

## THEME SESSION

on

### Environment – Plankton – Fish Linkages (M)

#### ICES CM 2000/M:01

##### ***Prorocentrum lima* (Microalgae: Dinoflagellata): killer food for zooplankton**

C.C. Ajuzie and G.T. Houvenaghel

The toxicity of the microalga *Prorocentrum lima* and its probable toxic effects on zooplankton were tested using actively growing cells of *P. lima* and filtered culture medium of *P. lima* on *Artemia nauplii*. Filtered *P. lima* culture medium at concentrations  $\geq 50$  % killed the brine shrimps within 24 hours. Three days old brine shrimps consumed *P. lima* cells within 30 minutes following the introduction of the latter into wells holding the animals. Death of brine shrimps occurred from around 90 minutes onwards, following the introduction and consumption of the toxic cells. Older nauplii (3 days old) reacted readily and showed early responses from intoxications than younger nauplii (1 day old). A single *P. lima* cell in the gut of brine shrimp is enough to kill the animal. The probable cause of death in intoxicated brine shrimp is discussed.

Keywords: *Artemia* (brine shrimp), behaviour, culture medium, dehydration, gut contraction, microalga, *Prorocentrum lima*, zooplankton.

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#### ICES CM 2000/M:03

##### **Patterns in growth, ingestion and survival probability of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) larvae on Georges Bank**

L.J. Buckley, E.C. Caldaron, R.G. Lough, and T.L. Ong

The amount of RNA and DNA in individual larvae was used to estimate the condition, recent growth and survival probability of Atlantic cod and haddock larvae on Georges Bank. Sampling between 1992 and 1999 was concentrated in the months of April and May when larvae were most abundant on the southern flank, with more limited sampling in March. Distinct patterns in RNA-DNA ratios and growth were seen with larval size or age and water temperature. Recent growth increased with larval size after first feeding and approached an asymptotic level later in the larval period. Maximum variability in growth occurred within a size range corresponding to a brief period after yolk-sac absorption and feeding initiation. Growth increased with water temperature reaching maximum values of 0.15/d in May at about 7°C. Ingestion rates estimated using a bioenergetic model increased with temperature, however above 7°C the rate of increase was insufficient to meet the increasing metabolic costs and maintain rapid growth. These data suggest that growth was temperature limited below 7°C and food limited at higher temperatures. Survival probability was related to larval size and water temperature.

Keywords: cod, growth, haddock, ingestion, larvae, survival, temperature.

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## ICES CM 2000/M:04

### ***Calanus finmarchicus* in Icelandic waters: population genetics and ecology at the Norwegian Sea/N. Atlantic Ocean boundary**

A. Bucklin, O.S. Astthorsson, A. Gislason, and P.H. Wiebe

Large-scale circulation patterns in the N. Atlantic may partition the ocean basin into three semi-distinct gyre systems: the Norwegian Sea, the northern N. Atlantic, and the western N. Atlantic. Zooplankton entrained in these gyres may be ecologically, reproductively, and (perhaps) genetically distinct due to geographic isolation in different circulation systems and/or to isolation by distance. Ocean basin-scale genetic structuring of *C. finmarchicus*, and especially the boundary between the N. Atlantic and the Norwegian Sea, was a focus of our efforts during the Spring Surveys of the Marine Research Institute (Reykjavik, Iceland) in May/June, 1999 and 2000. Population genetic analysis demonstrated the differentiation of populations of *Calanus finmarchicus* in different water masses surrounding Iceland. DNA sequence variation of mitochondrial cytochrome oxidase I (mtCOI) and the nuclear gene encoding phosphoglucose isomerase (PGI) was evaluated using a suite of population genetic and statistical tests to quantify the genetic distinctiveness of populations and characterize population genetic structuring at the targeted scales. The distribution, abundance, and genetic variation of *C. finmarchicus* was placed in a realistic ocean setting, including water mass structure and ocean circulation patterns, in order to understand the interaction between zooplankton stocks and production and physical circulation patterns.

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## ICES CM 2000/M:05

### **Long term changes in the North Sea – A two-model system?**

R. Clark and C. Frid

We present data on long term trends from climatic, oceanographic and biotic time series for the North Sea area. Long term changes in the ecosystem appear to be forced by one of two models. In those areas of the North Sea which are predominantly influenced by Atlantic inflow (northern, central and western areas) long term changes in biological systems are primarily governed by changes in climate, while in the south eastern areas of the North Sea (the bights and the Danish coast) long term changes in the ecosystem are driven by changes in nutrient concentrations. Specifically, in the majority of the open North Sea area, climatic effects dominate and override the influence of nutrients, whereas in the southeastern North Sea, changes in nutrients have been of sufficient magnitude to control most aspects the ecosystem.

