1998) or Atlantic inflow induced variability (1996–2002). Within these periods, physical parameters such as the depth of the thermocline, turbulence and nutrient transports were found to be hydrodynamic indicators for ecosystem variability. Distinct variability of zooplankton production and biomass was identified from model results as well in timing.

Keywords: Ecosystem Modelling, North Sea, Zooplankton, Frontal Production.

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Interannual and seasonal changes of the mortality rates of sprat eggs in the Gotland Basin (Eastern Baltic Sea)

Andrei Makarchouk

Instantaneous mortality coefficients (per day) and mortality rates of eggs of sprat (*Sprattus sprattus balticus* Schneider) have been calculated for the number of years from 1973 to 2003 using the data bases of Latvian Fish Resources Agency on ichthyoplankton and hydrography. These mortality rates were influenced by ambient water temperature in the mean depth of eggs, mainly in the end of the spawning season. Due to the peculiarities in their vertical distribution during the spawning season sprat eggs usually develop in the colder water in the second part of the season. Thus, ambient water temperatures are closer to the limit of eggs survival in the end of the spawning season, and this must stronger influence their development. Higher mortality rates were observed between 1st and 2nd stages of development rather than between 2nd and 3rd ones. Significant negative correlations between mortality rates of sprat eggs and success of spawning were found only for July. Highest mortality rates were usually registered in June. No big differences could be found in the value of mortality rate between the southern and central parts of the Gotland Basin. Extremely high mortality of eggs has been observed in the samples collected in the water surface layer and over the smaller depths.

Keywords: sprat, eggs, mortality rates, interannual changes.

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The linkage between frontal hydrography and distributional patterns of meso-zooplankton and fish larvae

Peter Munk, S. Jonasdottir, and H. A. Thomsen

Distributions of both meso-zooplankton and fish larvae/juveniles are concentrated in restricted areas, often close to the coast or in the vicinity of offshore banks. These areas are hydrographically diverse, often traversed by fronts, and the distribution of plankton organisms appear linked to the hydrographical patterns. In the present study we investigate the physical-biological linkages in detail, using information assembled during four surveys from a field study in 2001 within the LIFECO programme (“Linking hydrographic Frontal activity to ECOsystem dynamics”). We use data from CTD casts and depth-integrated samples of meso-zooplankton and fish larvae from stations covering a series of cross-bathymetric transects in the north-eastern North Sea. Seasonally, we covered the early spring period in March into the summer period in July.

The different copepod species showed characteristic distributional patterns, duplicated along transects and between cruises, some species were distributed offshore (e.g. *Calanus* sp. and *Metridia* sp.), while other species (e.g. *Pseudocalanus* sp. and *Oithona* sp.) were distributed further inshore. Marked differences were also observed among the dominant fish larvae (e.g. cod (*Gadus morhua*), whiting (*Merlangius merlangus*), sandeel (*Ammodytes marinus*)). The abundances of all species of planktonic organisms peaked within restricted ranges of water densities. Ranges differed among species, but were generally the same for a given species throughout the season. Apparently each species are distributed in water masses of specific hydrographical characteristics, and accordingly species diversity was enhanced in the frontal zone(s). The present findings are in accordance with other findings of relative differences in the distribution of species, the magnitude of their abundance, and their relationship to hydrography. This recurrence of patterns demonstrates the strength of linkages between plankton/fish distribution and the frontal hydrography in coastal waters. Hence, while the strength and distribution of the fronts varies seasonally and annually, the conditions determining the growth and survival of meso-zooplankton and fish larvae in these areas will fluctuate accordingly.

Keywords: LIFECO, hydrographic fronts, water density, meso-zooplankton, fish larvae, physical/biological linkages, species diversity.

