

Theme Session G

Linking oceanographic physical features with biological production and fish habitat potentials

ICES CM 2007/G:01

Linking water column structure, phytoplankton distributions and planktonic productivity: predator behaviors are a key ingredient

Susanne Menden-Deuer

Layers of high plankton concentrations, bordered by steep gradients, termed plankton-rich layers (PRLs) were characterized with respect to their spatial and temporal extent and potential importance to planktonic productivity in a shallow fjord in the Northeastern Pacific (East Sound, Washington, USA). These naturally-forming phytoplankton patches provided a large scale (km, days) system to test hypotheses suggested by prior laboratory and modeling results which indicate that estimates of trophic and demographic rates of phytoplankton-consuming protists are enhanced by over an order of magnitude when their foraging behaviors are accounted for (Menden-Deuer & Grünbaum, 2006). The diatom genus *Chaetoceros* dominated phytoplankton biomass, whereas heterotrophic protist biomass was dominated by thecate dinoflagellates with oligotrich ciliates and athecate dinoflagellates at times abundant. Different processes drove phytoplankton and heterotrophic protist distributions: phytoplankton species were found throughout the water column (although in different concentrations), whereas heterotrophic protists were aggregated by and large within PRLs when present. Phytoplankton prey within PRLs uniformly exceeded dominant predators' survival threshold, whereas prey concentrations outside PRLs were insufficient to support growth in any but three samples. As predicted, spatially concentrated prey and predators' ability to locate prey fundamentally altered trophic dynamics within the system. PRLs would have served as the only prey source to heterotrophic protists and led to locally much higher ingestion rates than predicted based on average prey concentrations. Therefore, prey distribution and more importantly predator foraging behaviors have important ramifications for ecosystem productivity and the transfer of organic matter and energy to higher order food-chain components.

Keywords: plankton, productivity, predators, behaviors, distributions, model.

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ICES CM2007/G:02

Estuarine habitat dynamics and telemetered movements of three pelagic fishes: Scale, complexity, behavioral flexibility and the development of an ecophysiological framework

John P Manderson, J. Pessutti, J Rosendale, and B Phelan

Movements of fish across seascapes should reflect the management of physiological and fitness requirements in the context of spatial habitat dynamics. We released acoustically tagged Striped bass (N=34), Bluefish (N=29) and Weakfish (N=15) in a New Jersey, USA estuarine observatory (~900 hectares) in which moored acoustic receivers, physical probes and rapid habitat surveys allowed measurement of movement responses to habitat dynamics at space/time scales of 350m to 10km and 10mins to months. Age 1+ bluefish and striped bass used the observatory for a median of ~20d; weakfish and age-0 bluefish for ~36d. Individuals of all three species responded to habitat dynamics at two space/time scales. Individuals moved over distances of 350m to 2km at minute to 12hr time scales and these "daily home range" excursions often entrained tidal and/or day-night cycles. Animals often moved from deep habitats to marsh creeks or ecotones defined by steep gradients in salinity and primary productivity. However, new cycles of movement within daily home ranges, home range expansions, or broad scale searches and establishments of daily home ranges in new locations occurred during episodes when freshwater discharge, seasonal temperature, or anthropogenic disturbance were high. Our observations suggest that animals adapted to meet fitness requirements on seascapes in which critical habitat resources are spatially dynamic show a high degree of behavioral flexibility. We develop an ecophysiological framework integrating behavioral physiology and spatial habitat dynamics to account for behavioral flexibility at individual, ontogenetic and species levels.

Keywords: Spatial habitat dynamics, fish movements, ecophysiology.

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ICES CM 2007/E:03

Dante's Ocean and the Paradox of the Plankton "Abandon all hope ye who enter here". Dante Alighieri (1314) The Divine Comedy or "How [is it] possible for a number of species to coexist in a relatively isotrophic or unstructured environment, all competing for the same sorts of materials?". G.E. Hutchinson (1961) The paradox of the plankton.

John P Manderson, J. Quinlan, P. Shaheen, and J. Kohut

Coastal ocean areas consistently receiving freshwater discharge from estuaries support rich fishing grounds, and recruitment for many species is positively correlated with discharge at time lags indicating effects are focused on early life history processes. We use observations from adaptive hydrographic/hydroacoustic/plankton surveys conducted within the footprint of an observing system in the coastal ocean off the Hudson/Raritan River USA outflow to formulate the "Dante" hypothesis. The "Dante" hypothesis proposes that tidal pulsing of less dense water into specific coastal areas produces multiple vertical density and velocity shear discontinuities at cm to meter scales. These discontinuities stall the descent of colonial phytoplankton and flocs which support a succession of microbial/protist and zooplankton communities and serve as sites for critical exchanges of materials and energy. These biophysical mechanisms engineer high vertical habitat diversity at scales matching body size and movements of fish larvae, decapod larvae, and interacting species. Although these biophysical layers continuously erode, and episodic storm disturbances homogenize the water column, high frequency pulsed intrusions of less dense water both maintain and rapidly regenerate these vertically complex habitats in specific areas. We suggest coastal ocean areas where physical forcing produces intrusions of less dense water at frequencies shorter than the mixing rate of vertical density and shear discontinuities have layered heterogeneously diverse biotopes analogous to tropical rain forests. They allow for high niche diversification, species diversity and may be critical in determining the dynamics of pelagic ecosystems and early recruitment for resource species using them.

Keywords: "Dante hypothesis", thin layers, larval habitat, estuarine plume.