Secondary productivity (zooplankton, benthos, fish and bird communities) are, over the long term, mainly forced by changes in food supply, although there are exceptions. Consequently, secondary productivity is ultimately driven by one of these two models.

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## ICES CM 2000/M:06

### **Are the macrozooplankton populations in the Barents Sea controlled by predation?**

P. Dalpadado, B. Bogstad, N. Borkner H. Gjøsæter, S. Mehl, and H.R. Skjoldal

There appear to be strong predator-prey interrelationships between macrozooplankton (krill and amphipods) and their main predators (capelin and cod) in the Barents Sea. Some of the evidence for is already published, and some is

intended for publication in the near future. The results show an inverse relationship between the krill and amphipod biomass and the stock size of capelin in the Barents Sea. In the mid 80s and 90s, when capelin stock was at extremely low levels, cod switched from capelin to alternative prey such as amphipods and krill. Cod growth was slower at time periods with low capelin abundance. In the present ICES paper these zooplankton data are supplemented with the data from recent years. We intend to synthesize these results and discuss these in relation to physical parameters such as advection and temperature. Our aim is to improve the understanding of zooplankton-fish interactions in the Barents Sea Ecosystem.

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## **ICES CM 2000/M:07**

### **The effects of *Calanus* on the recruitment, survival and condition of cod and haddock on the Scotian Shelf**

K.F. Drinkwater, K.T. Frank, and B. Petrie

An exploratory correlation analysis between zooplankton abundance and cod and haddock recruitment, survival and growth are presented. The zooplankton data were collected by the continuous plankton recorder (CPR), which is towed at approximately 7-m depth from commercial ships at regular monthly intervals along fixed routes. Data are averaged over the northeastern and southwestern portions of the Shelf. The CPR data were collected during 1961–75 and from 1991 to present. The zooplankton indices included the abundance of *Calanus finmarchicus* (averaged over stages 1–4 and over stages 5–6), *Paracalanus* and *Psuedocalanus*. The abundance of cod and haddock in the southwestern and northeastern Scotian Shelf were obtained from the virtual population analysis estimates. Results indicate a statistically significant negative relationship between the early stages (1–4) of *Calanus finmarchicus* and the recruitment and survival of cod and haddock on the northeastern Scotian Shelf. In addition, residuals from a Ricker stock and recruitment relationship were negatively correlated with *Calanus finmarchicus* stages 1–4. The larger *Calanus* were only significantly correlated with condition of haddock on the southwestern Scotian Shelf. The only statistically significant correlation with *Paracalanus* was with haddock recruitment in the northeastern shelf region. The possible mechanisms behind the negative correlations between zooplankton and fish are explored.

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## **ICES CM 2000/M:08**

### **Measurements and modelling of ocean climate and zooplankton in the Barents Sea**

A. Edvardsen, D. Slagstad, K.S. Tande, and P. Jaccard

The coastal shelf of northern Norway and the Barents Sea is a highly productive area, with a food chain in which phytoplankton and zooplankton supports the recruitment of major fish stocks such as herring, capelin and cod. This area is a highly advective one, mainly perturbed by the North Atlantic Current and the Norwegian Coastal Current, which is an important factor for spatial and temporal distribution of zooplankton. This work was conducted along the western border of the Barents Sea repeatedly during 1998 and 1999. We implemented a new approach to study the interaction between zooplankton; vertical migration and advection using technology like Scanfish-OPC-ADCP-MOCNESS and hydrodynamical models. Zooplankton community structure was monitored by net tows and zooplankton abundance fields were mapped using an Optical Plankton Counter (OPC) counting copepodide life stages CIII-CV of *Calanus finmarchicus*, which is the major contributors to the dietary input of planktivorous fish in this region.

Current fields were measured by a ship mounted ADCP and the residual current fields were calculated by subtracting the tidal component obtained from a hydrodynamical model. The flux of zooplankton during each cruise was calculated by combining the zooplankton- and residual current fields.

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## **ICES CM 2000/M:09**

### **On the food of herring in the western part of the Norwegian Sea**

A. Gislason and O. S. Astthorsson

The food of herring (*Clupea harengus*) was studied in the western part of the Norwegian Sea, where the Norwegian spring spawning herring migrate for feeding during summer. The material was collected on 3 cruises in 1995 (April, May, June) and 2 cruises in 1996 (May, June). A total of 653 stomachs of herring ranging in length from 24.0 to 39.0 cm were examined. Of these 622 or 95% were found to contain food. The proportion of stomachs with food was lowest in April, and highest in May and June, indicating that the main food intake took place during May and June. As judged from the mean stomach fullness the herring fed mainly during the night. Copepods (mainly *Calanus finmarchicus*, *C. hyperboreus* and *Metridia longa*) were most important prey of herring, both in terms of weight and biomass. In June Amphipods (mainly *Themisto abyssorum*) were also important in the diet. The relations between herring migrations and the distribution and seasonal abundance of zooplankton are discussed. The food of herring was found to be largely similar to the composition of zooplankton in the sea.

