

Theme Session O

Spatio-temporal characteristics of fish populations in relation to environmental forcing functions as a component of ecosystem-based assessment: Effects on catchability

ICES CM 2006/O:01

An age-structured model of winter skate abundance in the western Atlantic: Sustainability and uncertainty

Michael G. Frisk, Steve J. D. Martell, Kathy Sosebee, and Thomas J. Miller

The ecological importance of winter skate, *Leucoraja ocellata*, was emphasized by the large increase in biomass during the 1980s on Georges Bank during a period when many commercial species were at low biomass levels. However, limited information on vital rates and commercial catch data has hindered efforts to assess the winter skate population. Here we utilize recently estimated vital rates of winter skate, commercial landings, survey cpue, length-specific cpue, and commercial landings to fit an age-structured model for the western Atlantic for 1963–2003. Models fit to alternative length structures predicted an increase in winter skate population biomass indicated in the surveys in the 1980s with predicted fishing mortality rates, ranging $F = 0.02$ to 0.35 . However, the models differed in the degree to which they could resolve the pattern of increase observed in the survey. Models with highly resolved length structures fit the increase in biomass in the 1980s better than models with a more aggregated structure. We addressed three inferences that can be drawn from the discrepancy between observed and predicted abundances: (i) the model was misspecified, (ii) the survey does not reflect the dynamics of a closed population, or (iii) empirical estimates of vital rates are inappropriate.

Keywords: winter skate, migration, population dynamics.

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ICES CM 2006/O:02

Assessment of the NEA cod (*Gadus morhua*) stock on the basis of the satellite synoptical monitoring and informational technology

B. M. Shatokhin, D. N. Klochkov, B. N. Kotenev, and V. M. Borisov

The estimates are based on the experience of Russian studies of pelagic fishes of the Norwegian Sea in 1997–

2004. Computation involved the satellite positioning of the fishing fleet including individual trawl hauls, sea surface temperature (SST), and altimetry satellites which describe the hydrodynamic status of the Barents Sea. Three sites of maximum aggregations of feeding cod attached to the branches of the main current were identified where cod stay relatively isolated during feeding. The entire time of observations (May–November) was subdivided into 15-day periods which approximately corresponded to synoptic stability. Biomass estimates were obtained by 10-mile squares of each feeding area identified with due regard to the type of commercial vessels, characteristics of their trawls, speed of trawling, and catchability rates. Their biomass peaks indicating full advent of cod to their own feeding ground were calculated using the daily catch of each fishing boat, and all fishing operations (trawlings) were mapped by satellite position monitoring data. The total biomass of fishing stock of cod in the identified feeding areas was assessed at 2.56 million tonnes. The inclusion to the scheme of calculations of the data of satellite and conventional monitoring of habitat at a synoptic scale allows us to consider this verified technique as an element of ecosystem approach to stock assessment and to the establishment of TACs.

Keywords: NEA cod, stock assessment, establishment of TACs, satellite monitoring, synoptical scale, ecosystem approach.

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ICES CM 2006/O:03

Long-term variations in the relationships between the main components of the Barents Sea ecosystem (cod and capelin), ecological and physiological aspects of their interactions

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Main trends in the dynamics of the cod-capelin relationship were studied using long-term (starting from the 1970s) data and taking into account stock dynamics and climatic variations. The number of capelin per one cod was taken as an indicator of abundance of the main food which is related to such factors as fisheries on capelin, its consumption by predators, and overlap of cod and capelin distribution. Major trophic relationships of cod, diet switch to substitute prey (polar cod, herring, fish fry,

crustaceans, benthos), seasonal and interannual fatness variations, and development of feeding patterns were studied for years with different availability of capelin. According to the first feeding pattern, characterised by high abundance and availability of capelin, cod is provided with good food supplies (and has large fat reserves) during the entire feeding period. This ensures stable conditions of wintering, growth, and maturation. The second feeding pattern, when cod suffers from food deficiency and has low fatness, entails anomalous growth and maturation. In warm years, however, low abundance of capelin is compensated for by its high availability. The consumption of capelin in such years is therefore close to that observed in the years of high capelin abundance. Presently, the effects of predation (by cod only) on the capelin stock are greater than those related to fisheries.

Keywords: capelin, cod, distribution, feeding patterns, stock, substitute food objects.