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ICES CM 2007/G:04

Three dimensional prey aggregations and fine scale foraging patterns of Humpback whales (*Megaptera novaengliae*) in Stellwagen Bank Marine Sanctuary

Elliott L. Hazen, Ari Friedlaender, Dave Wiley, Michael Thompson, Colin Ware, and Mason Weinrich

Prior research has quantified prey densities at depth in association with foraging whales and suggests that these predators require a minimal prey density threshold for effective foraging. Even in the few cases where individual whales have been the focus of a directed study, however, it has been difficult to observe the behavior of individual whales in a three-dimensional environment. We addressed such information gaps directly by employing a novel research approach to study the fine-scale foraging behavior of Humpback whales (*Megaptera novaengliae*) and simultaneously measure the distribution and density of their prey, sand lance (*Ammodytes americanus*). Non-invasive multi-sensor acoustic data logging tags measured whale movement and behavior in three dimensions. Concurrent synoptic prey data were collected using 120 and 38 kHz EK60 echosounders with simultaneous ADCP measurements of current direction and velocity. CTDs were used to measure vertical profiles of the water column during feeding bouts. Combining these measurement techniques allows us to monitor and quantify changes in whale foraging behaviors (e.g. bubble netting, lunge feeding, and bottom feeding) relative to oceanographic and prey conditions. Determining threshold densities of prey required for whale foraging, the effects of predation on prey school size and behavior, and examining the effects of oceanographic conditions on predator-prey interactions can augment knowledge regarding foraging theory of top predators in marine systems.

Keywords: acoustics, sand lance, predator-prey, foraging theory, oceanography.

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ICES CM 2007/G:05

Simulation of zooplankton prey fields in the German Bight to study sprat growth variability in time and space

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The present study connects the investigation of lower and higher trophic levels, which are both influenced by their physical and biological environment. Copepods were focused due to their key role within the ecosystem acting simultaneously as predator and prey item within the food web. An improved ECOHAM version (ECOlogical Model, HAMBURG) has been developed to simulate the North Sea ecosystem and to study the temporal development and spatial variability of zooplankton biomass and abundance. Therefore, the zooplankton was enhanced by a stage-structured population representing *Pseudocalanus elongatus* competing to the rest zooplankton biomass. Simulated three-dimensional fields were analysed to investigate the regional distribution of primary and secondary production in relation to the locally different stratification and circulation characteristics and their influence on population dynamics and total zooplankton biomass. Using reported weight-length relationships we gained a size-resolved spectrum of food items, which served as input for a coupled transport and individual-based growth model (IBM) for fish larvae. The IBM predicts growth and survival of larval sprat (*Sprattus sprattus*) depending on local prey availability and hydrodynamical conditions in the German Bight. The ecosystem model determined high variability of the different size classes due to the physiological succession of copepod stages resulting in alternating match/mismatch patterns of prey for the sprat larvae, which could not be resolved using zooplankton biomass only. The development of the larvae exhibits a corresponding variability depending on available food: at higher food concentrations the influence of temperature determines the maximum reachable length.

Keywords: ecosystem model, IBM, copepod, fish larvae, German Bight.

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ICES CM 2007/G:06 Withdrawn

ICES CM 2007/G:07

Environmental variables and their influence on growth of the great scallop (*Pecten maximus*) in the English Channel

M. T. Smith and P. Whelpdale

Recent and historic surveys of the great scallop (*Pecten maximus*) in the English Channel showed that whilst most scallops exhibit similar growth characteristics at a specific location, groups more than a few tens of kilometres apart show different growth characteristics and these differences appear to be relatively stable through time. Many studies of scallop species have linked growth with a wide range of environmental factors. The stability through time of characteristic growth patterns for scallops implies that the particular environmental conditions responsible for specific growth characteristics are relatively persistent and are more influential than very fine scale micro-environmental conditions that might affect an individual scallop. We estimated von Bertalanffy growth parameters for scallops at survey stations in the English Channel and also extracted environmental variables from available datasets for these locations. Regression analyses carried out to explore the relationships between growth parameters and environmental variables suggested that temperature and seabed stress were positively related with maximum size (L_{∞}), while increasing depth had a negative effect. The k parameter was influenced by catch rate (i.e. abundance), sediment type and depth, whereas Φ prime was influenced by temperature, although seabed stress was also significant when considered alone. As in many studies of this kind, strong correlations both between environmental signals and between the growth parameters themselves complicated interpretation.

Keywords: scallop, *Pecten maximus*, growth, environmental variables, English Channel, temperature, seabed stress, depth, sediment type, catch rate.

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ICES CM 2007/G:08

Impact of equatorial Kelvin waves on aggregations of sardinellas (*Sardinella* spp.) in Angolan waters.

Marek Ostrowski

High yields of pelagic fish in Angolan tropical waters are associated with seasonal upwelling. The Angolan upwelling is forced by a large-scale eastward tilt of the main thermocline in the tropical Atlantic. Near the coast, the nutrient-rich layer of central water elevates to less than a 20 m depth. Enrichment and high productivity occurs in the absence of upwelling favourable wind, forced by low energetic processes such as lateral mixing or internal waves. Evidence on echograms and in a Vessel Mounted Acoustic Doppler Current Profiler (VMDCP) data suggests that the current is dominated by subinertial internal wave fluctuations whereas the mean flow is low. Under these conditions, small pelagic fish (mainly *Sardinella aurita* and *S. maderensis*) forms highly contiguous aggregations aligned along topographic features and close inshore along the front separating offshore stratified from the inshore well mixed waters. Twice a year, the upwelling conditions are interrupted by a strong El Niño-like poleward current, associated to coastally-trapped Kelvin waves remotely forced in the western tropical Atlantic. The thermocline becomes depressed to 40–60 meters while the surface layer is intruded by an oligotrophic layer of warm and low salinity water of equatorial origin. Downwelling conditions dominate along the entire coast. However, the downwelling is visibly stronger to the north of Luanda (latitude 8° 50'S) where the sea level rises and thermocline depresses additionally due to partial blocking of the poleward flow by the westward offset of the continental shelf located just south of city. Under these conditions distribution patterns of *Sardinella* changes significantly. They appear to use the poleward current as the transport mechanism to avoid harsh conditions. Few fish are detected to the north of Luanda; their largest aggregations are shifted further the south, off Porto Amboim (latitude 10° 45'S), coincident with the location of the seasonal cyclonic eddy, evidenced in the VMADCP data. Individual schools or school clusters are typically larger to those observed during upwelling seasons. However, at larger scales fish distributions are not contiguous and not related to oceanographic or bathymetric gradients.