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## **ICES CM 2000/M:10**

### **Interannual variations in hydrography and spring bloom dynamics, and their effect on *Calanus finmarchicus* distribution and reproduction on the Scotian Shelf in the late '90s and 2000**

E. Head

The eastern Scotian Shelf (SS) has as its upstream source the Gulf of St. Lawrence, (GSL), whereas the mid-central and western SS are influenced by the Nova Scotia Current and by springtime intrusions of water from offshore. Both the GSL and offshore are springtime sources of overwintered *Calanus finmarchicus* and for the latter, the degree of penetration on to the shelf appears to be linked to the position of the Gulf Stream in a given year. Reproduction always starts later for the population on the eastern SS than for the one in the west, which may be due to temperature differences or to the earlier arousal of the offshore population. In 1999, an unusually early occurrence of the spring bloom on the eastern SS apparently led to an early onset of reproduction in *C. finmarchicus*. In 2000, water temperatures were generally warmer than those seen in the 90s: the effect on the *C. finmarchicus* populations is being examined.

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## **ICES CM 2000/M:12**

### **The role of plankton fluctuations in the production of pelagic fishes in a sensitive ecosystem**

A.E. Kideys

Since the last few decades, striking changes have been occurring in the pelagic ecosystem of the Black Sea. These changes which are mainly induced by man are particularly striking at the planktonic level. The overall impact is the

fluctuations seen in the catches of this commercially important pelagic fishery. Here I present what the main changes in plankton are and how these affect the commercially important pelagic fishery in the Black Sea.

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### **ICES CM 2000/M:13**

#### **Seasonal variation of plankton dynamics in the Kuroshio extension region based on a 3-D ecosystem model**

K. Komatsu, Y. Matsukawa, K. Nakata, T. Ichikawa, and K. Sasaki

An ecosystem model was developed to be incorporated biological processes of lower trophic level into a three-dimensional physical primitive model, and applied to the Kuroshio extension region in the northwest Pacific where most of winter-spawned larvae of Pacific saury (*Cololabis saira*) are distributed.

Mesoscale eddies and meander around the extension were appropriately reproduced, and biological results responded to the temporal change of physical field and indicated strong sensitivity to wavelength of the meander and depth of the mixed layer. In comparison of model estimates with observed values by research vessels in meridional cross sections across the extension, the supply of nutrient from lower layer was richer especially in the north-side of the ridge of meander, and the model showed chlorophyll maximum at surface in spring and at sub-surface in summer as well as observations. The model also simulated the almost similar seasonal variation and spatial distribution of zooplankton biomass, which is one of important factors responsible for growth and mortality of saury larvae.

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### **ICES CM 2000/M:14**

#### **Plankton size distribution and predator-prey relationship in the Belgian coastal zone**

A. M'harzi, S. De Galan, M. Tackx, M.H. Daro, and L. Goeyens

Distribution of phytoplankton around several sandbanks of the Belgian Coast was investigated in February 1995 and 1997. The TWINSPAN dendrogram, for the 2 years, shows a clear separation of cluster, corresponding to different sandbanks. The nearshore banks phytoplankton community structure differed significantly in terms of species composition from the offshore Banks.

Canonical Correspondence Analysis (CCA) of the phytoplankton data-set revealed, that beside temperature, salinity and turbidity, the nutrient concentration (NO<sub>2</sub>-) contributed substantially to explain the variance in phytoplankton species. The observed differences in phytoplankton species distribution could be explained by the position of the sandbanks.

Westhinder, Oostdyck and Oosthinder are positioned further from the coast than Kwintebank, Middelkerke, and Stroombank, and the plankton community over Westhinder, Oostdyck, and Oosthinder are clearly influenced by the Atlantic current penetrating the southern North Sea from the English Channel.

The sub-areas, which were separated based on phytoplankton species composition, also displayed a different situation with regard to the biomass size spectra and the potential trophic transfer between phytoplankton and zooplankton.