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ICES CM 2005/O:31

Investigating Effect of Circulation on Jellyfish Transport in the Waters around Shetlands

Mohamed Elzeir and Steve Hay

Jellyfish attacking many coastal areas causes considerable economic loss besides its effect on recreational and other coastal activities. The waters of Shetlands, the UK are attacked by jellyfish with harmful effect on fisheries industry. It is needed to provide a reasonable protection against these attacks. The protection can be in terms of preventing the jellyfish from approaching the area of interest or, alternatively, giving the users of the coastal areas warning well in advance of the attack. The EU-funded research project EUROGEL concentrates on jellyfish. This paper deals with that part of the project, which studies the interplay between the physical processes of currents and jellyfish outbreaks. MIKE 3 is hydrodynamic software that is used to simulate circulation in the shelf zone around Shetlands. DROG3D is a particle-tracking model that is developed and adjusted to study the effect of the circulation pattern on jellyfish transport. The paper will use the results of both models to investigate effect of individual atmospheric, hydrodynamic and topographic parameters, e.g. bed slope, wind, vertical transport, on jellyfish transport.

Keywords: Shetlands, MIKE 3, particle-tracking model, jellyfish, physical-biological interaction

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ICES CM 2005/O:32

Biological and hydrographic aspects of the Norwegian spring-spawning herring migration variations before and after collapse in the 20th century

A. I. Krysov and E. V. Sentyabov

The paper analyses variations of the Norwegian spring-spawning migration for almost half-century period because of the changes of this fish population structure and hydrographic conditions in the Norwegian Sea. The data from biological and hydrographic investigations having been conducted by PINRO in the period of traditional complex “June” surveys in the Norwegian Sea since 1954 and the results from the international research on herring are used. Wide variations in the Norwegian spring-spawning herring population abundance and considerable changes in population structure happened in 1950-2004 caused the global alterations of the migration cycle and feeding area, which had covered, practically, all the area of the Norwegian Sea when the abundance was high, but in the period of collapse it was limited by the coastal areas of Norway. In the periods of relative stabilization of herring population abundance, the fish feeding migrations were greatly affected by the redistribution of water heat content in the area of the Norwegian and East Icelandic Currents, as well as by the position and sharpness of the frontal zones between Atlantic and Antarctic water masses. The paper considers variations in population structure and hydrographic conditions in 1950–1960 and 1990–2000: before and after collapse of the herring stock.

Keywords: herring, hydrography, migration, the Norwegian Sea, population structure.

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ICES CM 2005/O:33

Environmental, spatio-temporal and operational effects on long-line swordfish catch rates in the Eastern Mediterranean Sea

Dimitrios Damalas, M. Apostolopoulou, C. Yannopoulos, and P. Megalofonou

Generalized additive models (GAMs) were applied to examine the relative influence of environmental, spatio-temporal and operational factors on swordfish catch rates in the Greek swordfish long-line fishery during the period 1998–2004. GAM analysis accounted for 56% of the variance in nominal Catch-Per-Unit-Effort expressed in number of fish per 1000 hooks. Stepwise GAM building revealed the relative importance of nine variables ranked by decreasing magnitude: fishing gear type, sea surface temperature, week of year, bottom depth, distance from land, year, longitude, lunar index and latitude. Long-lines having deeper, thicker and more resilient branch lines with illuminated fish attractants yielded significantly higher swordfish catches. CPUE peaked at the sea surface temperatures 17° and 28° C, during the last quarter of the fishing season, at depths greater than 3000 m, around a buffer zone ten nautical miles distant from the coast and when the lunar disc illumination was high. Elevated relative abundance was observed in southern latitudes and eastern longitudes, corresponding to the Levantine region. No obvious indication of a decline in swordfish abundance was detected throughout the six years.

Keywords: swordfish, generalized additive models, CPUE, long-line, SST, lunar index.