Keywords: tropical ecosystem, Kelvin waves, pelagic fish aggregations.

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ICES CM 2007/G:09

Vertical segregation of the zooplankton plankton community by hydrography and implications for trophodynamic interactions in the central Baltic Sea - A multivariate discriminant function- and canonical analysis

Jan Schulz and H. J. Hirche

The impact of hydrography on the vertical zonation of the zooplankton community was studied in the Bornholm Sea. A total of 832 vertically stacked multinet samples were used for the analysis. By means of multivariate discriminant function and canonical analysis we show a distinct separation of the zooplankton community. Three main habitats, reflecting the hydrographic situation, were identified with characteristic differences in zooplankton composition: 1) The summer surface layer, bounded by the thermocline at its lower rim. Species of this layer are only seasonally abundant or forced to adjust to the cooler winter water beside the warm season. 2) The intermediate winter water, bounded by the halocline below and the thermocline or surface above. Species dwelling in this layer face a reduced volume and are cut off from the high primary production when their habitat is compressed by warm summer waters. 3) The layer between the permanent halocline and the sea floor. The taxonomic composition of this layer showed no significant effect in relation to observed inflows. Five different utilisation strategies of the dominant zooplankton species were identified from these three habitats. Based on the results we discuss the impact on trophodynamic interactions and advective processes.

Keywords: vertical distribution, zooplankton, Central Baltic Sea.

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ICES CM 2007/G:10

Usage of the island water dynamics by spawning red cod, *Salilota australis* (Pisces: Moridae) on the Falkland Islands Shelf (Southwest Atlantic)

A. Arkhipkin, P. Brickle, V. Laptikhovsky

The red cod, or tadpole codling, *Salilota australis* (Günther, 1878) is an abundant commercial fish that inhabits shelf and slope waters of the South Atlantic from 40°S to 55°S, the Straits of Magellan and slope of southern Chile up to 45°S in the southeast Pacific. In spite of its wide distribution, the Southwest Atlantic red cod population spawns predominantly in one area where the cold-water Falkland Current reaches the continental slope to the southwest of the Falkland Islands. The current splits into two main northward flowing streams that pass the Falkland Islands on both the west and east sides, causing a strong upwelling of the Sub-

Antarctic Superficial Water mass (SASW). As a result, the SASW extends onto the shelf, mixing with shelf waters and produces two quasi-stationary eddies in austral spring (September-October). Exactly at this time of the year, dense spawning aggregations of *S. australis* occur at depths between 180 and 200 m on the offshore sides of underwater ridges situated on the upwelling periphery which is marked with a near-bottom water density of 26.75 kg/m³. Red cod is an intermittent near-bottom spawner with a potential fecundity ranging from 500,000 to 9,000,000 eggs in females of 39 to 83 cm total length (LT). Spawning takes place throughout the day with a major peak during the late afternoon and early evening (1600–2000 hrs). Batch size increases with female size from 30,000 to 900,000 eggs. In females between 65–75 cm LT, which represents the modal size of spawners, batch size varies between 60,000 and 867,000 eggs (mean 394,000). Each female releases at least 10 batches of eggs during the spawning period. Eggs are pelagic, of 0.95–1.23 mm in diameter and are characterised by a large oil droplet. Egg development takes 4–5 days at 5.5–8.5°C. The Southwest Atlantic population of red cod makes effective use of the islands' hydrography, spawning upstream in the highly productive upwelling waters and then dispersing their pelagic larvae and fries downstream within the two branches of the Falkland Current over the entire Patagonian Shelf.

Keywords: Falkland Current, *Salilota australis*, spawning, fecundity.

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ICES CM 2007/G:11

Mapping fish reproduction areas along environmental gradients on the SW coast of Finland

Meri Härmä, Antti Lappalainen, and Lauri Urho

On the coastal areas of the northern Baltic Sea freshwater fish species are common. Roach (*Rutilus rutilus*) have recently become more abundant, especially in the outer archipelago of the Gulf of Finland. On the other hand, locally decreasing trends in pike (*Esox lucius*) catches and stocks have been reported in the northern Baltic Sea. This research aims to determine the reproduction areas and the critical factors governing the reproduction of pike and roach on the SW coast of Finland. Reed belts formed by *Phragmites australis* are a dominant feature in sheltered shores in the northern Baltic Sea and serve as the main spawning habitat for both roach and pike. We used remote sensing to locate reed belt shores in the archipelago area. Field surveys were carried out to produce data on the spatial distribution of pike and roach larvae along environmental gradients. Linear logistic regression models were then constructed to link the occurrence of larvae to environmental variables. By using GIS, spatial prediction maps of the reproduction areas of pike and roach were produced for the archipelago area. The results illustrate that low salinity (<4‰) is an important factor governing the success of roach reproduction. Reed belt shores in the innermost archipelago and bay area, substantially influenced by freshwater runoff, constitute the main reproduction areas of roach. Location in the archipelago zone proved to be determining for successful pike reproduction. Compared to roach, pike reproduce sporadically also in reed belt shores in the intermediate and outer archipelago.

Keywords: coastal area, pike, *Esox lucius*, roach, *Rutilus rutilus*, larval habitats, remote sensing, spatial modelling, mapping.