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## ICES CM 2000/M:15

### **Environmental forcing of zooplankton variability on Georges Bank**

D. Mountain, J. Kane, and J. Green

Plankton and hydrographic measurements from Georges Bank over the last 25 years indicate a close relationship between salinity and the abundance of zooplankton during the spring. Both time series also exhibit significant relationships with the North Atlantic Oscillation (NAO). The salinity may be a proxy for physical processes or conditions that influence the zooplankton abundance. Analysis of the salinity data indicates that the variability is associated with different physical processes at different times. Finding a consistent mechanistic connection between NAO variability and physical processes that would control salinity and have a realistic linkage to zooplankton variability is difficult. Identifying which parts of the apparent relationships represent true forcing-response connections and which may be simply fortuitous is the subject of the discussion.

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## ICES CM 2000/M:16

### **Interannual variations of the amount of herring in relation to plankton biomass and activity, temperature and cloud coverage in the Baltic Sea**

L. Postel

Herring biomass in the ICES Sub-divisions 22, 24–32, compiled by (Thurow 1997), depend on eutrophication of the Baltic Sea during the 20th century. Superimposed, there are interannual variations, which coincide with those of mesoplankton biomass and phytoplankton activity (production index), temperature (SST, air [near bottom]) and cloud coverage. The latter fits with the amount and phase of the galactic cosmic ray flux as described by Svensmark and Friis-Christensen (1997) and Svensmark (1998).

Keywords: activity, Baltic Sea, cloud coverage, galactic cosmic ray flux variations of herring biomass, plankton biomass, temperature, 1972 to 1992.

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## ICES CM 2000 M:17

### **The effect of spatial and temporal variations zooplankton concentrations on larval cod growth and survival on Georges Bank: a sensitivity analysis based on modelling and observations**

J. Runge, J. Quinlan, E. Durbin, L. Incze, G. Lough, J. Manning, D. Mountain, B. Niehoff, S. Plourde, and F. Werner

The U.S. GLOBEC Georges Bank/NW Atlantic program has generated an unprecedented body of data on vital rates, abundance and distribution of zooplankton and ichthyoplankton on Georges Bank. Concurrent with the data-gathering activity has been the development and refinement of coupled a physical-trophodynamic model describing survival and distribution of larval cod and haddock. Using zooplankton data from the Georges Bank broadscale cruises, we expand the biological model to include a 3-D and time-dependent description of the zooplankton prey field to address hypotheses linking interannual variations in copepod production on the Bank to growth of cod larvae. Prey concentrations are interpolated between monthly broadscale cruises applying species specific rates of reproduction, growth and mortality obtained from process cruise measurements and literature values. We determine when and where prey concentrations were limiting larval fish growth and we examine the sensitivity of modelled growth rates to realistic variations in egg production and naupliar concentrations of dominant copepod species, including *Calanus finmarchicus* and *Pseudocalanus* spp.

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## **ICES CM 2000/M:18**

### **Decadal plankton changes on the eastern Nova Scotian Shelf and western North Atlantic**

D. Sameoto

A comparison study of the phytoplankton colour index, selected phytoplankton and zooplankton taxa from the eastern Scotian Shelf (CPR E-line) and from the Northwest Atlantic (CPR Z-line) showed a significant similarity in yearly abundance changes. It is suggested that environmental changes, influencing both regions, are causing the organisms to respond in a quasi-synchronous manner. Changes in abundance of the population of *C. finmarchicus* in the Northwest Atlantic were correlated with the abundance of *C. finmarchicus* on the Scotian Shelf. This correlation could be explained if the populations of *C. finmarchicus* from the Northwest Atlantic contribute to the reproducing population of *C. finmarchicus* on the eastern Scotian Shelf. The period between 1991 and 1998 was a period of high levels of phytoplankton colour index and low levels of *C. finmarchicus* and euphausiids on both CPR lines.

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## **ICES CM 2000/M:19**

### **Zooplankton as an ecological indicator in a fish stock recovery assessment**

K. Sherman, J. Kane, S. Murawski, W. Overholtz, and A. Solow

Spatial and temporal biomass and species diversity time-series of zooplankton have been examined in a continental shelf ecosystem for indications of variability in abundance levels associated with effort reduction management actions for the recovery of depleted bottom fish stocks. Analyses were conducted on 15,000 zooplankton samples collected seasonally over two decades from the U.S. Northeast Shelf ecosystem (1970s to 1999). Fish stock results were obtained from the Northeast Fisheries Science Center's bottom trawl survey indices of spawning biomass of selected demersal (cod, haddock, yellowtail flounder) and pelagic (herring and mackerel) fish species. Following a decline in the late 1970s, the emerging pattern of the zooplankton component of the ecosystem showed a robust upward trend with the capacity to support recovery of early life and adult stages of herring and mackerel in the mid-1980s and the early life stages of cod, haddock, and yellowtail in the late 1990s.