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ICES CM 2005/O:34

Validation of a biophysical larvae drift, growth and survival model on anchovy in Biscay with a framework for its operational use

Pierre Petitgas, Pascal Lazure, and Patrick Grellier

A larvae growth and survival model that used a circulation model was developed for anchovy in Biscay to predict recruitment. The biophysical model predictions for the years 1997–1999 agreed with the recruitment series estimated by ICES in that period. The strong spatio-temporal pattern in the circulation model led to a working hypothesis on larvae survival in Biscay. Larvae that stayed on the shelf experienced higher growth and survival than larvae that crossed the shelf break into the outer ocean. The biophysical model was driven by biological field data and also simplified the drift processes. New data collected in recent years partly validated model assumptions and predictions. Tracking experiments of real drogues released at sea showed the dominance of advective (deterministic) movement over diffusive (turbulent) movement, validating the approach followed in modelling drift. Additional larvae and juveniles otolith growth data collected in 2003 validated the growth and survival pattern predicted by the biophysical model. A framework is presented and discussed for appreciating the reliability of the recruitment prediction as well as for making use of the prediction in building scenarios of population projection.

Keywords: biophysical model, validation, larval growth, recruitment, anchovy, Biscay.

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ICES CM 2005/O:35

Physical-biological factors affecting recruitment of small pelagic fish off Northwest African coast

Pavel P. Chernyshkov, N. M. Timoshenko, and A. M. Sirota

Recruitment variability is mainly insignificant in small pelagic fish of the low latitudes, except upwelling areas. So the direct assessment of young fish is very appropriate. Such assessment and its interpretation may be confused by a number of different conditions affecting survey results. Number of comprehensive surveys which were carried out off Northwest African coast in 2003–2005 demonstrated that interannual variability in recruitment abundance and distribution might be partly explained by environmental factors. The main factors are mesoscale physical processes (e.g., coastal upwelling, eddies and hydrographic fronts). Data of remote sensing (e.g., satellite altimetry) are good addition to the in situ measurements and allow revealing peculiarities of environmental conditions. The analysis revealed that in some cases interannual variability of the recruitment abundance index might be caused by cohort's abundance rate, while in the other cases the index was mostly influenced by survey conditions. Thus, it was quantitatively demonstrated that environmental share might prevail among all the other factors.

Keywords: small pelagic fish recruitment, environmental factors.

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ICES CM 2005/O:36

Application of satellite altimetry for fisheries research

Alexander M. Sirota, S. N. Burykin, and P. P. Chernyshkov

Ocean currents, hydrographic fronts and eddies as well as coastal upwelling are supposed to be an important demonstration of marine turbulence. Satellite altimetry data provide good possibility to reveal of these zones of high dynamic activity. The three oceanic regions were considered: Mid Atlantic Ridge (North Atlantic), Canary Upwelling Region (Eastern Central

Atlantic), and Southeast Pacific. Both satellite altimetry data (TOPEX/Poseidon, ERS -1, 2) and *in situ* measurements (oceanographic surveys) demonstrated good correlation between these two different types of data in revealing of dynamic features at the ocean surface. The main dynamic features in the regions are: Sub-Polar Front and North Atlantic Current (Mid Atlantic Ridge), Canary Current and coastal upwelling (Eastern Central Atlantic), Sub-Tropical Front and South Pacific Current (Southeast Pacific). Analysis of distribution, abundance and biological state of various fish species revealed the links between organisms and their dynamic environment in the considered regions. Variability of the distribution and abundance of rock grenadier over Mid Atlantic Ridge is closely connected to variations of Sub-Polar Front location. Mesoscale features of Canary Current and coastal upwelling influence distribution of small pelagic fish in Canary Upwelling Region. Sub-Tropical Front meandering and eddies in Southeast Pacific influence significantly horse mackerel distribution. Thus the peculiarities of dynamic features of the ocean surface which can be derived by satellite altimetry might be a good opportunities for fisheries research.

Keywords: dynamic features, satellite altimetry, distribution and abundance of fish.