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ICES CM 2007/G:12

Turbidity affects prey selection on pike larvae

Maiju Salonen, J. Engström-Öst, and L. Urho

Recent eutrophication has caused the turbidity to increase in the Baltic Sea. This has affected the ecosystem and species interactions in many ways. Pike (*Esox lucius*) has diminished in some areas of the coastal Baltic Sea. Low recruitment of newly hatched larvae to the population is thought to be one reason for this problem. Our aim was to find out more about the recruitment problem by collecting larvae and measuring environmental parameters in different spawning areas. Our results show that pike larval condition varies greatly in different areas of the archipelago, and that turbidity is a major factor connected to the condition of newly hatched pike larvae. Experimental studies revealed that the foraging of pike larvae changed in turbid water. Turbidity did not affect the ability of pike larvae to catch *Daphnia longispina* (Cladocera) in turbid water, whereas *Eurytemora affinis* (Copepoda) were caught at a much lower rate in a turbid environment. In another feeding trial, turbidity also changed the preferences for the species in two different zooplankton assemblages (inner and outer archipelago zooplankton). Our results suggest that water turbidity and prey availability affect larval condition and that turbidity complicates both prey search and prey capture for visual predators, such as pike. This, in turn, may affect the survival and growth of young pike and furthermore, the recruitment of pike larvae to the adult population. Future studies should reveal potential food quality variations between prey species and sampling areas.

Keywords: pike larvae, turbidity, food selection, eutrophication.

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ICES CM 2007/G:13

Variation in hatch date distributions, settlement and growth of juvenile plaice (*Pleuronectes platessa* L.) in Icelandic waters

Björn Gunnarsson, Thor H. Ásgeirsson, and Einar Hjörleifsson

Hatch date distribution, settlement date and subsequent growth of juvenile plaice (*Pleuronectes platessa*) in different regions around Iceland were determined by otolith microstructure analysis. Length, age and hatch date frequency distributions were obtained from juveniles captured in a 1 m beam trawl on 30 stations at 0.5-1 m depth all around Iceland in July 2006. The main spawning has generally been assumed to take place at the south- and southwest coasts. Eggs and larvae are then distributed by currents along the west- and north coasts. Contrary to expected dispersal pattern, both size and age of juvenile plaice decreased from south to north. The observed spatial variation in size of the juveniles is not explained by different growth rates but by age. The results indicate that juveniles at the south coast hatch earlier than juveniles on the north and east coasts, have a shorter larval period, and higher growth rates. The study provides evidence that the juvenile plaice population may in fact originate from multiple spawning sites located not only along the south- and southwest coasts, but along the whole coast of Iceland. The findings are discussed in relation to currents and temperature in Icelandic waters.

Keywords: *Pleuronectes platessa*, juvenile, age, hatch date.

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ICES CM2007/G:14

Linking anchovy and sprat distributions with bio-physical oceanographic features: a Bay of Biscay – North Sea comparison.

Martin Huret, P. Petitgas, C. Schrum, and B. Planque

Small-pelagic fish spatial distributions show migration pattern at seasonal scale, meaning that they use different habitats with different environmental physical and biological characteristics. In the Bay of Biscay, anchovy gather in the southern part of the Bay from the winter to spring when they spawn, before moving north from summer to fall. In the North Sea, anchovy spend the winter in the north west before moving back to the southern part for the rest of the year. In contrast, sprat is more resident in similar habitats around the year. We use both satellite (SST and chlorophyll-a data) and physical and biological model outputs (river discharge, water column stratification, phytoplankton production) to investigate the link between the observed fish distributions and oceanographic physical and biological features. We also investigate using available models the bio-physical conditions determining potential spawning and potential larval survival and map these conditions. Fish distribution patterns cannot be explained solely with temperature, salinity or stratification. At mesoscale, the maps of chlorophyll-a concentration are closely linked to physical features (i.e. river plumes, eddies, stratification, fronts...), but such link will depend on the time of the year through light and temperature-dependent processes. Thus emphasis is put on the interaction between physical and biological data when explaining fish distribution features. The comparison between two regional systems and two species allows a better understanding of what bio-physical context drives fish distribution patterns at a seasonal scale.

Keywords: fisheries oceanography, fish habitats, anchovy, sprat, Biscay, North Sea.

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ICES CM 2007/G:15

The structure of small-sized fish assemblages and reflections from differences in abiotic conditions

Lari Veneranta and Lauri Urho

The small-sized fish assemblages of 11 different shallow, structurally simple sandy beaches were compared in the SW coast of the Gulf of Finland. Sampling with small beach seine was carried out throughout the growth season in 2005. The differences in species richness, diversity and abundance among beaches were assessed and the significance of environmental factors, as exposure to wind, depth slope, surface area of

shallow water, coarseness of sediment, temperature and turbidity for fish assemblage composition were investigated. A total of 21 species belonging to 12 taxa were recorded; Gobiidae, Gasterosteidae and Ammodytidae were the most representative during the study period. Major changes in the fish assemblages were observed on temporal scale: the hatching of fish larvae multiplied the abundance of fishes. The community composition of larvae and older fishes differed significantly. On the whole, shallow sandy beaches are not ideal reproductive areas for most of the species except for Gobiidae. The study shows that temporal and spatial variations in the small-sized fish assemblages are related to environmental conditions and biological dynamics. The extremity of temperature and lack of shelter for fishes are factors affecting the community composition and defining the species that live successfully in harsh conditions. The results suggest that abiotic features together with biotic parameters regulate the small-sized fish assemblage at nearshore shallow environments.

Keywords: fish community, shallow water, Gulf of Finland, abiotic, spatial and temporal.

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ICES CM 2007/G:16

Habitat preferences of selected demersal species in the Bay of Biscay and the Celtic Sea

Cécile Persohn, Pascal Lorange, Verena Trenkel

Fish individuals are distributed according to preferred environmental conditions, and the distribution area of fish populations may vary with their total abundance. Then, observed distribution is a combination of habitat suitability and population abundance due to density-dependant effects.

