Theme Session S

Joint ICES/PICES Theme Sessions on "Responses to climate variability: comparison of northern hemisphere marine ecosystems"

ICES CM 2010/S:01

CAVIAR: climate variability of the Baltic Sea area

A. Lehmann, K. Getzlaff, H-H. Hinrichsen, and F. Köster

The warming trend for the entire globe (1850–2005) is 0.04°C per decade. A specific warming period started around 1980 and continues at least until 2005, with a temperature increase of about 0.17°C per decade. This trend is equally well evident for many areas on the globe, especially in the northern hemisphere in observations and climate simulations. For the Baltic Sea catchment, which lies between the maritime temperate and continental Subarctic climate zones, an even stronger warming of ca. 0.4°C per decade has appeared since 1980. The annual mean air temperature increased by ca. 1°C until 2004. A similar warming trend can be observed for the sea surface temperature of the Baltic Sea. Even the annual mean water temperatures averaged spatially and vertically for the deep basins of the Baltic Sea show similar trends. We provide a detailed analysis of the climate variability and associated changes in the Baltic Sea catchment area as well as in the Baltic Sea itself for the period 1958–2009, in which the recent acceleration of the climate warming happened. Changes in the atmospheric conditions cause corresponding changes in the Baltic Sea, not only for temperature and salinity but also for currents and circulation. These changes in the physical conditions have strong impact on the marine ecosystem structure and processes.

Keywords: Baltic Sea, climate variability, modelling.

Contact author: A. Lehmann; IFM-GEOMAR, Department of Ocean Circulation and Climate Dynamics, Duesternbrooker Weg 20, 24105 Kiel, Germany [e-mail: alehmann@ifm-geomar.de].

ICES CM 2010/S:02

Walleye pollock biomass dynamics in the Bering Sea: possibility of long-term forecasting

O. A. Bulatov and L. B. Klyashtorin

This study investigates relationships between climate variations and dynamics of walleye pollock biomass in the Bering Sea. A 100-year time-series of the major climate indices were examined: air temperature in the Arctic (Arctic d*T*), Pacific decadal oscillation (PDO), Aleutian Low Pressure Index (ALPI), and 150-year temperature time-series of temperature changes in Gulf of Alaska (GOA SST). In addition, a 100-year series of variations in the Total Solar Irradiance (TSI) index was examined. All climatic indices and TSI show common cyclic dynamics of 60–65 year periods with peaks in the 1940s and 2000s and minima in the 1960–1970s. The overall Bering Sea pollock biomass dynamics was assessed by three major fishing regions: Donut hole area (+ Bogosloff area), West and North Bering Sea, and East Bering Sea. Each region has its own characteristics of biomass dynamics, although a comparative analysis of walleye pollock biomass changes in the entire Bering Sea and climate indices reveals their similarity. The correlation can be seen between the total walleye pollock biomass dynamics and North Pacific climate indicators (PDO and ALPI). A historical maximum in walleye pollock total biomass was observed in the mid-1980s (32 million tons), which was followed by a notable decline in biomass. The authors suggested a stochastic model to estimate long-term changes in the total abundance of the Bering Sea pollock According to the model the downward trend in the total pollock biomass will continue up to historic minimum in 2020–2030.

Keywords: biomass, climate impacts, walleye pollock.

Contact author: O.A. Bulatov, Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia [e-mail: obulatov@vniro.ru].

ICES CM 2010/S:03

Comparison of the atmospheric forcing and oceanographic responses between the Labrador Sea and the Norwegian and Barents Seas

Ken Drinkwater, Eugene Colbourne, Harald Loeng, Svein Sundby, and Trond Kristiansen

The Labrador and Norwegian Seas lie within the Subarctic region on opposite sides of the North Atlantic, whereas the Barents Sea is one of the marginal seas comprising the Arctic continental shelf. Warm Atlantic inflow from the south into the Barents Sea results in the Barents Sea containing flora and fauna similar to that of several of the Subarctic regions farther to the south. A comparison of the mean and variability in the climate and physical oceanography between the Labrador Sea and the Norwegian/Barents seas regions was carried out. The previously reported out-of-phase relationships of air and sea temperatures and sea ice conditions was confirmed between the Labrador Sea and the Norwegian/Barents Seas regions from the 1950s until the mid-1990s owing to their opposite response to the variability in the large-scale atmospheric pressure patterns as reflected in the North Atlantic Oscillation (NAO) index. However, since the mid-1990s, air and sea temperatures have been in phase, generally showing strong warming and reduced ice coverage in both regions. The cause of this change is linked to changes in the spatial structure of the atmospheric pressure patterns and a generally weakening of the influence of the NAO pattern. The effect of these changes on the primary production and higher trophic levels will be discussed as well as their implications on making projections for both the climate and ecosystems in these regions under future climate change.

Keywords: climate, comparisons, NAO, physical oceanography.

Contact author: Ken Drinkwater, Institute of Marine Research and Bjerknes Centre for Climate Research, Box 1870 Nordnes, N-5817 Bergen, Norway [e-mail: ken.drinkwater@imr.no].