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ICES CM 2005/O:37

How climate affects year-class strength: case studies for three Northeast Atlantic commercial fish stocks

Andrei S. Krovnin and G. P. Moury

The climatic situations leading to formation of favourable/unfavourable survival conditions for three Northeast Atlantic commercial fish stocks (Northeast Arctic cod and haddock, Norwegian spring-spawning herring) were analyzed. It was shown that the most favourable survival conditions for cod and haddock did not depend on the phase of the North Atlantic Oscillation (NAO), the leading climatic factor of the region. They were formed when the atmospheric pressure gradients over the Norwegian and Barents Seas were weak, and Icelandic Low and Azores High were located in their mean long-term position. The unfavourable survival conditions for these two stocks occurred in years with the sharpened pressure gradients and shift of both centers of action far to the east. Thus, the survival conditions for cod and haddock depend largely on the strength of atmospheric pressure gradients. For herring, the links were quite different. The favourable/unfavourable survival conditions resulting in appearance of strong/weak yearclasses occurred in years with the high/low values of the NAO index and did not depend on the pressure gradients. The results obtained are in contrast with the results of principal component analysis applied to the 50 climatic and biological time series for the 1960–2001 period. The later revealed the significant positive correlations between the NAO index and survival indices of three stocks under consideration. The mechanisms of climate impact on habitats of the above stocks are discussed.

Keywords: Northeast Arctic cod, Northeast Arctic haddock, Norwegian spring-spawning herring, survival conditions, North Atlantic Oscillation, atmospheric pressure gradients.

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ICES CM 2005/O:38

Using an empirical traffic light procedure for monitoring and forecasting in the Gulf of St Lawrence fishery for the snow crab, *Chionoecetes opilio*

J. F. Caddy, E. Wade, T. Surette, M. Hebert, and M. Moriyasu

A traffic light procedure is used for comparing temporal evolution of indicators of the snow crab (*Chionoecetes opilio*) abundance, fishery success and environmental change. Indicators related to recruitment success in the fishery between 1968 and 2003 were followed and comparisons with life history stages (in trawl surveys conducted over 15 years) allowed the temporal sequence of events in the life cycle. Although recruitment seems to be synchronized with bottom temperature, and may be related to abundance changes in groundfish predators, the main factors determining recruitment fluctuations appear to be density dependent interactions between life history stages. Establishing the abundance and timing of successive life

history stages using the traffic light approach seems to provide a reliable indication of their passage through the fishery, and might be used to make forecasts of the condition of the fishery several years ahead. The analyses raises the question of which of a number of possible density-dependent factors applies. Two management approaches by reference points and fisheries control rules are suggested.

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ICES CM 2005/O:39

Hotspots: Marine top predator foraging habitat predicted from a detailed understanding of temporal and spatial oceanographic processes

B. E. Scott, J. Sharples, O. Ross, and K. Camphuysen

Any fisherman can tell you there are ‘hotspots’ or areas where high densities of fish are likely to be found again and again. What makes these regions so predictive and interesting to fish and higher order predators? In a multi-disciplined EU study (IMPRESS) investigating the foraging habitat of seabirds with both field investigations and a use of long-term data, we found that seabird foraging patterns provided vital clues as to what particular physical aspects of the marine ecosystem are critical to defining ‘hotspots’ (regions where there are critical ecosystem linkages between the trophic layers). With spatially targeted at-sea observations of fish eating seabirds we were able to identify causal links with daily bird foraging behaviour and regionally and temporally specific physical characteristics. Using a 1-D bio-physical model parameterised with site-specific data, we produced a 30-year time series to characterised several temporal and spatial components of the annual primary production within the study area. The combination of our short and long term temporal investigations and our detailed spatial investigations provides insights into physical and biological reasons for the spatial connectivity of ecosystems.

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Abundance and potential fishing estimates of the deep-water red crab (*Chaceon affinis*) off the Azores

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This paper reviews the available abundance information on the deep-water red crab (*Chaceon affinis*) in the Azores. Data come from several exploratory fishing surveys and from some commercial experimental fishing carried out in the islands of the Central Group of the Azores archipelago since 1994. Sampled areas were stratified in coastal areas and banks/seamounts and also stratified by depth. An average abundance index was estimate for each of these aggregate areas by depth. An average abundance index was also estimate for the depth strata 500–900 m, considered as the preferential depth habitat of the species (mode of the depth distribution). Biomass of the species for the Azores EEZ was then estimated using the theoretical area of influence methodology (on the assumption that sampled areas are representative of all the potential area of the distribution of the species). MSY, interpreted as potential maximum sustainable yield, was then calculated using empirical methods for virgin resources. Results indicate that the total biomass for the Azores EEZ, for the base case, is around 73500 mt, (72 000 mt for banks/seamounts and 1500 mt for coastal areas) which correspond to a mean density of 2 individuals/1000m² and a potential maximum sustainable yield of 2205 mt. Sensibility analyses of some uncertain variables, like the theoretical radio of trap attraction and the exploitation rate, show that in the pessimist scenery is estimated a MSY of 398 mt and about 5512 mt under an optimistic one.