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ICES CM 2006/O:04

Spatial distribution characteristics of fishing species in relation to trawl catchability as an important component in stock assessment and management

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The current practice of trawl and acoustic surveys is based on the assumption of using gear constant catchability. This assumption is true for neither pelagic nor bottom trawls. Spatial heterogeneity of the target species distribution characteristics stipulates a considerable haul-to-haul variability of the trawl catchability in the survey area. The effect of trawl catchability variability on the research survey results are considered by the example of krill and icefish surveys. The comparative analysis of catchability of different trawl types used in the said surveys is presented. Comparative analyses of commercial trawl catchability in relation to krill are also shown. In this study the trawl catchability was estimated with the acoustic method and applying analytic models. The importance of population spatial distribution characteristics for developing ecosystem-based stock management is discussed by the example of krill as a crucial food source for many predators (seals, penguin, bird species) and as a traditional fishery object in the South Georgia Subarea. It is shown that the fleet and dependent species operate in different locations, which differ both in biomass density and spatial distribution patterns of krill. The latter fact evidences that krill aggregations availability is important for fishery as well as for dependant species. Therefore, investigations of foraging tactics of dependent predators and comparison of the availability of different krill aggregation structures to predators and fleet (as trawl

catchability) can be important for the future studies on the strategy of krill fishery management.

Keywords: spatial distribution patterns trawl catchability.

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ICES CM 2006/O:05

Relationships between population spatial distribution and population dynamics

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Population dynamics is commonly described non-spatially using parameters of population demography and vital traits. Population spatial distribution is therefore considered implicit and its importance in the population dynamics ignored. The present study identifies correlations between population spatial distribution indices, population abundance, recruitment, and mortality for a variety of stocks. Series of research fisheries monitoring surveys were considered for a range of different stocks (cod, herring, anchovy, hake, mullet) in different regions of the North East Atlantic and Mediterranean (North Sea, Barents Sea, Baltic Sea, Bay of Biscay, Thyrenean Sea, Ionian Sea, and Aegean Sea). For each population, each age, and each year, 9 spatial indices were computed that characterized the spatial distribution in their center of gravity, inertia, anisotropy, number of patches, spatial extension (positive area, equivalent area, spreading area) and microscale structure. For each population and age, spatial indices were linearly regressed on the abundance, on the recruitment in the following year, and on the mortality into the next year. A meta-analysis table was constructed that showed the number of times that significant correlations occurred. The result is that spatial indices provide additional indicators for assessing population status and could be helpful in the context of stock decline and habitat loss.

Keywords: geostatistics, indicators.

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ICES CM 2006/O:06

Comparative study of habitat modelling strategies to investigate marine fish life cycle: A case study on whiting in the Eastern English Channel

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Fish habitat is an area where the environmental conditions are suitable to survive and live in a spontaneous state, i.e. environmental factors define the abundance of a particular species. Habitat modelling was used to relate whiting (*Merlangus merlangus*) spatial distribution to environmental factors. This study was based on data obtained from IFREMERs Channel Ground Fish Survey and ichthyoplankton surveys, including both species abundance and environmental data. Adults, juveniles, and larval stages were treated separately to study ontogenic shifts in the spatial distribution of whiting. Several methodologies allowing for the modelling of habitat were used, including measures of fit and model validation techniques. In brief, habitat modelling based on glm or gam (delineating realised habitat) or non-parametric multi-linear quantile regressions (predicting potential habitat) were used to relate species abundance to depth, temperature, salinity, seabed stress, fluorescence, and sediment type. Stepwise selection resulted in habitat models that described species affinity with a subset of significant environmental variables and that were used to map whiting habitats using GIS. Model outputs were compared amongst themselves as well as with interpolated outputs obtained by geostatistics and observed patterns of distribution. The best performing method will be identified and the resulting models discussed for each life stage studied. This work will help in elaborating guidelines for the conservation and protection of natural habitats of marine living resources in the face of climate change and anthropogenic disturbances.

Keywords: whiting, Eastern English Channel, fish habitat, habitat modelling, GIS.

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ICES CM 2006/O:07

Assessment of the influence of some environmental variables on trawl catches using a semiparametric mixed model

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In this work, the goal is to determine the factor which influences the abundance of different species in trawl catches. This study presents data collected during the Mertail survey carried out in the Bay of Biscay. A mixed semiparametric model was adopted for the data analysis.