We used data from an annual bottom trawl survey to assess associations between fish distribution and habitat characteristics. Cumulative distribution functions were used to describe the general frequency distribution of the environmental variables observed during the survey (depth, temperature, salinity) and their relationships with fish population distributions and abundances. This method was applied to the most abundant demersal fish populations (hake, blue whiting, poor cod, lesser-spotted dogfish) of the Bay of Biscay and Celtic Sea. Over 1992-2006, environmental conditions changed, populations abundances varied significantly, and some species showed clear preferences for selected depth, temperature and salinity. This analyse was performed on total fish populations, and on separated juvenile and adult populations. It allows to separate environmental and density dependent effects on the geographical distribution of demersal fish populations. Observed changes in the main demersal fish populations are discussed in terms of environmental variations effect on the distribution of populations and habitat preference.

Keywords: groundfish distribution, habitat selection, environmental variability, Bay of Biscay.

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ICES CM 2007/G:17

Internal waves interact with topography over a small bank to produce a highly-focused feeding environment for fish, whales and birds

Lewis Incze, N. Wolff, J. Lerczak, S. Rosen, S. Kraus, P. Stevick, and A. Baukus

A small (9x15 km) offshore bank in the Gulf of Maine (Platts Bank) is sometimes the focal point of intense feeding by herring, marine mammals and birds. Humpback whales (*Megaptera novaeangliae*) use only a small portion of even this small bank as they feed on euphausiids (*Meganyctiphanes norvegica*). The euphausiids are similarly abundant on and off the bank, but form dense surface swarms near the crest of the bank. The swarms form abruptly and last only a few minutes or less before euphausiids descend below the surface, but they are quickly exploited by whales that appear to be well tuned to the brief but frequent appearances. The swarms appear to form in response to velocity shifts in advance of internal waves that are brought near the surface as the pycnocline shallows over the crest (internal tide) during periods of strong tidal flow. This only occurs when euphausiids are above the pycnocline and it may be reinforced by density-dependent (schooling) behavior, factors that may account for within- and between-year differences in feeding activity on the bank. While euphausiids are supplied to the crest from a large area related to the tidal ellipse and a residual flow field, the trophic transfer remains spatially very constrained.

Keywords: internal waves, euphausiids, whales, feeding, bank.

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ICES CM 2007/G:18

Physical control of the biological production on the Faroe Shelf

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The Faroe Shelf has a highly variable primary production. The accumulated new production during spring and early summer varies by at least a factor of three from one year to another and this seems to affect even top predators like the local cod and haddock stocks, which exhibit inter-annual variations in both recruitment and growth in phase with the primary production. Previous studies have indicated a causal link between these variations and winter air temperature. In cold winters, the on-shelf water becomes considerably denser than the off-shelf water. This density difference is hypothesized to reduce the horizontal exchange between on-shelf and off-shelf waters and numerical models indicate that this can allow a strong spring bloom, whereas a weak density difference from a warm winter is suggested to enhance horizontal exchange and inhibit the spring bloom. This hypothesis is well supported by detailed investigations carried out since 1990, but it will only work, if off-shelf waters change slowly. Here, we expand the hypothesis by using the output from a numerical ocean model (MICOM) to simulate off-shelf conditions. From these, and observed atmospheric parameters, we use a simple model to calculate accumulated new primary production during the spring bloom for all years since 1960. These results are compared with measured new production since 1990 and with cod and haddock recruitment and growth since 1960, in order to test the hypothesis.

Keywords: physical control, biological production, Faroe Shelf.

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ICES CM2007/G:19

Comparing habitat suitability for sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) in the North Sea: a modelling study

Ute Daewel, Myron A. Peck, Michael A. St. John, and Corinna Schrum

The suitability of marine habitats depends on the complex interplay of biotic as well as abiotic factors. The hydrodynamic characteristics of an area are especially important since these impact all trophic levels of the marine foodweb. For example, the strength of mixing processes (e.g., tides and convection) is an important factor influencing the productivity of specific regions. To define habitat suitability for sprat (*Sprattus sprattus*) and Atlantic cod (*Gadus morhua*) in the North Sea, three interlinked models were employed. We used 1) an Eulerian coupled hydrodynamic / ecosystem (NPZD) model to provide estimates of both 3-d fields of hydrographical properties, and spatially and temporally variable zooplankton prey fields, 2) a Lagrangian transport model to simulate temporal changes in cohort distribution, and 3) an individual-based model (IBM) to depict foraging, growth and survival of fish early life stages. The couple model system was adapted for use with sprat and Atlantic cod by utilizing species-specific IBM parameterisations. Larval fish growth and relative survival were calculated for the year 1990 and the results were interpreted with respect to differences in species-specific life history strategies including spawning times and locations and larval physiology. Spatial, temporal and inter-specific differences in fish vital rates were assessed with respect to both the physical characteristics (e.g., temperature and an index of frontal strength) and biological characteristics (rates of primary and secondary production) experienced by the early life stages of both species. First results indicate a strong correlation between larval fish survival and frontal dynamics in the southern North Sea.

Keywords: spatially-explicit IBM, North Sea, sprat, cod, habitat suitability.

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Hydroacoustic resolution of small-scale vertical distribution of cod (*Gadus morhua* L.) in the central Baltic Sea at different hydrographic regimes

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The small-scale vertical distribution of cod (*Gadus morhua* L.) in the Bornholm Basin, central Baltic Sea, in years with different hydrographic conditions is presented. Investigation was focused on peak spawning time after an inflow situation and during a stagnation period. Cod were identified by aggregating and allocating single echoes from hydroacoustic distribution data to individual fish by application of an echotracking algorithm. Habitat preferences and limits in relation to temperature, salinity, oxygen concentration and oxygen related egg-survival probability were resolved by individually allocating ambient hydrography to each fish identified. Distribution patterns derived from echosounder data were validated by comparison to distribution

data recorded simultaneously by Data-Storage-Tags attached to cod. Results show ambient salinity and oxygen concentration being distinct factors in limiting cod habitat and shaping of vertical distribution patterns during spawning time in the Bornholm Basin. Our aim is to present a method to detailed resolve the small-scale distribution as needed for the understanding of behavioural patterns and for the identification of habitats and limits in a highly stratified system.

