ICES/NAFO Decadal Symposium 2011

Oral Presentations

ICES/NAFO Decadal Symposium 2011/Ref. 6

Navidad current in the Canary Current Area related to Upwelling and NAO indexes under the period 2000–2009 and their possible impact on fisheries

K. Hilmi, A. Benazzouz, S. Kifani, A. Makaoui, and J. Larissi

The interannual variability of the Navidad current in the Canary Current Area is established under the period 2000–2009 and correlated with the North Atlantic Oscillation (NAO) Index. Winter warming is observed generally with a warm and salty surface current, so called "Navidad". It circulates poleward and develops numerous eddies which interact with the bottom topography along the continental slope. These typical eddies are named "swoddies" (Slope Water Oceanic Eddy) (CNES/CLS). Using various indexes from climate/remote sensing/altimetry data (upwelling index, NAO index, sea level anomalies), these swoddies are particularly observed during winters 2006, 2009 (and 2010) in this area, with a negative NAO index and weak upwelling index. Their possible impact on fisheries is also discussed.

Keywords: Navidad current, swoddies, NAO index, Upwelling Index, Canary Current Area

Contact author: K. Hilmi, Institut National de Recherche Halieutique, 02 Rue Tiznit Casablanca 20030, Morocco [e-mail: hilmi@inrh.org.ma].

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Current state of the Atlantic waters and climate of the Barents Sea

V. Boitsov, A. Karsakov, and A. Trofimov

The year-to-year variability in temperature of the Atlantic waters, having a great influence on the marine climate and ecosystem of the Barents Sea, was analysed using the data from the Kola section. It was found that with a positive trend of the mean annual temperature having been observed since the late 20th century, only positive anomalies were registered during the last decade. During 9 years the temperature was warmer than the long-term mean by 0.5-1.2 °C, and, in 2006, the historical maximum for 110 year period of observation along the section was recorded. It was revealed that high air and water temperature caused reduced ice coverage in the sea, especially, in the period from October to April when a seasonal enlargement of the ice-covered area took place. An analysis of the long-term fluctuations of the Barents Sea integral climate index, which allows for the total variability in temperature of the Atlantic waters, the air temperature and the ice coverage, is presented and a long-term prediction of the future sea climate state is given.

Keywords: water temperature, climate, the Barents Sea

Contact author; A. L.Karsakov, Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, 183763, Murmansk, Russia [e-mail: karsakov@pinro.ru].

ICES/NAFO Decadal Symposium 2011/Ref. 14

Differential impacts of climate change on spawning populations of Atlantic cod in US waters

L. A. Kerr, S. X. Cadrin, M. Fogarty, and J. Churchill

Recent genetic data revealed population structure of Atlantic cod in U.S. waters is composed of three primary spawning components including a northern spring spawning, southern winter/spring spawning, and Georges Bank spring spawning group. We examine the potential impacts of climate change on the productivity, stability, and yield of spawning populations of cod with unique spatio-temporal distributions in the northwest Atlantic. Specifically, we consider two climate change impacts documented in the north Atlantic since the 1970s: increased water temperature, as observed in fishery-independent survey data, and wind-driven storm forcing, as evidenced by positive trends in the power dissipation index (PDI). Climate change impacts were incorporated into an age-structured simulation model of cod in the region, consisting of three genetically-defined population components, through their influence on the recruitment and growth functions of populations. Future changes in water temperature were predicted from three atmosphere-ocean general circulation models and changes in PDI were estimated based on its close association with sea surface temperature. Climate change impacts differentially influenced cod spawning groups based on the timing and location of spawning and different growth environments of each population. Recognition of the role spatio-temporal distributions of populations play in determining their sensitivity to climate change impacts is important to understanding the severity of climate change effects on fish and fisheries.

Keywords: climate change impacts, cod, temperature, wind, population productivity, Georges Bank, Gulf of Maine

Contact author: Steve, Cadrin, University of Massachusetts Dartmouth School for Marine Science & Technology, 200 Mill Road Suite 325 Fairhaven MA 02719, USA [e-mail: scadrin@umassd.edu].