ICES CM 2010/S:04

Using production models as a tool to examine factors that influence productivity of marine systems: a comparative analysis among ten northern hemisphere ecosystems

Bernard A. Megrey, Jason S. Link, Thomas J. Miller, Tim Essington, R. Ian Perry, Alida Bundy, and Ken F. Drinkwater

The inherent complexity and large scale of marine ecosystems suggest that progress toward understanding how marine ecosystems influence and regulate patterns of fishery production requires a comparative approach. We present the results of an international workshop focused on applying various surplus production model configurations as a tool for ecosystem comparison with the goal to answer the question—how does ecosystem structure and function interact to support fishery production, and what processes amplify, dampen, or obstruct the production that ecosystems provide? Our workshop goal was to understand how multiple drivers of productivity in fishery ecosystems simultaneously interact to determine overall production levels. These drivers reflect the triad of factors influencing fishery production including fisheries, the environment, and trophodynamics. In this presentation, we describe a common methodological framework (i.e. surplus production models) that was applied across several levels of taxonomic aggregation, for several species, and communities from several marine ecosystems and examine model outputs from multiple production modelling packages. We estimate management-relevant metrics and ecosystem attributes and compare them across populations and ecosystems. We also describe the utility of applying surplus production models in single-species, multispecies, and aggregate species group frameworks. We conclude by elucidating challenges of fitting such modelling approaches to similar species or functional guilds in contrasting arrangements (different species within ecosystems and similar species between ecosystems) to better delineate what controls ecosystem fishery production. Implications of our results for future work relevant to operational oceanography, population, and community modelling, and ecosystem-based fishery management are discussed.

Keywords: comparative ecosystem analysis, ecosystem productivity, surplus production models.

Contact author: Bernard A. Megrey, National Atmospheric and Oceanic Administration, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA 98115, USA [e-mail: bern.megrey@noaa.gov].

ICES CM 2010/S:05

Long-term variability in the fish populations in the Japan Sea, with special reference to the impact of the mid-1970s regime shift

Yongjun Tian and Hideaki Kidokoro

It is reported that a regime shift, characterized by an abrupt change from a cool to warm conditions, occurred in the Tsushima Warm Current (TWC) region in the Japan Sea in the late 1980s, and associated large changes in the TWC ecosystem. However, the impacts of the well-documented 1976/77 regime shift on fish populations in the Japan Sea are not well understood yet. Variation patterns in the fish community in the Japan Sea and its relations with environmental factors were examined using long-term fisheries and environmental data. Detailed analysis including PCA (principal component analysis) showed that fish populations from demersal to pelagic species changed abruptly during the early 1970s with increase in cold-water species such as walleye pollack and sardine, and decrease in warm-water species such as anchovy and horse mackerel, but no evident changes occurred in the mid-1970s. The variation pattern in the fish populations corresponded well with the winter and summer water temperature in the TWC. These results indicate the change in the early 1970s associated largely with the change in the summer water temperature, and the impact of the 1976/77 regime is not evident. It suggests the response pattern to the 1976/77 regime shift is different between the Japan Sea and central–eastern North Pacific.

Keywords: community, fish population, Japan Sea, regime shift, Tsushima Warm Current, water temperature.

Contact author: Yongjun Tian, Japan Sea National Fisheries Research Institute, Fisheries Research Agency (FRA), Suidou-cho 1, Chuo-ku, Niigata 951-8121, Japan [e-mail: yjtian@affrc.go.jp].

ICES CM 2010/S:06

Processes driving differences in major foodweb linkages of the Gulf of Alaska and eastern Bering Sea ecosystems: a conceptual view

Mary E. Hunsicker, Lorenzo Ciannelli, Kevin M. Bailey, and Stephani Zador

Key foodweb linkages and species dynamics can diverge in seemingly similar ecosystems owing to differences among physical and biological factors. The eastern Bering Sea (EBS) and western Gulf of Alaska (GOA) represent two such ecosystems. These systems are adjacent at similar latitudes, separated by the thin Alaska Peninsula; they are inhabited by similar species communities, and are affected by similar anthropogenic and large-scale forcing. However, population dynamics of some of the key species, specifically arrowtooth flounder (*Atheresthes stomias*) and walleye pollock (*Theragra chalcogramma*) are driven by the differences in their predation interactions among these regions. For example, cannibalism is the greatest source of predation on pollock in the EBS whereas predation by arrowtooth flounder is not so important. In the GOA, the roles are reversed, and predation by arrowtooth flounder exerts the highest source of predation mortality on juvenile pollock. These differences within the GOA and EBS foodwebs inspire questions about the causes and the consequences at the community level. Here, we present multiple hypotheses on possible local-scale abiotic and biotic processes that may have facilitated the divergence in these linkages. In support, we also evaluate the spatio-temporal distributions of arrowtooth flounder and pollock in the GOA and EBS systems and the physical and biological factors that facilitate overlapping distributions. We identify environmental conditions that generate strong overlaps between these species to improve our understanding and ability to predict how these important key trophic linkages may change under alternate climate scenarios.

Keywords: arrowtooth flounder, eastern Bering Sea, foodwebs, Gulf of Alaska, walleye pollock

Contact author: Mary Hunsicker, College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon, USA [e-mail: mhunsicker@coas.oregonstate.edu].

ICES CM 2010/S:07

Comparative analysis of zooplankton communities in the east and west coast of United States—biological response to large-scale driving forcing?