Keywords: Deep-water crab, abundance, biomass, potential catch, seamount

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Importance of variations in 0-group fish predation mortalities for recruitment success and implications for fisheries management

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Diet selection in the official ICES North Sea multi-species assessment tool 4M can be parameterized by two stomach data sets which are available from the "Years of the stomach" 1981 and 1991. Between these two stomach data years the North Sea ecosystem was subject to large changes caused by fisheries as well as the large scale bio-physical regime shift during the late 80s. The analysis of the 2 stomach data sets suggests that trophic flows in the upper level of the North Sea food web were substantially different before and after the regime shift.

In our paper we investigated the impact of variations in 0-group fish predation mortalities between these two different states of the North Sea ecosystem on the recruitment success of commercial important species. Differences in the feeding behaviour of predator species and in the availability of 0-group fish via changes in spatial predator-prey overlap between 1981 and 1991 were described. The strong impact of the observed changes in the higher trophic levels of the North Sea food web on recruitment success and on stock developments could be demonstrated by simulating a regime shift in the same order of magnitude as observed between 1981 and 1991 inside 4M. Consequences of the model results for current ICES fisheries management strategies (e.g., stock recovery plans, precautionary approach to fisheries management) were evaluated in a multi species context.

Keywords: MSVPA, predation, recruitment variability, regime shift, fisheries management.

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Characterisation of bottom sediment on *Nephrops norvegicus* (Decapoda: Nephropidae) grounds off the southwest and south-eastern coast of Portugal

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A study into the physical and biological characteristics of the sediment found on Norway lobster, *Nephrops norvegicus* (Linnaeus, 1758) grounds was carried out. Samples were collected during the "2004 Crustacean Survey", from designated locations off the southwest and south-eastern coast of Portugal at depths ranging from 250 to 650 m. All samples were collected with a (60 x 60 x 60) cm box-corer. Water content in all samples ranged between 36 and 59% in weight, with the mud sediment attaining higher values than sandy-mud. Total organic matter content varied between 2.5 and 4.5% in weight, with the highest values found in mud (i.e., sediment with more than 90% of the particles <63µm). Superimposition of sediment characteristics onto a map showing the estimated abundance and distribution of the Norway lobster, indicated that they occur more frequently on sandy-mud than in mud grounds. The invertebrate macro-faunal analysis has shown that polychaetes are the most abundant animal class found on these grounds, yet present results did not provide enough information for the characterisation of the macro-fauna associated to *N. norvegicus* habitat down to species level.

Keywords: *Nephrops norvegicus*, sediment, granulometry, S. Portugal, habitat, characterization, box-corer.

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Growth of juvenile three-spined stickleback (*Gasterosteus aculeatus*) sublethally exposed to harmful algal blooms in the Baltic Sea

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The frequency and intensity of harmful algal blooms of toxic cyanobacteria *Nodularia spumigena* appear to be increasing in the Baltic Sea. Thus, juvenile phases of several fish species may be exposed to the blooms. Three-spined stickleback (*Gasterosteus aculeatus* L.) is a short-lived, abundant planktivorous fish species in the Baltic Sea, which is also preyed upon by several economically important fish species. Sticklebacks spawn in June, and juvenile fishes spend their first year in the littoral zone, where they may confront *N. spumigena* blooms. *N. spumigena* may affect the fish in at least two ways: through a toxic effect, and through mechanical or visual interference on fish foraging success. We studied feeding and physiology of juvenile three-spined sticklebacks under exposure to *N. spumigena*. Juvenile three-spined sticklebacks were exposed for 15 days to *N. spumigena* through water and zooplankton diet. Food consumption was highest when feeding on cyanobacteria-exposed zooplankton. The escape behaviour of the copepods may have been affected by nodularin, which may make them easier to capture. The higher food intake did not produce higher growth rates, but the RNA:DNA-ratio and protein synthesis of the fishes was reduced. Thus, we suggest that a longer-term effect on juvenile fish in the littoral zone may arise through decreased condition and protein synthesis of the fish, which may have an effect on survival and recruitment.