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Barents Sea ecosystem state: climate fluctuations, human impact and system resilience

E. Johannesen, R. Ingvaldsen, P. Dalpadado, E. Eriksen, M. Skern-Mauritzen, J. E. Stiansen, H. Gjøsæter, B. Bogstad, and T. Knutsen

The Barents Sea has been influenced by human activity for many decades, historically mainly by fishing and hunting of marine mammals. In the same period climate has varied considerably. Climate variation and over-fishing of top predators have caused a restructuring of several formerly cod dominated North Atlantic shelf ecosystems. Despite high fishing pressure, the Barents Sea currently holds the world's largest cod stock, and has not undergone ecosystem restructuring.

Available data for assessing the effects of climate, fishery and interactions on ecosystem structure and functioning has increased from mostly catch data in earlier times, to the present ecosystem surveys, advanced models and satellite technology. Here we review available data and use multivariate statistics to contrast the ecosystem state and variation in exploitation, climate, plankton, pelagic fish, demersal fish, and interactions between trophic levels in 2000–2009 with earlier decades.

While the 1980s had low temperatures, high exploitation, and low stocks of demersal fish, the situation improved in the 1990's. The last decade has been the warmest on record and demersal stocks have reached levels comparable to the 1950's and 1960's. The 1980's and 1990's were dominated by strong interactions between capelin and its prey and predators. The importance of capelin on lower and higher trophic levels has been less evident the last decade. We propose possible explanations for this latter change.

Keywords: Ecosystem state, trophic regulation, time series, Barents Sea

Contact author: Edda Johannesen, Institute of Marine Research, PO Box 1870, 5817 Bergen, Norway [e-mail: eddaj@imr.no].

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Hydrographic Variability in the Norwegian Sea during 1995–2010

K. A. Mork and Ø. Skagseth

We investigate the hydrographic changes in the Norwegian Sea during 1995–2010. The hydrographic data used in the studies are taken from the annual international coordinated pelagic surveys in the Norwegian Sea during May from 1995 to 2010 together with Argo floats for the similar period. Means, trends and yearly anomalies of heat and salt content, and depth of isopycnals are calculated at each grid point. The contribution to these changes by local air-sea heat flux and dynamical changes by advection (and wind stress) are quantified. Finally, we present large-scale integrated parameters of heat and salt content and depth of isopycnals. These are used to explore the observed changes in the biological production during the period 1995–2010.

Keywords: Water mass, Heat content, Atlantic Water, Norwegian Sea

Contact author e-mail: Kjell Anre Mork, Institute of Marine Research, Nordnesgaten 50, P. O. 1870 Nordnes, 5817 Bergen, Norway [e-mail: kjell.arne.mork@imr.no].

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Cycles and trends in the Iberian sardine (*Sardine pilchardus*) stock and catch series and their relationship with the environment

M. B. Santos, G. J. Pierce, I. Riveiro, J. M. Cabanas, and C. Porteiro

The Iberian sardine (*Sardine pilchardus*) is a good example of the typical life strategy of small pelagic fish species around the world: short life span, fast growth and long spawning season, which in the case of the Iberian stock presents two peaks (in winter and spring). This life strategy makes new year classes very dependent on the right environmental conditions to survive the early life stages. Egg and larval survival relies on the right oceanographic mechanisms, to ensure retention in favourable areas, and availability of food. Dispersal of eggs and larvae seriously reduces their survival and decreases the chances of a good new year class. Because of this dependency on environmental conditions in early life, there is no relationship between the stock size (measured as SSB) and recruitment. Previous studies have explored the relationship between environmental variables, at large and local spatial scales, and sardine recruitment in the Galician and Portuguese sardine fishery but have faced two main analytical challenges: short time series and autocorrelated data. We carry out new analysis using statistical methods designed to cope with these challenges, including Dynamic factor Analysis and mixed modelling, to identify and characterise relationships between sardine populations (recruitment, spawning stock biomass, and (to extend the time series) fishery landings in the area) and a series of global, regional and local environmental variables.

Keywords: sardine, time series, environmental drivers, Iberia

Contact author: M. B. Santos, Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, P.O. Box. 1552; 36280 Vigo, Spain [e-mail: m.b.santos@vi.ieo.es].