Hongsheng Bi, Bill Peterson, Cheryl Morgan, Jon Hare, and Joseph Kane

Zooplankton samples were collected in June 1998–2008 along the Washington and Oregon coast, the west coast of the United States, and May–June in 1977–1987 and 1992–2008 in Georges Bank, on the east coast of the USA. Although two systems are dramatically different, the west coast is a typical eastern boundary current system with strong upwelling and narrow shelf, and the east coast is a western boundary current system with a broader shelf, we examine how zooplankton communities respond to large-scale decadal variation in climate forcing. Non-metric multidimensional scaling (MDS) was applied on both datasets. Pacific decadal oscillation (PDO) and Atlantic multidecadal oscillation (AMO) were adopted as indicators for large-scale forcing in the two systems, respectively. Zooplankton communities in the west coast were consistent with PDO. When PDO was positive, there were more warm-water species and when PDO was negative, cold-water species were abundant. Zooplankton communities in the east coast did not display a consistent pattern with AMO, especially after 2000. We hypothesized that changes in zooplankton community structure in both coasts were associated with source water. On the west coast, when PDO was positive, more offshore water entered the coast and warm-water copepods were abundant, and when PDO was negative, more cold water came from Alaska coast and cold-water copepods were abundant. On the east coast, when more low-salinity water from north entered the coast, smaller copepods became more abundant.

Keywords: AMO, communities, multidimensional scaling, PDO, transports, zooplankton.

Contact author: Hongsheng Bi, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD 20688, USA [e-mail: hbi@cbl.umces.edu].

ICES 2010/S:08

Interannual variability in the Northern California Current foodweb structure: inferred changes in energy flow pathways and system response to alternate forcing scenarios

James J. Ruzicka, Robert L. Emmett, Jeannette E. Zamon, Cheryl A. Morgan, Andrew C. Thomas, John H. Steele, and Richard D. Brodeur

The Northern California Current (NCC) is a seasonally productive and open ecosystem. It is home to both a diverse endemic community and to seasonally transient species. Productivity and foodweb structure vary seasonally, interannually, and decadally owing to variability in the rate of nutrient input via coastal upwelling, forcing by climate-scale physical processes, and the abundance of migratory species entering the system. Important community structure changes observed between years include changes in the relative abundances of large jellyfish and small pelagic fish (anchovies, sardines) at intermediate trophic levels that form alternate energy transfer pathways linking lower to upper trophic levels. Annual plankton, fish, and seabird surveys provide information about pelagic community composition variability within the NCC. From these observations, interannual variability in trophic interactions and energy flow through the NCC system was inferred within a series of independent, mass-balanced foodweb models. Using these models, we quantified relative changes in energy transfer efficiency from bottom to top trophic levels, and we identified the relative importance of alternate energy transfer pathways at intermediate trophic levels. Alternate scenario investigations were used to analyse system sensitivity to variability in the strength of individual trophic linkages and system-wide response to changes in upwelling strength through time. Analysis of the range of ecosystem states observed interannually and system response to alternate forcing scenarios will improve our ability to predict

NCC ecosystem response to environmental change and quantify trophic pressures acting upon individual species.

Keywords: foodweb model, interannual variability, northern California current, sensitivity, upwelling ecosystem.

Contact author: James J. Ruzicka, Cooperative Institute for Marine Resources Studies, Oregon State University, Hatfield Marine Science Center, 2030 Marine Science Dr., Newport, OR 97365 USA [e-mail: Jim.Ruzicka@oregonstate.edu].

ICES CM 2010/S:09

How does exploitation of prey fish affect population growth rate in changing seas?

Joël M. Durant, Manuel Hidalgo, and Lorenzo Ciannelli

Population growth, hence the population's persistence, is affected by several factors such as climate, species interaction, and harvesting pressure the latter having been shown to make the marine populations more sensitive to climate forcing. Alternatively, age-truncated or juvenescent populations are a worldwide consequence of the protracted size-selective mortality of commercial fishing on the older and larger individuals. This process also increases a population's ability to directly respond to environmental fluctuations, emphasizing the importance of the interaction between fisheries, environment, and internal dynamics that produces complex synergic effects on the population dynamics of marine species. We used a comparative approach investigating commercially fished species on four different systems: the Norwegian Sea–Barents Sea (northeast Arctic cod), the Atlantic Ocean (European hake), the Mediterranean Sea (European hake), and the Bering Sea (pollock). Our objective was to address in a comparative way the ecological consequences of fishery effect on population properties (e.g. intrinsic growth rate) in relation to different environmental conditions (fishing intensity, climate, and prey abundance). For this, we have applied techniques based upon age-structured population matrices to analyse estimated stock sizes. By combining all sources of information, we investigated differences in the coupling between life-history traits and population dynamics for all stocks that display different level of juvenescence. This study will advance our understanding of the underlying mechanisms behind the transitory relationships between climate and fish populations.

Keywords: Barents Sea, European hake (*Merluccius merluccius*), fisheries, Leslie matrix, Mediterranean Sea, northeast Arctic cod (*Gadus morhua*), Pollock (*Theragra chalcogramma*).

Contact author: Joël Durant, Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Oslo, PO Box 1066 Blindern, NO-0316 Oslo, Norway [e-mail: joel.durant@bio.uo.no].