Keywords: single-fish tracking, small-scale distribution, cod, Baltic Sea.

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The distribution of Baltic Sprat (*Sprattus sprattus* L.) and its relation to physical features – observations and models

Daniel Stepputtis, Uwe Böttcher, and Thomas Neumann

The Baltic Sea offers a good environment to study the behavioural response of organisms to physical forcing at several scales. Within the German GLOBEC-project, the distribution of Baltic sprat was studied intensively (amongst others), whereby Baltic sprat is actually the dominating fish species in the Baltic Sea. Small scale effects of water column stratification and diel vertical migration, as well as meso-scale patterns caused by wind events and basin wide patterns caused by the 2002/2003 Baltic inflow event will be described by examples. The analysis of observations results in a good understanding of the physical factors, which influence the distribution of sprat. Especially temperature, oxygen and light seem to be the most important factors. This knowledge was applied to develop models which predict the habitat of adult sprat in the Baltic Sea. These models are essential to incorporate the enormous ecological impact of Baltic sprat in ecosystem models.

Keywords: behaviour, pelagic fish, model, habitat.

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Physical controls of lower trophic level production

Irina Alekseeva and C. Schrum

Significant relationships have been identified between climatic variability and main characteristics of the North Sea lower trophic levels dynamics. However, available observations, which are limited and irregular, do not allow for identification of certain controlling factors due to their weaknesses to describe natural non-linear spatial-temporal variability in external influences and complex interactions in the ecosystem itself. The aim of our study was to investigate the physical controls of lower trophic level production and hence to provide a guidance for development of suitable physical indices for higher trophic level induced climatic variability. We employed the 3D coupled physical-biological model ECOSMO to assess the role of climatic factors controlling variability of lower trophic levels via air-sea interactions. Data on biomass and production for the first 2 trophic levels are provided from the model as daily means on a 10kmx10km grid and stratification resolving vertical resolution for the period 1980–2004. A statistical analysis has been performed to reveal and evaluate possible relations between climatic changes (meteorological NCEP 6-hourly data were used) and the simulated plankton dynamics. The analysis showed that simulated ecosystem responds in a complex manner to meteorological conditions, sensitive to local hydrodynamics and seasonality. Highest correlations between physical environmental parameters and the modeled ecosystem variability were obtained for the wind speed, with higher correlations on the seasonal time scale than on annual scales. The impact of wind speed explains the close relation between lower trophic level production and stratification intensity (or thermocline depth), which has been shown earlier in our previous studies.

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Biophysical controls and survival of striped bass larvae in the Chesapeake Bay estuarine turbidity maximum

E.J. Martino, E. W. North, and E. D. Houde

Variability in a prominent mesoscale physical feature, the Estuarine Turbidity Maximum (ETM), contributes strongly to the >15-fold variability in recruitment of striped bass *Morone saxatilis* in Chesapeake Bay. The

influence of environmental variability on egg through juvenile stages was investigated using field studies and synthetic analysis of larval stages, prey availability, feeding, and growth in five years with contrasting physical conditions (1998, 1999, 2001–2003). Striped bass spawn within and just above a prominent ETM that is strongest in years of high freshwater flow to the estuary. Abundances of yolk-sac larvae were similar between years but feeding-stage larvae were 10 times more abundant in a strong recruitment year, indicating that survival at the first-feeding stage coarsely controls recruitment. Larvae are more associated with the ETM and associated salt front, feed more successfully, grow faster, and experience higher survival in wet years. Probable mechanisms leading to observed patterns include effects of light, estuarine circulation, and larval behavior. Growth rates were 25% higher in a wet year (2003) compared to an average flow year (2001). The biophysical controls and coupling responsible for observed relationships are being analyzed. High larval-stage survival supported by the physical properties and enhanced trophic transfer in the ETM does not always lead to exceptionally strong year classes. Density-dependent growth and survival in the juvenile stage regulate year-class strength and can compensate for the coarse controls on egg and larval stages attributable to ETM properties and dynamics.

Keywords: estuarine turbidity maximum, recruitment variability, striped bass.

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ICES CM 2007/G:24 Poster

Impact of subterranean flow on coastal process “mud banks” and fisheries potential.

Joseph Sebastian Paimpillil

The mudbank (south west Indian coast) is a unique coastal oceanographic phenomenon. A favourable combination of several factors like rainfall intensity and duration, temperature, salinity and some other unknown faculties - lead to the formation, extent and duration of continuance. The mud bank provides an attractive environment for fishing while the 2–3 m high monsoon waves make fishing outside the mud bank impossible. The mud bank appears to be a biologically fertile, which seem to attract the juvenile fishes and the larger fishes, which feed upon them. The role of the exchange of coastal water and groundwater across the sediment-water interface in mud bank formation was investigated. The coastal waters had sufficient hints of ground water seepage to sea through the narrow strip of submerged porous lime shell beds running almost parallel to the coast, transporting primary nutrients to the coastal waters and preconditioning it for rich primary production. The present study had shown chlorophyll a, approximately 3 times greater than the peak values (14 mg/m³) reported so far. A band of N/P > 15 funneling out from coastal region indicated an ‘external source’ of nitrogenous compounds far away from any river mouth. The low saline ground water influx can be a triggering mechanism for the mud bank in coastal region. The necessary force for the ground water flow to overcome the frictional resistance in porous medium is attained during the periods of critical level difference between the fresh water in backwater and the sea level. Such critical conditions prevail during the peak southwest monsoon months due to heavy river discharges. The possibility of heavy rains and flash floods linked with climate variability, such critical conditions can occur during other seasons and also at similar locations of the coast.