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## ICES CM 2000/M:20

### Regional dynamics of *Calanus* in the Norwegian Sea in response to ocean climate in 1997

D. Slagstad, K. Tande, W. Melle, B. Ellertsen, and F. Carlotti

A coupled 3D hydrodynamic and ecological model has been set up for the Norwegian Sea (i.e. SINMOD). The hydrodynamic model uses the z-coordinates in the vertical direction. The horizontal grid point distance is 6.67 km and covers the northern North Sea, Mid Norwegian Shelf, Lofoten Basin, and Faroes Shelf. The western limit is just at the eastern boarder of the Icelandic Shelf. The open boundaries are taken from a regional model using 20-km grid resolution. The models have been forced with atmospheric input from 6 hourly wind and pressure fields. The ecological model has eight state variables in addition to a structured model of *Calanus finmarchicus*. The state variables are nitrate, ammonium, silicate, diatoms, flagellates, microzooplankton, and slow and fast sinking detritus. The *Calanus* model uses developmental structure for the nauplii and weight structure for the copepodites. Data from Station M (66°N, 2°E) has been used to adjust the mortality rates of *Calanus*. 10% of the CV's are allowed to develop into females and start a new generation and the remaining 90% is transferred into an overwintering stage having a depth distribution between 500 and 1500m. The overwintering stock of *Calanus* at Station M below 600m was taken as an initial distribution for the whole model domain (north of the Scotland-Iceland ridge). The model simulates the pattern of phytoplankton growth, which is in accordance with observational data from several cruises in the region during the year of *Calanus*. An early start (March/April) in the Coastal Norwegian waters and at the front between the coastal water and the Atlantic waters was found. The spring bloom starts gradually later West and North in the Norwegian Sea. The earliest spawning took place near the shelf break off Norway where ascending *Calanus* met the spring bloom in surface waters. At Station M the timing of the spring bloom and the successive copepodite stages are simulated correctly. The simulated second generation is two weeks earlier than observed in field data. However, there is a large heterogeneity around this position in the Norwegian Sea on the southwestern slope of the Vøring Plateau. Coastal water and perhaps water from the East Iceland Current may change the property (vertical mixing and nutrient supply) and the history of the *Calanus* stock entering this geographical region. Two generations are of *Calanus* simulated in the southeastern part of the Norwegian Sea. Along the shelf break the second generation is advected as far north as the entrance to the Barents Sea. In the Northern North Sea the temperature and the supply of food is sufficient for the model to produce three generations.

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## ICES CM 2000/M:21

### How to get more fish: ecosystem and environmental options

J. H. Steele

Linear network analysis of a simple (10 box) food web is used to explore options for increasing biomass of fish stocks corresponding to past pristine, or future well-managed ecosystems. The options include; older fish; no "jellies"; minimal benthic invertebrate predators; increased primary production; decreased microbial loop (detritus). The general conclusion is that no single option gives much more than a doubling of fish biomass, and a concatenation of options seems unlikely.

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## ICES CM 2000/M:23

### Geographical variation of Chl-a seasonality, and its interannual variation in the subarctic North Pacific Ocean

K. Tadokoro, T. Saino, and T. Sugimoto

To make understood clearly the geographical variability of Chl-a seasonality in the subarctic North Pacific Ocean, we compared the seasonal variation of biological and physical conditions among waters. The spring blooming appeared in the Oyashio, sea of Okhotsk, Bering shelf water. On the other hand, western, central, eastern pacific, and Bering basin water did not have spring blooming. MLD (mixed layer depth) of the Oyashio and sea of Okhotsk was reached at 40m depth at April due to decrease salinity. However, the MLD of western, central, eastern pacific, and Bering basin still existed below 100m depth at April. The timing of the seasonal pycnocline formation may play important role for the Chl-a seasonality in the subarctic North Pacific. The climatic regime shift occurred during mid 1970s and subarctic circulation accelerated in the North Pacific Ocean. Consequently advection from the Okhotsk Sea to the Oyashio water enhanced. In the Oyashio water, sea surface salinity decreased, and Chl-a concentration of April increased from mid 1970s. There is possibility that the low saline water advected from the Okhotsk Sea acts the development of seasonal pycnocline formation, and causes high Chl-a concentration from mid 1970s in the Oyashio water.