ICES CM 2010/S:10

Eastern Scotian Shelf and Barents Sea intercomparison: climate fluctuations, human impact, and system resilience

Edda Johannesen, Mette Skern-Mauritzen, Randi Ingvaldsen, Jan Erik Stiansen, and Emma Orlova

Climate variation and overfishing of top predators have caused a restructuring of several formerly cod-dominated North Atlantic shelf ecosystems. The Barents Sea, currently holding the world's largest cod stock and having undergone significant demersal fish biomass fluctuations, has not experienced major ecosystem restructuring. In contrast, the collapse of eastern Scotian Shelf demersal fish stocks in the early 1990s led to a trophic cascade with a dramatic increase in forage fish and alternating responses at lower trophic levels. In the early 1990s, the Barents Sea had the lowest 5-year cod fishing mortality ($F = 0.45$) since the 1950s; whereas cod fishing mortality ($F = 0.96$) on the eastern Scotian Shelf was the highest on record. At the same time, a deepening of the Icelandic low-pressure system led to increased inflow of warm-water masses to the Barents Sea and colder water temperatures on the eastern Scotian Shelf. These interacting forces of ocean climate and fishing mortality led to diametrical responses: a rapid increase in Barents Sea cod biomass during the mid-1990s and a collapse of the eastern Scotian Shelf stocks. Evidence indicates

that a predator-prey role reversal is an important factor in the lack of recovery of the eastern Scotian Shelf demersal stocks despite a nearly 20-year fishing moratorium. In the Barents Sea, a limited overlap between the distribution of forage fish and demersal fish larvae, and a directed forage fish fishery limits the potential for predator–prey role reversal.

Keywords: climate variation, ecosystem effects of fishing, spatial overlap, trophic regulation.

Contact author: Edda Johannesen, Institute of Marine Research, 5817 Bergen, Norway [e-mail: edda.johannesen@imr.no].

ICES CM 2010/S:11

Regime shifts in marine and lake ecosystems: teleconnection patterns

Carola Wagner, Rita Adrian, Jürgen Alheit, Thorsten Blenckner, Stephanie E. Hampton, Franz Hölker, Douglas J. Beare, and Daniel E. Schindler

Climatically induced regime shifts in aquatic ecosystems can re-organize plankton communities and thus alter structural and functional system properties. These changes may be synchronized over large spatial scales and across different types of aquatic ecosystems. We studied the timing and type of long-term changes for several indicators of abiotic and biotic system components. The synchrony of regime shifts was analysed with regard to system type (marine, freshwater), season (spring, summer), and geographic location. We chose two marine systems (North Sea, Baltic Sea) and three lakes (Lake Erken, Lake Müggelsee, Lake Washington). We hypothesized coherent shifts of all physical system components in spring during the late 1980s in Europe—possibly synchronized by NAO dynamics—regardless of system type and location, but out of phase with the North American systems. Further, biological responses were expected to be less coherent but there were still obvious shifts in ecosystems. Responses of all system components are expected to be more variable during summer.

Keywords: climate variability, regime shifts.

Contact author: Carola Wagner, LeibnizInstitute for Baltic Sea Research, Warnemünde, Rostock, Germany [e-mail: carola.wagner@io-warnemuende.de]..

ICES CM 2010/S:12

Impact of the Atlantic multidecadal oscillation (AMO) on Northeast Atlantic ecosystems

Jürgen Alheit and Carola Wagner

The AMO is a mode of multidecadal climate variability whereby warm and cold periods alternate over large parts of the northern hemisphere. Anecdotal records since the late nineteenth century and long-term time-series since the early twentieth century indicate that multidecadal changes in sea surface temperature associated with the dynamics of the AMO have impacted on dynamics of zooplankton, intertidal benthos, and fish populations of Northeast Atlantic ecosystems. During the warm periods (i) in the late nineteenth century, (ii) from approximately 1930–1960, and (iii) since the 1990s, many zooplankton, benthos, and fish species have extended their northern boundaries. Southern species have been observed in the North and Baltic Seas during these times, but were not recorded in the intervening periods. Examples of these apparently climatically driven changes in species distribution and abundance will be presented and comparisons will be made to similar phenomena in the North Pacific.

Keywords: AMO, benthos, climate variability, fish, Northeast Atlantic, northern Pacific, zooplankton.

Contact author: Jürgen Alheit, Leibniz Institute for Baltic Sea Research, Seestr. 15, 18119 Warnemünde, Germany [e-mail: juergen.alheit@io-warnemuende.de].

ICES CM 2010/S:13

Contemporary ocean warming and freshwater conditions contribute to delay the completion of maturation in Atlantic salmon throughout the Norwegian range of distribution

Jaime Otero, Arne J. Jensen, Jan Henning L'Abée-Lund, Nils Chr. Stenseth, Geir O. Storvik, and Leif Asbjørn Vøllestad

The completion of maturation in Atlantic salmon (*Salmo salar*) depends on environmental conditions that affect both feeding opportunities and growth, which would provide sufficient lipid stores for reproduction. However, if the level of energy reserves of a given fish is below a certain genetic threshold at a critical decision time further gonadal development is arrested and full maturation postponed. This individual development pattern suggests that the proportion of fish maturing at a given sea age could vary from year to year according to the feeding opportunities in the oceanic migratory habitat, and the growth rate during freshwater residence that might be associated with growth at sea. In this study we show that sea age at maturity of adults caught in multiple Norwegian rivers has increased with increasing sea surface temperature (SST) experienced by the fish in autumn months during their first year at sea. Furthermore, freshwater conditions measured by river discharge during summer one year ahead of seaward migration is positively related to increasing sea age at maturity. This result is discussed within the broad changes occurring in the Northeast Atlantic pelagic foodweb, mostly related to the current ocean warming, and river conditions influencing growth rates.

Keywords: Atlantic salmon, *Salmo salar*, maturation, Norwegian rivers, sea surface temperature, run-off.

Contact author: Jaime Otero; Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Oslo, PO Box 1066 Blindern, N-0316 Oslo, Norway [e-mail: j.o.villar@bio.uio.no].