ICES/NAFO Decadal Symposium 2011/Ref. 21

Structure of the Barents Sea plankton communities under climate change conditions in 2000–2009

E. Orlova, V. Boitsov, A. Trofimov, and A. Yakovlev

Considered are the hydrographic conditions in the Barents Sea in the first decade of the 21th century, which were characterized by warmer-than-normal temperature of different water masses and lower-than-normal ice coverage. It was shown that higher water temperature observed for a long period combined with an increased rate of the ice retreat in summertime resulted in the extension of the sea area that was favourable for development of plankton in the warm season. That caused northward distribution of the Arctic copepod species, among which *Calanus glacialis* was the most abundant. It was found that, during the recent warmest years, the part of the Barents Sea area with positive temperatures extended northwards to 77–79°N. In that connection, in the north of its central part and in the east, differentiation in the copepod distribution occurred, with *Calanus glacialis* dominating the Franz Joseph Land area and *Calanus finmarchicus* prevailing in the area influenced by Atlantic waters to the east.

Keywords: *Calanus glacialis*, plankton, water temperature, Barents Sea

Contact author: A. Trofimov, Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Street, 183763, Murmansk, Russia [e-mail: trofimov@pinro.ru].

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Variability in the physical structure, ocean chemistry, plankton ecology and commercial fish species of the seas surrounding Ireland between 1997 and 2010

G. Nolan, K. Lyons, S. Fennell, T. Mc Grath, D. Guihen, C. Cusack, and C. Lynam

Since 1997, an enhanced capability to monitor hydrobiological variability has been developed in Irish waters. Seasonal and yearly research cruises have begun to elucidate changes in the physical structure of both deep and shelf water masses. A progressive freshening of the Labrador Sea Water layer has been observed in the late 2000's in the Rockall Trough while a complex interaction of Sub-Arctic and Mediterranean waters occurs at the Porcupine Bank. Shelf waters have warmed consistent with the positive phase of the Atlantic Multidecadal Oscillation. In recent years the WOCE hydrographic sections of the late 1990s have been revisited showing nutrient and oxygen distribution changes of the various water masses in Rockall Trough. Early indications are that surface waters have acidified across the region since 1996.

Changes in the physical structure of shelf waters has had an effect on both phytoplankton and zooplankton species. *Karenia mikimotoi*, a harmful algal bloom causing organism, has increased in abundance in Irish waters since the early 1990's while a warm water zooplankton species, *Calanus helgolandicus* has been on the increase in the Celtic Sea throughout the past decade. Abundance of some key fish species has also changed over this period with an increase in the abundance of dogfish and poor cod to the north of Ireland and decreases to the south. Concomitantly key commercial species have generally declined. This paper will link the changes in physical and chemical properties with changes in the living marine resources around Ireland between 1997 and 2010.

Keywords: oceanography, variability, ecosystem, Irish Atlantic waters

Contact author: Glenn Nolan, Marine Institute, Rinville, Oranmore, Ireland 2 National University of Ireland, Galway, Ireland [e-mail: glenn.nolan@marine.ie].

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Sub-decadal oceanic oscillations regulate the north-eastern Atlantic shelf ecosystems

H. Hátún, A.B. Sandø, M. Heubeck, and M. Frederiksen

Large biogeographic shifts in the north-eastern Atlantic Ocean have previously been attributed to exchanges of subarctic and substropical water masses, which in turn are associated with changes in the strength and extent of the subpolar gyre. We here show that the biological production on the adjacent shelves – the south Iceland and Faroe shelves and the north-west European margin – is regulated collectively by the sub-decadal component of the gyre dynamics. Recurrent and intermittent northward propagation of eastern water from the 'inter-gyre region' and the hydrographic impact on the subarctic seas after 1-2 years is demonstrated using a numerical ocean model and remotely sensed and *in situ* oceanographic data. A broad time series selection on primary production, zooplankton, sandeel, seabirds and economically important fish stocks from these shelf ecosystems reveals rapidly increased production during the cooling and freshening phase following a pulse of eastern water. The intensification of these sub-decadal oscillations after 1990 is here linked to the wind-driven meridional Sverdrup transport and to a possible ocean-atmosphere feedback through local heat exchange. Our results potentially facilitate realistic 1-2 years forecasts of the marine climate and important planktonic and fish prey-species for both seabirds and commercial fish stocks.