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## ICES CM 2000/M:24

### Modelling growth and advection of larval cod and haddock on Georges Bank in evolving flow and prey fields: a synthesis of observations and model results for spring 1995

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Surveys conducted as part of the U.S. GLOBEC/NW Atlantic program from March-June 1995, encountered a large number of cod and haddock eggs and larvae on the Northeast Peak of Georges Bank. These cohorts were sampled for three months as they were transported along the Southern Flank of the Bank. Detailed information was obtained on larval abundance and growth, and the space-time structure of the zooplankton prey field and hydrography. These data are being synthesized and interpreted using spatially explicit physical and biological numerical models. We present the results of our efforts examining the growth and survivorship of the larval fish cohorts using individual-based models (IBM) embedded in realistic, dynamic copepod prey and hydrodynamic flow fields. Our larval fish IBM includes considerations of turbulence, light, prey choice and behaviour. Our copepod prey field includes naupliar and copepodite stages of major species of copepods on the Bank (including Pseudocalanus, Calanus, Centropages and Oithona).

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## ICES CM 2000/M:25 (Poster)

### Sound scattering from macrozooplankton aggregations off Patagonia at 38 kHz

G.L.A. Colombo and A.O. Madirolas

During a series of routine annual surveys for fish abundance estimation off the South Patagonian Shelf (Argentina), additional acoustic and plankton sampling was performed every year along a transect established at the 51°LS. The spatial distribution and aggregation pattern of macrozooplanktonic concentrations was studied utilising 38 kHz acoustic data. Large plankton scattering layers were detected and its species composition identified. The scattering layers occupied mainly the 25–50 m depth range during night hours, ascending rapidly to the surface at dawn and vanishing at the beginning of the day. No scattering layers were detected during daytime. Correspondence between plankton samples and echorecordings revealed hyperiid amphipods as the main scattering source at the working frequency. The results obtained in this work point out the potential of fish assessment surveys databases as a source of information for the study of the abundance of macrozooplankton in the Argentine shelf.

Keywords: Acoustics, euphausiids, *Euphausia lucens*, *Euphausia vallentini*, hyperiid amphipods, macrozooplankton, Southwest Atlantic, spatial distribution, *Themisto gaudichaudii*, vertical migration, 38 kHz.

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## ICES CM 2000/M:26 (Poster)

### Carrying capacity of apex predators and the frequency and cadence of physical forcing in marine food webs

K. Aydin, P. Livingston, and R.C. Francis

Carrying Capacity has been defined as the maximum biomass "supportable" for a given level of primary productivity. For apex predators, this supportable biomass is also a function of the food web's structure. Current discussions emphasize that carrying capacity may change as part of a "regime shift." In this frame of reference, a shift in primary productivity may be considered to be an alternation between two carrying capacities. However, if the change represents an oscillation, changes in the food web structure or an apex predator's long-term carrying capacity will depend not only on the amplitude of the oscillation, but on its frequency and cadence, where cadence is defined as the sequencing of the extremes of productivity. In this paper, we examine quantitative models of several North Pacific marine food webs. The ecosystems range from the Bering Sea to subarctic and subtropical gyres to the Eastern

Tropical Pacific. Each ecosystem has been hypothesized to respond differently to ENSO and decadal scales of physical variation. For each model, we determine a "static" carrying capacity for apex predators or the biomass supportable if primary productivity remained constant. Then, we manipulate each system by varying the frequency and amplitude of primary production to ask, "on what scale of variation does each ecosystem maximize production?" The results are compared to changes in frequency, amplitude and cadence of forcing that may be expected under scenarios of long-term climate change, and under fishing pressure, which may not have evolved to take advantage of the natural variation within the system.

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## ICES CM 2000/M:27 (Poster)

### The seasonal cycle of nitrate supply and potential new production in the Gulf of Maine and Georges Bank regions

J. J. Bisagni

Total primary production in the World Ocean may be divided into "new" and "regenerated" based upon the source of nitrogen. Allocthonous nitrogen (NO<sub>3</sub>) input into the Gulf of Maine and Georges Bank regions results from horizontal and/or vertical transport of NO<sub>3</sub> into the euphotic zone, river input, atmospheric deposition and nitrification.

Autochthonous nitrogen (NH<sub>4</sub>) input results from recycling by biota within the water column and sediments. In the absence of allochthonous nitrogen, any marine ecosystem will eventually become non-sustainable due to export of nitrogen through sinking of biogenic material, harvesting activities, and predation from migratory pelagic species. The Gulf of Maine and Georges Bank are regarded as highly productive from the standpoint of primary production and fisheries. However, despite high levels of primary productivity and fish production on Georges Bank, rates of secondary production are lower than expected based on values from other productive seas. Hypotheses put forth to explain observed lower secondary production on Georges Bank are 1) advective losses of zooplankton, and 2) nitrogen limitation. In an effort to detect the presence of nitrogen limitation and to better understand apparent lower secondary production over Georges Bank, amounts of new and regenerated primary production are estimated using a quantity which has been termed "potential new production" (PNP). PNP can be estimated through vertical integration of NO<sub>3</sub> from the surface to the maximum depth of the euphotic zone (Z<sub>e</sub>), usually taken as the depth of the 1% PAR light level, assuming that all NO<sub>3</sub> is eventually used by the phytoplankton. This paper reports on work to determine the seasonal cycle of new primary production over the Gulf of Maine and Georges Bank using PNP as a proxy for new primary production.