This leads first to evaluate the relationship of catch data with specific variables and to have a random effect for species, allowing catch numbers to vary by species. It shows that the swept area of the haul is not linearly related to catch composition. The linearity of the relationship between catch data and the volume of water trawled (per haul) is not clear with this data and needs more assessment.

In a second step, the analysis was performed on catch data by fish species. The time of day was used as an indicator of variable catchability. Here, we also allow the underlying population density to vary by spatial zone (area). For horse mackerel, hake, and whiting the results did not show any significant changes in the course of the day.

For Norway lobster, there was a notable decrease in catch abundance during the morning with a stabilisation later on.

Keywords: catchability, mixed semiparametric model, spatio-temporal variables.

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ICES CM 2006/O:08

An autonomous system for evaluating groundfish populations: the Ocean Groundfish Observatory

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Overfishing and possibly unfavourable environmental conditions have resulted in the depletion of New England groundfish stocks. With the implementation of strict fisheries regulations including seasonal and annual closures, some stocks, e.g., haddock and redfish are recovering, while others, e.g., cod and yellowtail flounder, are not. As estimating fish biomass in closed areas necessitates the use of non-invasive techniques, an autonomous ocean groundfish observatory (OGO) is being developed to improve assessments and complement traditional acoustical and net survey methods. This approach uses acoustics for enumeration and optics for species identification and measurements of fish length. The system provides data near the seafloor where ship-mounted echo sounders have well known limits, e.g., vessel avoidance, the acoustic "dead zone", and need for groundtruthing via nets. The stationary component of the basic OGO is an array of acoustical-optical platform (AOP) elements each consisting of a 200 kHz steered-beam sonar with 16 bit resolution, stereo video cameras with laser references, and CTDs. Target strength, species, size, and observation angle are quantified when a fish is simultaneously detected by the sonar and optical sensors. This information is necessary for estimating fish biomass. An autonomous underwater vehicle with low-light cameras will be employed along transects between the AOPs to increase the

survey area. The OGO is a first step towards associating spatial and temporal distributions of groundfish with environmental factors. As closed areas increase and CPUE decreases, this technology may provide the data required to track population dynamics of the New England groundfish stocks.

Keywords: groundfish, acoustics, optics, autonomous sampling.

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ICES CM 2006/O:09

How and why acoustic detectability and catchability of herring change with individual motivation and physiological state in a variable environment: a multi-scale study on a local herring population in south-western Norway

Lise Langård, Leif Nøttestad, Arne Johannessen, Anders Fernö, Jan Tore Øvredal, Rune Vabø, Georg Skaret, and Gro Nilsson

The understanding of distribution and aggregation in schooling Atlantic herring (*Clupea harengus*) can be enhanced by integrated multi-scale studies in limited ecosystems. In a protected basin system in south-western Norway with a local herring population we used active and passive acoustics, underwater camera, biological sampling of herring and predators as well as physical oceanographical sampling to investigate individual behaviour and schooling dynamics of herring on different small scales. Altogether 5–7 rather dense pelagic herring schools were observed during the overwintering period from September to February. All the recorded schools were vertically extended in the waters with the most variable temperature and oxygen profiles, probably enabling individuals to adjust speed of maturation to prevailing environmental conditions. From late February only one major pelagic school was observed, extraordinarily stationary in the only narrow inlet to the inner basin and fairly easy to detect and catch for more than one month. This stable positioning possibly enables herring to evaluate the amount of plankton flushing through the inlet and time the spawning accordingly to provide optimal conditions for feeding and survival of the larvae. A few weeks prior to spawning, herring spread out and became extremely difficult to detect acoustically. Only underwater camera and bottom gillnets could then be used to identify herring and spawning areas. We argue that the dramatic seasonal changes in acoustic detectability and catchability we observe is best understood and predicted based on detailed knowledge of how herring react to a changing environment according to their physiological state and motivation.

Keywords: herring, motivation, maturation, environmental forcing, acoustic detectability, catchability.