Keywords: mudbanks, ground water flux, coastal fertilization.

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Ecology of early life stages of smelt (*Osmerus eperlanus* L.) as acquire from otolith microstructure analysis

Dariusz P. Fey

The goal of this work was to describe for larval and juvenile smelt (*Osmerus eperlanus* L.) the possible mechanism of successful recruitment. Match-mismatch hypothesis assuming the importance of coupling between food resources availability and larval fish occurrence resulting from “proper” hatching time as well as the bigger-is-better hypothesis assuming higher survival of relatively larger and faster growing specimens were considered. Thus, the effect of temperature and zooplankton abundance on smelt growth rate as well as the effect of temperature on spawning and hatching period was analysed. The material – larval and juvenile fish – was collected within three-year-period, at 15 stations located in the Vistula Lagoon (Baltic Sea). Because of low depth and semi-enclosed conditions, the lagoon provides mesocosm-like environment. Large part of the data necessary for conducting the work was obtained using daily otolith increment analysis method. Generally, both the hypotheses were found to be of importance, and temperature-driven mechanism was described to clarify the issue of potential survival of smelt during early life period. Additionally to the

recruitment-related research, the assumption of proportionality between otolith growth and somatic growth was verified. The results of otolith growth analysis obtained for smelt were compared to ones obtained for larval herring – another pelagic species spawning in the lagoon during the same period. Although larvae of the two species are developing and growing in almost the same conditions, significant differences in otolith growth mechanism were found. While somatic growth was the key-factor affecting otolith growth for smelt, temperature was of higher importance for herring.

Keywords: smelt, *Osmerus eperlanus*, otolith microstructure, recruitment .

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ICES CM 2007/G:27 Poster

Spawning habitat of North Sea Plaice : descriptive and predictive approach

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Spawning habitat are usually modelled by relating eggs abundance to environmental factors. The potential spawning habitat is the environmental hypervolume of necessary conditions for a species be present in Hutchinson's ecological niche concept. Here, we propose to study the spawning habitats of the southern North Sea plaice populations by using both eggs densities and environmental conditions, but also by using information on spawners abundance. Data from 1st quarter of 2006 for the IBTS (International Bottom Trawl Survey) in the southern North Sea were used. Environmental conditions were monitored using CTD profiles as well as surface thermo-salinometer. Adults were caught by bottom trawling, sorted and counted by length, sex, maturity stage and age thereafter. Surface egg sampling was performed with a continuous underway fish egg sampler. Eggs data were mapped in a geographic information system using geostatistics to localize spawning grounds. Mapping was then improved using adults data and co-kriging. Eggs distribution was characterized environmentally to model potential spawning habitats, using important ecological factors for Plaice to spawn. Model evaluation was made using eggs data from 2007. The model can be applied where eggs are not sampled for the moment, to predict eggs densities. Resulting maps from kriging, co-kriging and the model were also compared.

Keywords : North Sea, Plaice, Habitat Modelling, GIS, IBTS.

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ICES CM 2007/G:28 Poster

Characterisation of juvenile flatfish habitats using generalised additive models

Ann-Britt Florin, Göran Sundblad, and Ulf Bergström

Continuous maps of habitats and ecological communities are needed for an efficient management of the heavily exploited coastal zone. Detailed knowledge on the spatial extent of essential habitats for fishes and other organisms in the Baltic Sea is however sparse, as is knowledge on the effects of habitat availability and quality on population sizes and structures. For flatfishes the availability of high quality nursery areas are detrimental for successful recruitment. To date we don't know which habitats are important for recruitment of flatfishes in the Baltic Sea and which factors that influence the survival of fish during this sensitive stage. To identify the characteristics of important nursery areas in the Baltic for flounder (*Platichthys flesus*) and turbot (*Psetta maxima*) a field study was conducted in autumn 2006 in the Stockholm archipelago (northern Baltic proper). An inventory of shallow bays using push net was done during late summer when the larvae had settled. The survey covered several different habitat types defined by substrate and wave exposure. Apart from density of flatfishes, a number of ecological characteristics of the habitat, such as occurrence of predators, food availability, habitat structure and vegetation were recorded. Furthermore, physical characteristics such as type of substrate, salinity, depth, turbidity and temperature were noted. The correlation between the spatial distribution of species and environmental conditions is studied using a Generalised additive models (GAM) and results discussed. The long term goal of this study is to identify important recruitment areas for flatfishes using predictive GIS habitat model.

Keywords: flatfish, essential fish habitats, GIS, GAM.

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ICES CM 2007/G:29 Poster

Hindcasting planktonic egg drift patterns of Atlantic mackerel in Irish shelf and oceanic waters

Christian Mohn, Leonie Dransfeld, and Martin White

A combination of model simulations and ichthyoplankton survey data is used to investigate spatial and temporal scales of mackerel egg transport along the continental slope from the western Celtic Sea to the northern Porcupine Bank. The Northeastern Atlantic mackerel stock has a spawning period extending from February to July with maximum spawning in mid May. Spawning is mainly concentrated along the shelf break with some evidence of enhanced spawning on the shelf. The hydrography of the shelf edge west of Ireland is dominated by three major regimes: (i) the poleward flowing shelf edge current (SEC) carrying warm, saline waters, (ii) a retentive clockwise recirculation cell over the Porcupine Bank summit and (iii) the Irish shelf front in shelf waters southwest and west of Ireland. To estimate the physical controls of mackerel egg drift in this region we used a combination of nested grid and particle tracking techniques. The model selected for this study is the Regional Ocean Modelling System (ROMS). The model results are compared with survey data from different years. The model is forced by realistic meteorological data and tides. In addition, the response of drift patterns to changes of environmental conditions is investigated.