Keywords: marine climate, ecosystems, predictability

Contact author: H. Hátún, Faroe Marine Research Institute, Box 3051, FO-110, Tórshavn, Faroe Islands [e-mail: hjalmarh@hav.fo].

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70 years of monitoring the Rockall Trough

T. Sherwin, P. Holliday, C. Johnson, and J. Read

The time series of temperature and salinity in the upper waters of the Rockall Trough can be traced back to 1950 when they were recorded by ships travelling out to OWS Lima in the Iceland Basin. From 1975 these data have been complemented by and then replaced by dedicated CTD sections initially conducted by the Dunstaffnage Marine Laboratory and later supported by NOCS the and occasionally Marine Scotland, Science (the so-called Ellett Line). Today they are enhanced by real-time observations (via satellite) of the upper 1000 m made by an underwater glider operated by SAMS. In the last decade there has been a steady increase in the annual section average across the trough of both temperature and salinity that might be taken as evidence of climate change. However, examination of the full dataset suggests that surface temperature and salinity can vary by up to 1° C and 0.15 units respectively on decadal timescales.

Nutrient (NO2/3, PO4 and Si) data have been collected systematically since 1996 and exhibit inter-annual section averaged variability, particularly in NO2/3, the causes of which are not immediately clear. Most of the upper layers flow northward, but temperature, salinity and nutrient gradients across the Rockall Trough reveal a significant southward flowing water mass derived from the Wyville Thomson Ridge to the north. The Ellett Line contains a unique archive of observations that can be used to place in context the recent changes in the local ocean climate.

Keywords: Physical oceanography, Nutrients, Rockall Trough

Contact author: Toby Sherwin, Scottish Association for Marine Science, Scottish Marine Institute, Oban, UK [e-mail: toby.sherwin@sams.ac.uk].

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A review of hydrographic variability in Icelandic waters during recent decades and related changes in distribution of some fish species in the area

Hedinn Valdimarsson and Olafur S. Astthorsson

In tandem with changes in the North Atlantic observations of hydrographical conditions over the last couple of decades have shown the increased distribution of Atlantic water to the south and west of Iceland. In this period the temperature and salinity have remained relatively high and markedly above the long term mean south and west of Iceland. Similarly, the conditions in the arctic influenced area to north and northeast of the country have more frequently been observed over the long term mean although not to the same extent as to the south and west. Further indications are that the influence of warmer and more saline inflows may have had remarkable effect on conditions in the Iceland Sea. In the same time period notable changes have been observed in the distribution of several fish species over and outside the Icelandic shelf. Also the occurrence of many rare fish species has increased and new fish species have also been recorded. In this paper hydrographic timeseries from the Icelandic standard sections are reviewed along with consequent changes in the distribution of several fish species in the area.

Keywords: Icelandic waters, hydrographical timeseries, changes in fish distribution, records of new species

Contact author: Hedinn Valdimarsson, Marine Research Institute, Reykjavik, Iceland [e-mail: hv@hafro.is].

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Long-term mesozooplankton changes in coastal waters of North Spain

R. González-Gil, F. González-Taboada, J. Höfer, and R. Anadón

The mesozooplankton community is a primary candidate for time series studies because of its key role in marine ecosystems and its particular life-cycle features. Coastal areas are especially sensitive to environmental changes and the Cantabrian Sea, due to its singular geographical conditions, is an attractive example to perform time series studies. To evaluate modifications and responses of mesozooplankton to environmental variations in the central Cantabrian Sea, we conducted a monthly sampling survey during 18 years (from 1993 to 2010) along a coastal-oceanic transect. Several physical variables (sea surface temperature, salinity on the 27.1 isopycnal, and upwelling index) and biological variables (Chlorophyll *a*, total and fractionated mesozooplankton biomass and mesozooplankton abundance) were analyzed. We characterized the general annual cycle for them at this location of the Cantabrian Sea, detecting differences between coastal and oceanic conditions. Also, we found different long-term trends during the time series period, which have been analyzed from an environmental change perspective. The outcomes of our analysis will help us to better understand the mesozooplankton community dynamics at the temporal and spatial scales representative of our study. Finally, we compared these results with those reported at other locations of the Bay of Biscay, and in a broader view, with other areas of the Atlantic Ocean.