ICES CM 2010/S:14

Climate variability drives anchovies and sardines into North and Baltic Seas

J. Alheit, C. Wagner, T. Pohlmann, M. Casini, A. Sell, and R. Vorberg

European anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) are southern, Lusitanian species needing warmer temperatures than boreal ones. After approximately 40 years of absence, they were observed again in increasing quantities in the North and Baltic Seas. Surprisingly, the population rise did not start in the late 1980s, when sea surface temperatures increased conspicuously in association with the increase of the NAO index. Instead, increasing numbers of eggs, larvae, juveniles, and adults of both species were recorded from the mid-1990s, indicating that temperature was not the only factor triggering their re-appearance and spawning in waters that are more northern. Apparently, climate variability drives anchovies and sardines into North and Baltic Seas. We will discuss which atmospheric (e.g. AMO, East Atlantic Pattern) and oceanographic (e.g. contraction of Subpolar gyre) drivers might be responsible for the occurrence of anchovies and sardines in North and Baltic Seas and other changes observed in plankton, intertidal benthos, and fish observed at the same time. Comparisons to similar northward migrations of anchovies and sardines in the North Pacific will be made.

Keywords: anchovies, climate variability, North Sea, sardines.

Contact author: Jürgen Alheit, Leibniz Institute for Baltic Sea Research, Seestr. 15, 18119 Warnemünde, Germany [e-mail: juergen.alheit@io-warnemuende.de].

ICES CM 2010/S:15

Changing states of North Atlantic large marine ecosystems

Kenneth Sherman, Kevin Friedland, John O'Reilly, and Kimberly Hyde

Effects of climate forcing are examined for 15 large marine ecosystems (LMEs) bordering the North Atlantic basin. Trends in multidecadal time-series data of temperature, chlorophyll, primary productivity, nutrients, and fish and fishery yields, differed among these LMEs. Responses to

climate warming varied between northwestern and northeastern Atlantic LMEs, with warming rates influencing changes in Northeast Atlantic LME plankton production and fishery yields more directly than in LMEs of the Northwest Atlantic, where warming rates are lower. In contrast, negative effects of nutrient over-enrichment in relation to harmful algal blooms and hypoxic conditions were greater in the Northwest Atlantic LMEs. Forecasts suggest significant increases in nutrient over-enrichment of North Atlantic LMEs by 2050. Fishery time-series analyses suggest increases in fishery yields for Subarctic LMEs, and declines in LMEs of more southerly latitudes.

Keywords: climate effects, fishery yield, large marine ecosystems (LMEs), North Atlantic, nutrient overenrichment.

Contact author: Kenneth Sherman, USDOC/NOAA/NMFS/ Northeast Fisheries Science Center, Narragansett Laboratory, 28 Tarzwell Drive, Narragansett, RI 02882, USA [e-mail: Kenneth.Sherman@noaa.gov].

ICES CM 2010/S:16

English Channel cuttlefish (*Sepia officinalis*) stock structure in the reproduction period

Michaël Gras, Olivier Goetz, Jehane Lepoittevin, and Jean-Paul Robin

Sepia officinalis is distributed from the West African coast to the North Sea and throughout the Mediterranean Sea. It is a semelparous species with a lifespan that varies between 12 and 24 months (from the south to the north of its distribution range). The migratory cycle of the English Channel population is now well known and coastal reproduction has been described in French waters (1989) as well as in English waters (1999). Spawning occurs inshore during the spring season on both sides of the English Channel. In the context of the global warming and in a species whose the life cycle can change in relation with temperature, updated information about sexual maturity is desirable. During the spring phase, the population is exploited by several métiers, including traps and otter trawls. A series of samples have been collected and analysed for biometric data and sexual maturity using a macroscopic key to determine the maturation stage. The different cohorts were identified with length–frequency data and size-at-maturity ogives were determined on a subsample of specimens. In addition to biological parameters, this work provides information about spatial and métiers-based differences in catch composition. Such elements are collected in order to develop a biomass model for the assessment of this stock.

Keywords: English Channel, global warming, life cycle, maturation, *Sepia officinalis*.

Contact author: Michaël Gras, UMR 100 PEMM University of Caen, Esplanade de la paix, 14032 Caen, France [e-mail: michael.gras@unicaen.fr].

ICES2010/S:17 Withdrawn

ICES CM 2010/S:18

Bottoms up: potential effects of environmental forcing on apex predators in the Gulf of Maine

Walter J. Golet, Jason Stockwell, Graham Sherwood, Andrew Pershing, Jeffrey Runge, and Molly Lutcavage

The Gulf of Maine, a highly productive shelf region in the Northwest Atlantic, supports a large biomass of energetically rich prey species such as Atlantic herring, Atlantic mackerel, and the copepod *Calanus finmarchicus*. Seabirds, marine mammals, and large pelagic fish migrate seasonally to this region where consumption of this prey base yields rapid accumulation of lipid stores used for reproduction and migration. Oceanographic data indicate the Gulf of Maine has experienced a pronounced shift in salinity, primary and secondary productivity during the mid-1990s. Generalized additive models suggest these oceanographic shifts may have contributed to significant changes in Atlantic herring and tuna condition and lipid energy stores during the previous decade. For example, medium and giant size classes of bluefin tuna experienced a 5–25% decline in summer body weight between the early 1980s and late 1990s. Such reductions to key energy stores have the potential to severely alter migration and reproductive patterns of highly

mobile species and highlight the importance of understanding and incorporating the effect of bottom–up forcing in fishery management.

Keywords: bluefin tuna, condition, herring, lipid.

Contact author: Walter Golet, Large Pelagics Research Center, University of New Hampshire, Durham, NH 03824, USA [e-mail: wgolet@unh.edu].