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ICES CM 2007/G:30 Poster

Oceanological conditions in the Southwest Atlantic outside the economic zone of Argentine and their influence on Argentine shortfin squid (*Illex argentinus*) distribution and fishery

A.V. Remeslo, P.P. Chernyshkov, I.A. Polischuk, and S.N. Burykin

Substantial volume of oceanographic observations *in situ* outside the economic zone of Argentine on board research vessels of the Soviet Union and, later, of the Russian vessels over the period from 1980 up to date enabled quite a detailed study of oceanographic conditions and their changeability in habitation area of Argentine shortfin squid – one of the most important commercial species in the Southwest Atlantic. In particular, according to the data from over 160 hydrological transects made along 46°S across the Falkland Current combined with the satellite observations, the structure and changeability of the Falkland Current were studied, and peculiarities of the water thermohaline structure in the fishing ground between 45–47°S revealed. The investigations in the open part of the Argentine depression were concentrated in the area of the Falkland and Brazil Currents interaction. Intensification of zonal westerly water-mass transports and correlated easterly carry-over of shelf waters, as well as the change in the intensity of the Falkland Current causing the change of water structure on the shelf edge and over the continental slope are among the most important parameters of the environment that exert the influence on distribution and fishery of Argentine shortfin squid in the area between 45–47°S. It is not improbable that the dynamics of anticyclonic frontal gyres in the Brazil Current exerts influence on commercial squid aggregations on the Patagonian shelf.

Keywords: Argentine shortfin squid (*Illex argentinus*), the Falkland Current, oceanological conditions, the Southeast Atlantic.

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ICES CM 2007/G:31 Poster

Multi-species analyses unveil the role of oceanographic fronts in modulating gene flow among marine fish populations

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The identification of the spatial patterns of genetic distribution in the marine environment is of primary importance when devising conservation-management strategies for marine resources. For many years, it was assumed that fish populations operate as an open system, where pelagic stages represent the main cause of genetic exchange due to their high potential for dispersal. However, mounting evidence shows that pelagic stages often fail to fully achieve their dispersal potential suggesting that the relationship between dispersal potential and realized gene flow is more complex than previously assumed. At present, we have a limited understanding about how oceanographic conditions may pose a barrier for the dispersal of pelagic stages and even less about how different species may respond to such barrier. Here, through the analysis of microsatellite markers and ocean data, we investigate the effect that two oceanographic fronts, the Almeria-Oran (AOF) and the Balearic front (BF) have in determining genetic connectivity in five fish species in the Western Mediterranean. The species differ significantly in their dispersal potential as judged by their pelagic

stage characteristics and were sampled at the same locations. The results show that the AOF affects all species independently of their dispersal capability by preventing gene flow from both sides of the front. The BF is less restrictive affecting only those species with limited dispersal capabilities. However, exemptions were found in species with limited capabilities that showed evidence of extensive gene flow across the BF. Thus, patterns of population genetic subdivision in fish species with planktonic development appear to be more strongly influenced by environmental features such as density fronts and circulation patterns than by inherent dispersal capabilities. These results emphasise the importance of studying several species in planning to incorporate population genetic information into conservation and management of marine fish resources.

Keywords: dispersal, fish, gene flow, oceanographic fronts.

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ICES CM 2007/G:32 Poster

Is the distribution Portuguese dogfish related with environmental factors?

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The Portuguese dogfish *Centroscymnus coelolepis* is a deepwater shark with a worldwide distribution that is exploited at 1000–1500 m deep in the Portuguese continental slope. As other deepwater sharks, this species presents a spatial and bathymetric segregation according to reproductive condition. The deepwater habitat is still poorly studied, both in terms of biological, ecological and physical conditions. The deep ocean has been assumed a stable environment, where temperature, pressure and salinity acquire values with low level of variation. Oceanographic data, particularly on temperature, pressure and conductivity, was collected on board of commercial longline vessels using data loggers, and during fishing operation. From each haul, specimens of *C. coelolepis* were measured, sexed and maturity stages were assigned. Adequate data analysis was performed to investigate if the segregation of this species is related to environmental factors.

Keywords: deepwater, *Centroscymnus coelolepis*, distribution, temperature, pressure, conductivity, Portuguese continental slope.

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ICES CM2007/G:33 Poster

Frontal production in the North Sea

Corinna Schrum, Irina Alekseeva, and Ute Daewel

Various studies indicated biomass maxima found to be related to hydrographic frontal structures and hydrodynamic indicators such as frontal intensity or gradient indices are currently under investigation to assess their suitability as an indicator for ecosystem variability in the North Sea. However, detailed investigations of the frontal dynamics in the North Sea, providing process based explanations for observed pattern, are still rare. With the present study we aim in investigating frontal structures, their dynamics and particularly their impact on productivity up to larvae growth and larvae distribution with respect to fronts. Here, we'll employ the coupled physical-biological model ECOSMO using its different components to evaluate biomass and productivity on different trophic levels. Primary and secondary production were derived from an Eulerian NPZD model and larvae productivity was exemplarily estimated for sprat using a complex, 3-d IBM approach.

Our results indicated significant local productivity maxima in relation to frontal characteristics. We found different pattern for the tidal mixing front and baroclinic frontal structures in the Skagerrak area. Tidal mixing fronts show significant off-set maxima in productivity, typically peaking to the well mixed side of the front. In contrast, Skagerrak frontal structures reveal productivity maxima coinciding with high frontal intensity. Results from the sprat IBM showed highest larvae growth at frontal locations, remaining on high levels towards the mixed side of the tidal mixing fronts, but with lowest larvae concentration here. The latter is partly caused by the faster growth and shorter duration of the larvae life stage here. Larvae concentration seem to peak at the front and offshore of the tidal mixing front and are here connected with significantly lower growth rates, potentially caused by lower subsurface level temperatures as compared to the shallower well mixed water column.

Keywords: North Sea, fronts, lower trophic level productivity, larvae growth.

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