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### **ICES CM 2000/M:28 (Poster)**

#### **Large scale interaction between sea ice dynamics and zooplankton community off east Antarctica**

S. Chiba, T. Ishimaru, G.W. Hosie, and M. Fukuchi

Yearly interaction between zooplankton community structure and environmental change off east Antarctica (90–160° BE) was studied, using zooplankton net samples taken in March during 1988–1996 by Japanese Antarctic Research Expeditions (JARE). Copepods-based community dominated, accounting for more than 80 % to total numerical abundance. Annual mean abundance of most of zooplankton species varied in a same manner. The abundance, except of salps, increased in years when distance of sea ice retreat during spring-summer was large, but markedly dropped in years of the least sea ice retreat. As minimum sea ice retreat during spring-summer indicates an ice-edge bloom of limited scale, it is indicated that production of copepod-based zooplankton community but salp-based one depended on rich phytoplankton resources derived on ice-edge bloom. Since negative correlation between yearly variability of Antarctic krill recruitment and salp biomass has been reported in relation to the seaice dynamics around the Antarctic Peninsula/Weddell Sea Region, effects of sea ice decrease due to global warming on krill-based Antarctic marine ecosystem is attracting scientific attentions. This study demonstrated that the similar interaction might exist between salps and copepods off east Antarctica where krill biomass was scarce. Pattern of yearly sea ice dynamics and Antarctic Circumpolar Wave (ACW) will also be discussed in the presentation.

Keywords: Antarctic Ocean, JARE, salps, sea ice, zooplankton community.

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### **ICES CM 2000/M:29 (Poster)**

#### **Reasons of plankton biomass dynamics in the southern Barents Sea**

S.S. Drobysheva and V.N. Nesterova

Based on regular plankton and hydrographic investigations having been conducted in the Barents Sea since 1959 we described the dynamics of prevailed species *Calanus finmarchicus* biomass against long-term fluctuations in the Barents Sea hydrological regime and stock variations of abundant fish consumers - cod and capelin.

Stable and unstable periods of plankton biomass variations with different mean annual value and range of interannual fluctuations have been revealed. The cold period of 1967–1981 was characterized by low mean annual level of biomass amounting to 150 mg/m<sup>3</sup> and its interannual variations not more than in 2-3 times; in relatively warm periods of 1952–1965 and 1982–1988 the increase in mean biomass up to 300 mg/m<sup>3</sup> and significant interannual fluctuations (to 6 times), that was indicative of instability of the biomass level, were typical.

Obviously, periodical variations of trends are caused by variation in the conditions of forming plankton production - the condition of water masses and intensity of their consumption by fish. The extent of each factor effect and their priority periodically varied. It is evidenced by the synchronism of the fluctuations of water temperature and *C. finmarchicus* biomass in the stable period and its disturbance in the unstable one. The latter was depressive for the main consumers of plankton.

The specific relationship of *C. finmarchicus* biomass with the temperature of Atlantic waters and fish abundance in different periods of interannual variations were considered on the basis of correlation analysis. The analysis showed that the advection of Atlantic waters determined constant recruitment of stock and, hence, boreal status of plankton in the southern Barents Sea, but the biomass level was regulated by biotic factor.

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### **ICES CM 2000/M:30 (Poster)**

#### **Phytoplankton biomass across and along the Angola-Benguela Frontal Zone in April 1999**

D.S. Neto, B.B. Sangolay, C.A. Ruby, M.L. Silva, and H.S. Marques

Environmental changes affecting distribution and dynamic of phytoplankton biomass exert an important influence on fish stocks. This study intends to contribute to the knowledge of phytoplankton distribution across and along the Angola-Benguela Frontal Zone (9.00S, 23.10S). Samples were collected (on board of German R/V 'Poseidon', April 1999), at three depths in each CTD station, at the maximum (at 20–50 m) and near the two extreme values (at 5–20, and 50–90 m) of the range of the fluorescence curve of chlorophyll-a (chl-a). Nutrients and oxygen, chl-a, phaeopigments (phaeo) concentrations and phytoplankton were determined. At low irradiance, phytoplanktonic organisms were found between 5–10 m in the water column and at high irradiance, or during the night, they were found deeper (40–50 m).