ICES CM 2010/S:19

Repeated observations of abrupt and persistent recruitment collapses in gadoids—a potential scenario in relation to climate change?

Tore Johannessen

Management, surveillance, and studies of ecosystems and their constituent species are generally based on the assumption of simple dose–response relationships. Gradual environmental changes or perturbations are expected to cause corresponding changes in the abundance of affected species. However, a unique time-series (since 1919) of 0-group gadoid abundance data from the Norwegian Skagerrak coast shows repeated incidents of abrupt and persistent recruitment collapses in gadoid fish. It is proposed that the recruitment collapses are caused by gradually increasing nutrient loads, which result in abrupt changes in the planktonic community and thereby reduced food variability for the 0-group gadoids. The results suggest that: (i) there are alternative stable states with different environmental optima in marine ecosystems; (ii) the change from one stable state to another appears as a catastrophic shift; (iii) different stable states may persist under overlapping environmental conditions, suggesting that marine ecosystems are highly resilient; and (iv) the eutrophication-induced shifts are linked to increasing turnover rates in the algal community with increasing primary productivity. This favours small, fast-growing algal species, which are then grazed by smaller herbivorous zooplankton. The fact that marine ecosystems may not respond in a gradual dose–response manner, but shift abruptly between alternative stable states seriously challenges our present approach of managing ecosystems and their constituent species, and the way we monitor potential impact of environmental changes. This is of particular concern with the prospect of global warming.

Keywords: climate change, ecology, eutrophication, recruitment, regime shifts.

Contact author: Tore Johannessen, Institute of Marine Research, Flødevigen, 4817 His, Norway [e-mail: torejo@imr.no].

ICES CM 2010/S:20

Comparison of the effects of climate variations on pelagic ocean habitats and their potential role in structuring the forage fish distributions in the Bering Sea and Gulf of Alaska

Anne B. Hollowed, Steven Barbeaux, Ned Cokelet, Stan Kotwicki, Patrick Ressler, and Christopher Wilson

Theoretical ecology suggests that competition between species and predator–prey interactions are modulated by the quality and quantity of suitable habitat. This paper examines whether climate variations influence the boundaries of suitable pelagic habitat, and whether these changes effect the spatial distribution and interactions between key fish species in the Bering Sea and Gulf of Alaska. The study focuses on the summer distributions of forage fish (age-0 and age-1 walleye pollock (*Theragra chalcogramma*), and capelin (*Mallotus villous*). Forage fish distributions were collected during summer acoustic and bottom-trawl surveys conducted as part of the NOAA groundfish trawl and acoustic surveys in the Bering Sea in 2003–2008, and the NOAA Fishery Interaction Team experiments in the Gulf of Alaska conducted in 2000–2006. We compare the responses of age-0 and age-1 walleye pollock, and capelin to climate induced shifts in pelagic habitats in the Bering Sea and Gulf of Alaska ecosystems. Habitat boundaries are defined using key explanatory variables including: forage fish density, predator distribution, depth, bottom temperature, surface temperature, and surface chlorophyll *a*. General additive models are developed to predict the

spatial distribution of age-0 pollock, age-1 pollock, and capelin in both regions. Comparison of the responses of three classes of forage fish in different ecosystems helps to better understand their expected responses to climate forcing. A framework is presented for integrating the relationships between climate variability, pelagic ocean habitats, and forage fish distributions into stock assessment models to permit forecasting.

Keywords: climate variability, Bering Sea, Gulf of Alaska, forage fish.

Contact author: Anne B. Hollowed, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115, USA [e-mail: Anne.Hollowed@noaa.gov]..

ICES CM 2010/S:21 Poster

Oscillations of abundance in North Atlantic fish in 1977–2010 compared with synchronous changes of commercially important species in other parts of the world ocean owing to global climatic variability

Feodor Litvinov, Nikolay Timoshenko, and Pavel Chernyshkov

Prediction of changes in the quantitative parameters (total biomass, recruitment, spawning biomass, etc.) of commercially important species is one of the most important tasks to be resolved by ICES and PICES, being the general basis for fishery management. Those parameters undergo various oscillations of the different amplitudes: quasi-periodical, synchronous, asynchronous, etc. Possibility of forecast strongly depends on general knowledge of a certain species' biology, its ecology, longevity, etc. and these factors differ significantly from species to species. Some severe oscillations cannot easily be derived from available data on environment and life history, but prediction with a certain accuracy is allowed, based on analogous changes in other species. Such species with analogous oscillations may be neighbouring fish of similar ecology or may be very distant organisms, spatially and taxonomically. The present paper presents analysis oscillation in blue whiting, northern mackerel, and Norwegian herring compared with Antarctic krill, pink salmon, and Chilean Jack mackerel. Significant similarities in oscillations were revealed, including opposite-directed, long-period, and short-period ones, caused most probably by synchronous changes in global processes in the ocean and atmosphere that are not perceived yet, but may be traced in integral indicators: living organisms. The synchrony revealed may be used for prediction of quantitative changes in commercially important species in North Atlantic, and other parts of the world ocean as well.

Keywords: Antarctic krill, Atlantic and Pacific fish, biomass oscillations, environmental background, quantitative changes.

Contact author: Nikolay Timoshenko, Atlantic Research Institute of Marine Fisheries, Kaliningrad, Russia [e-mail: timoshenko@atlant.baltnet.ru].