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ICES CM 2006/O:11

Investigating the influence of environmental variability and larval behaviour on oyster populations with linked larval transport and fisheries demographic models

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Annual variations in freshwater flow and wind may influence the dispersal of oyster larvae (by affecting circulation patterns) and the survival of adults (by influencing salinity-dependent disease mortality) in Chesapeake Bay, a region whose oyster fishery has greatly declined.

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

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

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ICES CM 2006/O:12

Spatial and temporal analysis of nekton community dynamics in a variable environment: changes in the nekton dominance structure associated with persistent biological hotspots

Douglas C. Reese and R. D. Brodeur

Within systems characterized by substantial spatial and temporal variability, abundances of organisms tend to be higher in localized areas. The identification and function of such marine, biological hotspots is a growing area of research and has broad implications for conservation, management, and the design of marine protected areas.

Furthermore, in order to understand how ecosystems function and persist, it is necessary to know how ecological communities are distributed. The goal of this study is to provide further understanding regarding the functioning of marine ecosystems in a variable environment and to provide information about the distribution and structure of marine communities. Sampling was conducted during June and August of 2000 and 2002 as part of the U.S. GLOBEC mesoscale surveys along the west coast of North America. A geostatistical approach was used to create surfaces used in a GIS to determine the distribution of various community characteristics. Two biological hotspots were identified and determined to persist in space and time, yet differed with respect to biological and physical features and in the amount of area covered. Despite the persistence of the biological hotspots, results of various community analyses indicate that the associations of key species with the hotspots change with season and year. The finding that large regional areas are composed of smaller, localized hotspots, where the majority of biological activity is occurring, suggests that the evaluation of large marine ecosystems may lead to erroneous or misleading results. Thus, studies should also investigate for the presence of persistent, localized biological hotspots.

Keywords: hotspots, nekton, distribution, community composition, species diversity, habitats, GIS.

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ICES CM 2006/O:13

Spatio-temporal shifts in the distribution of the Spanish Mediterranean pelagic community in relation to environmental influences

A. M. Brown, J. M. Bellido, V. Valavanis, and A. Giráldez

Populations of small pelagic fish form important fisheries in the Spanish Mediterranean, particularly anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*), and are distributed along the entire length of the Spanish continental shelf. At short temporal scales, environmental conditions affect the distribution and local abundance of fish populations within a region, with implications for catchability. A GIS-based approach is used to investigate the spatial structure of populations of small pelagic fish in relation to environmental variables. Acoustic survey data provide a time-series from 2003 to 2005 of the distribution of the pelagic community on the Spanish continental shelf. A broad suite of environmental variables are incorporated into the GIS, including: sea surface temperature, salinity, chlorophyll concentration, photosynthetically active radiation, wind characteristics, and precipitation. The area is divided into several zones based upon the species composition of the community. For each zone, generalised additive models (GAMs) are used to investigate relationships between each environmental variable and the fisheries data. From these results, essential fish habitat (EFH) is mapped for the pelagic community, based on the environmental ranges which they occupy. By analysing temporal trends in the distribution of EFH, variations in the catchability can be monitored. Expansion, contraction, and migration of EFH will affect the spatial structure of the pelagic community, and therefore the ease with which fishers are able to locate them.

Geostatistics are used to quantify spatio-temporal variation in the spatial structure of the community.

Keywords: pelagic, environment, distribution, GIS, essential fish habitat.

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ICES CM 2006/O:17

School type: a phenotypic result of behavioural response to independent stimuli, as demonstrated by a comparative observation of the schooling behaviour of small pelagic fish

Patrice Brehmer, C. Laurent, A. Achury, and F. Gerlotto

The results obtained by *in situ* echo sounder measurements on *Sardinella aurita* fish schools over Venezuelan and Senegalese coastal shelves are compared. *S. aurita* is predominant in the two areas and the two stocks are genetically independent. The Senegalese school typology has been previously described by an analyzing echogram database and was used as reference. Seven surveys per-

formed in Venezuela following the Senegalese procedure have showed that the Senegalese typology could be used and the type proportions were similar in both areas. In 1999, two additional surveys were carried out in Venezuela and Senegal, using the IRD R/V "Antéa", to study the circadian schooling dynamics. The circadian variability in schooling was comparable in Venezuela and in Senegal. The results showed that *S. aurita* and their associated species presented comparable schooling behaviours in both countries; the school morphology can therefore be considered related to species and independent of the ecosystems.