Keywords: mesozooplankton, time series, long-term trend, Bay of Biscay.

Contact author: R. González-Gil11Área de Ecología. Dpto. Biología de Organismos y Sistemas de la Universidad de Oviedo, C/ Valentín Andrés Álvarez s/n, E33071, Oviedo, Asturias, Spain [e-mail: rgonzalezgil@gmail.com].

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Changes in the NAO forcing in the North Atlantic during 2000–2009

K. Drinkwater, E. Colbourne, and H. Loeng

The North Atlantic Oscillation (NAO) captures the dominant large-scale pressure patterns over the North Atlantic Ocean. It consists of the Icelandic Low and Azores High, and the oscillation occurs because of the tendency for them to strengthen and weaken at the same time. Many physical and biological properties have been shown to exhibit statistical relationships with the NAO with the strength and sign of the relationships varying with location, variable or species. Since the decade of the 1960s to that of the 1990s, the NAO forcing has been responsible for the out-of-phase relationships between climate and oceanographic conditions in the Northwest and Northeast Atlantic. Typically, when there are cold conditions on one side of the Atlantic it is warm on the other and vice versa. However, beginning in the late 1990s and extending into the 2000s, the two sides of the North Atlantic have shown similar responses and a reduction in the importance of the NAO forcing. A detailed examination of reasons why will be discussed along with some of the effects on the physical and biological components of the ecosystems on both sides of the Atlantic.

Keywords: NAO, climate, impact, North Atlantic

Contact author: K. Drinkwater, Institute of Marine Research, Box 1870 Nordnes, N-5817 Bergen, Norway [e-mail: ken.drinkwater@imr.no].

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North-West Iberia Maritime Climate During the 20th Century and the Beginning of the 21st

M. Gómez-Gesteira, M. de Castro, M. N. Lorenzo, I. Alvarez, J. J. Taboada, A. J. C. Crespo, I. Iglesias, and F. Santos

World's climate change is now considered an irrefutable fact and likely antropogenicaly forced mainly by greenhouse gases emissions, changes in land uses and deforestation. Within this context of global change, we will make a review of marine and atmospheric trends along the last decades in the northwestern part of the Iberian Peninsula over to the territories of Spain and Portugal. The area ranges from 41 to 44 ºN and from 6.5 to 9 ºW and it is surrounded by the Atlantic Ocean and the Cantabrian Sea in approximately 50% of its extension.

A significant positive tendency of 0.24ºC dec^{-1} in Sea Surface Temperature (SST) was observed from 1974 on, which is about one half of the increase observed over land, 0.5 ºC dec^{-1}, for the same period. Nevertheless, this increase has not been constant during the past century, when several warming- cooling cycles were observed. In addition, SST changes were observed to be different at coastal and oceanic areas.

A significant positive tendency of 2 cm dec^{-1} was observed in Sea Level Rise from 1943 on. This, overall positive trend is far from being homogeneous showing important interdecadal differences.

In addition, Ekman transport normal to coast (upwelling index) showed a marked decrease since 1948, being especially intense during the last four decades. Once again, important interdecadal oscillations have been observed, which makes difficult to the accurate calculation of trends, which are far from being linear.

Keywords: Maritime Climate; North-West Iberia; Temperature; upwelling; Sea Level Rise

Contact author: M. Gómez-Gesteira, EPphysLab (Environmental Physics Laboratory), Universidade de Vigo, Spain [e-mail: mggesteira@uvigo.es].