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Relationships between climate/environmental factors and Pacific cod (*Gadus macrocephalus*) catch in the southwestern East/Japan Sea

Sangdeok Chung and Suam Kim

This paper investigates the habitat characteristics of Pacific cod (*Gadus macrocephalus*) and the relationship between Pacific cod catch and environmental parameters in the southwestern Japan/East Sea. The highest catch of Pacific cod occurred in the seawater temperature range of 2–4°C and salinity range of 33.8–34.0 PSU at 100 m. The cross-correlation function (CCF) analysis indicated that there is a significant negative correlation ($r = –0.380$, $p < 0.05$) between Pacific cod catch and seawater temperature at 75 m in spawning area with a time-lag of 5 years. Furthermore, annual catch of Pacific cod has a significant correlation with zooplankton biomass in coastal nursery areas with a time-lag: i.e. $r = 0.452$ and $r = 0.421$ for total zooplankton in June of 5 years ago, and euphausiids in February of 4 years ago, respectively. Also, total cod catch was negatively correlated with winter Arctic Oscillation Index (AOI), and the highest correlation ($r = –0.500$) was

shown with a time-lag of 4 years. This might explain that both biotic and abiotic environmental factors during early life stages have significant influence on cod recruitment after 4–5 years.

Keywords: climate, environmental conditions, Korean waters, Pacific cod.

Contact author: Suam Kim, Pukyong Department of Marine Biology, Pukyong National University, Korea [e-mail: suamkim@pknu.ac.kr].

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Are there evidences of environmental-driven fluctuations in landings from the Portuguese trawl crustacean fishery?

Ana Moreira, Paulo Fonseca, Cristina Silva, Miguel Santos, Aida Campos, and Maria de Fátima Borges

Crustaceans are a highly valuable component of the Portuguese continental bottom-trawling fisheries, being currently targeted by ca. 30 vessels operating mainly off the south coast and, to a lesser extent, the southwestern one, at depths ranging from ca. 150 to more than 600 m. The main target species are the Norway lobster (*Nephrops norvegicus*), a benthic burrowing species, and the deep-water rose shrimp (*Parapenaeus longirostris*). During a 23-year period (from 1986 to 2008), landings of both species fluctuated greatly, particularly rose shrimp (e.g. increase from 800 to 2000 tons between 1998 and 1999; decrease from 1000 to ca. 140 tons between 2003 and 2004). The fact that these species are often captured during the same fishing trip makes it difficult to allocate the fishing effort for each of them, thus preventing the correct estimation of catch per unit of effort. Furthermore, rose shrimp is a pivotal species because fishers reorient their effort towards Norway lobster depending upon fluctuations in the shrimp abundance. The latter fact adds a further level of complexity when trying to disentangle fishery-induced from environmental-induced fluctuations in landings. We examined the relationship between Norway lobster and rose shrimp landings from 1986 until 2008, assumed as a proxy of abundance, with environmental variables such as the eastern Atlantic and upwelling indices, regional average sea surface temperature and rainfall, and river hydrologic regime, by estimating maximum cross-correlation (and associate time-lags) among them. Preliminary results for Norway lobster led us to use a time-series of spawning-stock biomass of recruitment in place of landings. Both species displayed a significant positive correlation at different lags with the eastern Atlantic index. Good recruitment years seem to be associated with dryer, warmer conditions associated with higher values of EA. Water temperature may also be associated with species abundance, but with an opposite impact, positive correlation for the rose shrimp and negative for the Norway lobster. This may be related to the fact that the Portuguese coast is approximately the northern limit of the former species and the southern limit of the latter.

Keywords: deep-water rose shrimp, environmental variables, landings, Norway lobster, Portugal, spawning-stock biomass of recruitment, time-series.

Contact authors: Paulo Fonseca and Maria de Fátima Borges, INRB IP/IPIMAR, Portuguese Institute for Fisheries Research, Av. de Brasilia, 1449-006 Lisboa, Portugal [e-mail: pfonseca@ipimar.pt; mborges@ipimar.pt].

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Comparing trophic structure and diversity in northern ecosystems using stable isotope data

Silje Ramsvatn, Torstein Pedersen, and Einar M. Nilssen

Change in trophic level of catches has become a key indicator of fishery impact, ecosystem structure, and health. Whether because of fishing pressure, climate change, or other sources of physical or biological changes in an ecosystem, we propose to use isotope metrics in comparing key species and functional groups in ecosystems across the northern hemisphere. Layman *et al.* (2007) suggested an interesting approach for using stable isotopes in community-wide measures to represent a species trophic role, and they also presented a possible way of quantitatively measuring ecosystem structure and dynamics. By making a bi-plot of $\delta^{13}C$–$\delta^{15}N$ they proposed

using this to measure, for example, niche diversity and trophic redundancy. As a case study, we attempt to use this approach to compare northern ecosystems in Norway with Canadian Gulf of St Lawrence using stable isotope data. The systems exhibit similar physical and biological properties in being northern estuarine systems and share many of the same species, but have been under different stress from fishing pressure and other perturbations. Recently sampled stable isotope data from a Norwegian outer fjord system (Ullsfjord) were compared with published data from inner fjord systems and from Atlantic Canadian systems.

Keywords: diversity, ecosystem change, niche, stable isotopes, trophic redundancy.

Contact author: Silje Ramsvatn, Department of Marine and Arctic Biology, University of Tromsø, Norway [e-mail: silje.ramsvatn@uit.no].