Chl-a concentrations suggest that phytoplankton biomass was more concentrated on the Angola Dome region (8.50 S, 8.00 E.) and on the upwelling zone (15.00 S-17.00 S). Generally, a higher concentration of chl-a was found at 20–50 m however, the highest value was recorded during the day at 50–90 m (11.59 S, 12.10 E). Generally, phaeo were significantly higher than chl-a. The high quantity of detritus in the Angola waters could explain the high concentration of phaeo, as a result of chl-a deterioration. Flagellates and dinoflagellates dominated in Open Ocean and along the Angolan coast, and diatoms in the Namibian waters. The high quantity of dinoflagellates and flagellates observed in Angolan waters suggest a high probability of blooms.

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### **ICES CM 2000/M:31 (Poster)**

#### **Peculiarities of feeding behaviour in Arcto-Norwegian cod when major food objects are in deficiency**

E. Orlova, A. Dolgov, V. Nesterova, M. Antsiferov, and L. Konstantinova

Materials on feeding, distribution and fatness of cod systemized for the period 1980–1990 (data from literature and the authors' data) have reflected a wide range of conditions for its foraging and feeding adaptation. Types of cod foraging are distinguished depending on supply with the main food object - capelin. Peculiarities are revealed in its feeding when capelin are in deficiency (1986–1988, 1995, 1997–1998) which are accompanied with a low fatness of cod. Under these conditions an increased accessibility of capelin during specific years was a compensatory factor that has contributed to maintaining of a high level of fat content in fish liver (to 53 %), being close to that during an intensive feeding on capelin.

Variation in role of other food objects, caused by an overlapping of their areas with cod, is shown for some years with different temperature regimes. Due to intensive transition of predators to other food objects (redfish, non-target species, macroplankton and benthos) there were seasonal variations in periods and extension of feeding migration of cod related to biological peculiarities and behaviour of food objects.

Higher importance of macroplanktonic crustaceans (Euphausiidae, Gyperiidae) in feeding of cod, usual at a low abundance of capelin, has been established to increase even more during the moderate and cold years owing to a retarded development of crustaceans, successive formation of near-bottom concentrations in the direction from the west to the east. The most favourable conditions of cod feeding during autumn are formed at a high accessibility of polar cod; its seasonal consumption during a fall in water temperature, when linear and weight growth of fish terminates, is usually accompanied with a sharp increase in cod fatness.

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### **ICES CM 2000/M:32 (Poster)**

#### **Some features of distribution and feeding of the Atlantic herring (*Clupea harengus harengus*) in the Barents Sea**

E. Orlova, E. Seliverstova, and V. Nesterova

Based on the long-term data on local concentrations of immature Atlantic herring in the Barents Sea (1985–1996) peculiarities of their vertical and horizontal distribution depending on the temperature conditions are shown. A clear connection of herring distribution with food supply status (Copepoda, Euphausiidae) in the main areas of their habitation has been revealed. The dependence of herring vertical distribution and their feeding activity on the fatness and food supply has been established. The conclusions concerning the variability of copepod plankton role in herring feeding due to the differences of temperature conditions in the period of herring wintering and copepod accessibility because of seasonal variations in their development, another food availability, possible herring competition with capelin have been drawn.

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### **ICES CM 2000/M:33 (Poster)**

#### **Rapid variations of the Norwegian Sea water heat content during 1995–1999 and their influence on condition of the feeding plankton**

E. Sentyabov and N. Plekhanova

Temperature condition dynamics in the Norwegian Sea Atlantic waters in late 90s was characterized by the transition from cooling in 1995–1997 to significant warming in 1998–1999. That occurred against a temperature rise having been in progress since early 90s and reaching its maximum in 1997–1998 in the NorthEast Atlantic. This paper considers the main reasons of these variations connected with the atmospheric processes and their influence on seasonal development and the distribution of important food object - *Calanus finmarchicus*.

In cold 1995–1997 the spawning of *Calanus* was delayed, in June naupliuses were only registered in the Faeroes area. Water warming in the two following years was accompanied by earlier biological spring and the wider distribution of juvenile *C. finmarchicus* to the open sea. In these warm years east distribution of plankton elder age groups, the main component in pelagic fish feeding, was recorded, that also stipulated blue whiting and mackerel migration tracks becoming displaced. In 1996–1997 the redistribution of heat advection along the Norwegian Current branches alongside with the decrease in Atlantic water temperature was observed. The east branch was colder, and the west one – warmer, than usually. The situation turned out resulted in main *C. finmarchicus* concentrations shifting to the central Norwegian Sea.

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