Keywords: schooling, *in situ* observation, echo trace, school typology, small pelagic.

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ICES CM 2006/O:18 – Poster

Change in catchability caused by year class peculiarities: how is stock assessment based on separable cohort models able to take it into account?

(Some illustrations for triple-separable case of the ISVPA model - TISVPA)

Dmitri Vasilyev

Some species, e.g. Norwegian spring-spawning herring, are known to have peculiarities in special distribution of different year classes, including those related to their abundance. Consequently different year classes may have different catchability, at least for some age diapason. It is important to take this issue into account, both in stock assessment and in management.

It is often assumed that separable cohort models may not be applicable to many real life situations when the assumption about selection pattern stability is violated by systematic effects of higher or lower availability to fishery of different year classes (generations). Such an effect can originate either from changes in the spatial distribution of very abundant or poor generations, from a greater tendency to fish more abundant schools composed of species from more abundant generations, or for any other reasons. While common sense dictates this as a real problem for stock assessment by separable cohort models, the extent is still questionable and, if it is really so, the question arises how to diminish the problem.

The effect of implementation of so-called "triple-separable" assumption (incorporation of the third, generation-dependent, term into separable representation of fishing mortality) in comparison to results of separable cohort models based on ordinary separable assumption on simulated and real data is investigated in the paper. The results illustrate advantages of incorporation (and estimation within the model) of generation-dependent factors, both from the point of view of diminishing co-

hort effects in residuals, and in improving results of stock assessment. The results have also revealed that the extent of this effect depends on other model properties and requires optimization of the age interval to be included into the process of estimation and application of generation-dependent factors.

Keywords: changes in catchability, stock assessment.

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ICES CM 2006/O:19 – Poster

Spatio-temporal population dynamics of *Aristeus antennatus* in relation to environmental factors in the Balearic Islands (Western Mediterranean sea)

B. Guijarro, E. Massutí, J. Moranta, P. Oliver, J. M. Hidalgo, and A. Carbonell

The red-shrimp *Aristeus antennatus* is one of the target species of the bottom trawl fishery developed off the Balearic Islands. Studying the interaction of this important economical resource with the environmental conditions was one of the objectives of the multi-disciplinary IDEA research project (www.ba.ieo.es/idea). Seasonal and spatial differences of the species have been detected in its population dynamics in the island of Mallorca, from the analysis of one-year sampling (experimental and commercial hauls) and daily landings from 2000 to 2005, considering two different areas. Oceanographic data, trophic resources, and sediments were used as environmental factors in the analysis. Water mass seems to be the most important factor affecting yields, because positive relationships have been found between the salinity of water and catch rates of mature red shrimp. Inter-annual fluctuations in landings during the last decades have also been analysed, using annual catch per unit effort (CPUE) and population parameters (recruitment and spawning stock biomass), obtained from Virtual Population Analysis. They have been compared with global (Mediterranean Oscillation, MO) and regional indices. A negative significant effect of the regional index on CPUE and recruitment has been found while both spawning stock and CPUE seem to be enhanced by high values of the MO index. These high values of the MO index could reflect the major presence of the saline and warm Levantine Intermediate Waters (LIW) in the study area. The role played by environment on catchability should be taken into account in the stock assessment models for improving the management of this resource.

Keywords: red-shrimp, environmental factors, trawl fishery, catchability, Western Mediterranean, Balearic Islands.

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ICES CM 2006/O:21 – Poster

Monitoring of the Atlantic salmon smolt's migration in a large river system

Igor Studenov

The conditions of the Atlantic salmon smolt migration was studied in the large river system of the Severnaya Dvina (North of Russia). Surveys were conducted in 1995–2002 on the first-level inflow – the Vaenga river. The pound net was used from 1995 to 2000 and floating trap was used from 2001 to 2002. In the observed migra-

tion period changes in environmental parameters—the water level and temperature—were measured.

2803 smolts were examined from 1995 to 2002. On average 400 smolts were studied per year. The number of smolts varied from 54 (2001) to 915 (1996). The average catchability of traps was 18.8% and varied from 9.1% to 30.8%.

The number of smolts correlated to the water level was -0.49 and the number of smolts correlated to the water temperature was 0.34 . Smolt production was calculated from the unit of spawning areas.

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