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Comparing long-term changes in primary and secondary production in the North and Baltic seas: a modelling study

Dhanya Pushpadas, Ute Daewel, Corinna Schrum, and Sturla Winger Svendsen

Although the North Sea and Baltic Sea are located side by side and hence exposed to almost the same climatic conditions, their respective ecosystems are very different in terms of both physical and biological characteristics. Although the North Sea is an open system characterized by strong tides and a pronounced frontal system, the Baltic Sea ecosystem is almost enclosed and influenced by freshwater run-offs, creating a permanent halocline. Here we applied a three-dimensional ecosystem model (ECOSMO) simultaneously to both systems in order to identify interannual variability and long-term trends in primary and secondary production with a special focus on climatic impacts. Therefore, we present results from a 60-year (1948–2007) hindcast simulation and analysed both primary and secondary production with respect to specific climatic variables (e.g. windstress, 2 m air temperature, short-wave radiation). Previously performed scenario tests indicated that specifically changes in short-wave radiation determine spatial and temporal variability in North Sea production, depicting a rather direct source for variability. For the Baltic Sea, we expect both direct impacts of climatic forcing on primary and secondary production via, for example, solar radiation, or vertical mixing, as well as indirect impacts such as climatically triggered nutrient infusions from the North Sea, influencing nutrient availability and hence primary production. Comparing these two, similarly located ecosystems, raises not only the opportunity to identify climatic impacts on ecosystem dynamics, but to highlight the interactions with other environmental conditions such as bottom topography, tides, and exchange with other ecosystems.

Keywords: Baltic Sea, climate variability, ecosystem modelling, North Sea, primary production, secondary production.

Contact author: Dhanya Pushpadas, Geophysical Institute, University of Bergen, Allegaten 70, N-5007 Bergen, Norway [e-mail: Dhanya.Pushpadas@gfi.uib.no].

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Environmental effects on ocean entry of Atlantic salmon (*Salmo salar*) smolt across its range of distribution

J. Otero, T. Antonsson, J. Armstrong, F. Arnason, J. V. Arnekleiv, J.-L. Baglinière, P. Caballero, T. Castro-Santos, J. B. Dempson, J. Erkinaro, S. Gudjonsson, G. Horton, N. A. Hvidsten, A. J. Jensen, E. Jokikokko, I. R. Jonsson, J. F. Kocik, J. H. L'Abée-Lund, A. Lamberg, B. H. Letcher, E. Niemelä, A. Romakkaniemi, I. Russell, N. C. Stenseth, G. O. Storvik, A. J. Veselov, and L. A. Vøllestad

The smolt transformation process is the change in morphology, physiology, and behaviour that Atlantic salmon (*Salmo salar*) parr undergo before migrating to sea in spring. Temperature and photoperiod are the primary environmental cues regulating this process. Previous studies have identified water temperature and water flow as the main factors controlling the smolt downstream

migration. These factors vary with geographical location and habitat characteristics, suggesting that the pattern of downstream migration could differ within and among rivers. Survival appears to be dependent on a precise alignment with "optimal" conditions when entering the sea, thus making timing of smolt descent a critical life-history event. Moreover, there is heritability for timing of smolt migration. However, the importance of genes and environmental conditions might be spatio-temporal dependent, allowing for local adaptation and evolution. Whereas most of the previous research has focused on analysing single or only a few populations, here we present a meta-analysis that compiles information on downstream smolt migration covering much of the distributional range of this species within the North Atlantic basin. Using different modelling approaches and population-specific sampling, we aim at exploring how local environmental conditions affect the spatio-temporal patterns of Atlantic salmon smolt run.

Keywords: Atlantic salmon, *Salmo salar*, North Atlantic basin, river temperature, run-off, sea surface temperature, smolting.

Contact author: Jaime Otero; Centre for Ecological and Evolutionary Synthesis (CEES), Department of Biology, University of Oslo, PO Box 1066 Blindern, N-0316 Oslo, Norway [e-mail: j.o.villar@bio.uio.no].

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Monitoring and Evaluation of Spatially Managed Areas (MESMA)

Anke Weber Smit

The seas around Europe are home to an exceptionally wide range of marine habitats, which must also support a variety of marine industries. "Multiple use" can cause problems between various user groups, between economic interests and conservation requirements, and there is also a greater potential for degradation of the marine ecosystems themselves. This combination increases future challenges for marine environmental managers. The increasing pressures upon the European seas and coastal areas call for a well-planned approach for their continued spatial development. The challenge for marine spatial management is to find an optimal balance between the competing demands of economic use, ecological development, and nature conservation, while at the same time maintaining sensitivity towards traditional practices. MESMA is an EU 7th framework project on Monitoring and Evaluation of Spatially Managed Areas. The project was started in November 2009 and will last till November 2013. MESMA operates on a local, national, and European scale. Within MESMA, 19 partners from 12 countries will evaluate cross-border pan-European comparison of spatial management. We base our research on existing data of nine case studies. The project focuses on marine spatial planning and produces integrated management tools (concepts, models, and guidelines) for monitoring, evaluation, and implementation of spatially managed areas (SMAs). Within MESMA we will involve the stakeholders essential to the effectiveness of SMAs, assess the conflicts generated by SMA, and identify tools for "good practice" management. Beneficiaries of the results will be governments, local authorities, stakeholders, and managerial bodies for planning and decision-making.

Keywords: European Union, Marine Strategy Framework, 7th Framework Programme, spatial management, spatially managed areas.

Contact author: Norwegian Institute for Water Research, PO Box 1266 Pirsentret, 7462 Trondheim, Norway [e-mail: Anke.Weber@niva.no].