Keywords: growth, nodularin, HAB, juvenile fish.

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The spawning of cod (*Gadus morhua* L.) in Eyjafjordur, N-Iceland and the survival of its larvae

Konrad Thorisson

The ichthyoplankton in Eyjafjordur, a fjord in N-Iceland, was studied at approximately monthly intervals during April-August 1992 and 1993. The spawning stock biomass of the Eyjafjordur component of cod is for the first time estimated here as 140 ± 90 tonnes, which constitutes about 0.1 % of the total spawning stock of the Icelandic cod. The spawning in Eyjafjordur takes place in the middle part of the fjord during April and May and the cod larvae hatch in late May and early June. In spring 1993 cod larvae may have starved as crustacean eggs and larvae of the appropriate size as first food were extremely rare during the first feeding period.

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Temporal patterns of settlement and dietary changes of 0-group cod, haddock and whiting

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Work on the early life history of gadoid fish has identified settlement, the transition from pelagic to demersal habitat, as a critical stage for the survival of juveniles and consequently for recruitment. It is believed that in this period important density-dependent processes may take place, such as competition for suitable substrate, refuge or prey. It is crucial to understand whether the successful settlers are a random subsample of the pelagic juvenile population or whether certain characteristics, based on the timing of arrival to nursery areas, size, condition, etc. favour specific subsets of the population. From May to August 2004, weekly demersal and pelagic sampling was conducted at an inshore site off the east coast of Scotland. Almost 3000 0-group fish belonging to 3 major gadoid species (cod, haddock and whiting) were collected. Comprehensive morphometric and dietary analyses of the samples were carried out. The results show that the transition from the pelagic to the demersal habitat was associated with clear and progressive changes in the prey composition of the

juvenile fish. In addition, the analysis of 0-group fish length in the samples throughout the settlement season suggested clear differences in the patterns of settlement between the different species.

Keywords: juvenile gadoids, settlement, 0- group cod, 0- group haddock, 0- group whiting

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Eastern Channel Habitat Atlas for Marine Resource Management (CHARM Phase I) to a process-oriented approach (phase II)

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The INTERREG IIIa funded CHARM phase I has described the spatial distribution of marine living resources and their habitats in relation to the environment of the Dover Strait and adjacent waters. Available data and related project's output were compiled into an atlas accompanied with a review of the policy and legal framework for the protection of marine living resources and their habitats in the study area. CHARM phase II will extend this initial effort to the Eastern English Channel and will use a process-oriented approach to further explain phase I's results and develop predictive tools for assessing management options. In Phase II, marine species habitat modelling will differentiate between juveniles and adults. Then, having gathered relevant fisheries statistics on commercial fish stocks, both habitat models and statistics will serve as forcing variables and inputs to an integrative spatially explicit modelling approach of the marine ecosystem of the area. Two types of models are foreseen: (i) a model of the Eastern English Channel ecosystem functioning using mass-balance food web models (Ecopath with Ecosim) and the habitat models previously developed (Ecospace) will be built in order to evaluate management scenarios; and (ii) a conservation plan for the Eastern English Channel using the MARXAN spatial planning software will be developed and should enable to identify important sites for conserving biodiversity, whilst using anthropological, economic and legal data to minimise potential opportunity costs. The outputs from the modelled scenarios in Ecopath and MARXAN may ultimately be used to develop a draft management strategy of the Eastern English Channel.

Keywords: Eastern English Channel, CHARM, marine ecosystem modelling, spatial conservation planning.

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