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Climatic variability in the Skagerrak and coastal waters of Norway

J. Albretsen, J. Aure, R. Sætre, and D. Danielssen

During the period 1935 to 1947 the Institute of Marine Research (IMR) established a number of fixed hydrographic stations in Norwegian coastal waters. At these stations the vertical temperature and salinity profile are measured 2-4 times per month. Since 1952, the IMR has operated a standard hydrographic section across the central part of the Skagerrak between Torungen on the Norwegian side and Hirtshals on the Danish side. The section has on average been worked out 8-12 times a year. These data have been used to elucidate the long-term hydrographic variability along the Norwegian coast with special emphasis on the most recent decades.

The mean decadal winter temperatures in the deeper layers along the Norwegian coast and in the Skagerrak were relatively stable from the 1950's to the 1980's. A peak in the deep layer temperature in the early 1990's was followed by a marked decrease in 1993–1994. After that there has been a gradually increase to 2006–2007. The decadal mean temperature for 2001–2010 was the highest since the observations started in 1936. It appears to be a close positive correlation between the temperature and the NAO winter index up to around 1990, while no such relationship could be found for the subsequent years. During the cold winter of 2010 the water at the shallow North Sea plateau became dense enough to replace the Atlantic water in deeper parts of the Norwegian Trench and the Skagerrak. We see similarities with the 1960's were such cooling of the deep waters affected the marine life, in particular a reduction in shrimp catches.

Keywords: temperature, coastal waters, decadal variations, Norway

Contact author: J. Albretsen, Institute of Marine Research, Research Station Flødevigen, Nye Flødevigveien 20, 4817 His, Norway [e-mail: jon.albretsen@imr.no].

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Size-based indicators suggest sustained changes in size-structure of the Celtic Sea demersal fish community

Samuel Shephard, Tak Fung, Axel Rossberg, David G. Reid, and Steve Warnes

The Large Fish Indicator (LFI) and the Large Species Indicator (LSI) have been developed as univariate indicators of fish community 'state'. The key utility of these metrics is sensitivity to the effects of fishing and relative insensitivity to environmental variability. The LFI describes the proportion (by weight) of the fish community comprising 'large' *individuals*; the LSI describes the proportion (by weight) of the community represented by 'large' *species.* In each case the length threshold is chosen according to established criteria. Thus, both indicators express a well-understood community response to exploitation - the curtailment of size structure - by quantifying change in the biomass contribution to the community of the larger individuals or species that are typically removed by fishing. In the Celtic Sea, the LFI and LSI provide very similar values and both remained above 0.4 until 1990. There has been a subsequent strong decline and during the decade 2000–2009, the indicators fluctuated around 0.1 despite some strong recruitment events in target fish populations. The LFI is known to show a time-lagged response to changes in fishing pressure, reflecting trophic dynamics in the exploited community. However prolonged depression of the Celtic Sea LFI suggests long-term overfishing that may be exacerbated by discarding. Modelling community trajectories in different fishing scenarios indicates that recovery could take several decades.

Keywords: Ecosystem indicators, size-structure, fish community
Keyword Geographic: Celtic Sea

Contact author: Samauel Shephard, Galway-Mayo Institute of Technology, Dublin Road, Galway, Ireland [e-mail: samuel.shephard@gmit.ie].

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More microbes with warming? Analysis of planktonic time-series in the southern Bay of Biscay continental shelf

X. A. G. Morán, L. Díaz-Pérez, E. Nogueira, and A. Bode

Oceanographic time-series in the North Atlantic have only recently incorporated monitoring of picoplankton (i.e. organisms <2 μm in diameter). We analyze here temporal patterns in abundance, biomass and single-cell characteristics of picophytoplankton (*Synechococcus*, *Prochlorococcus* and picoeukaryotes) and heterotrophic bacteria from two microbial observatories in the northern Iberian continental shelf (A Coruña and Xixón). Marked seasonal patterns in picophytoplankton were evident in both sites, with late summer-early autumn maxima in abundance (>10^5 cells mL^{-1}) and predominance of cyanobacteria (>80%), and minima in early spring (10^3 cells mL^{-1}). Heterotrophic bacterial abundance (0.2-1.5 10^6 cells mL^{-1}) showed a unimodal distribution in A Coruña and bimodal in Xixón. In the latter site, the fraction of high nucleic acid (HNA) bacteria, usually larger and more dependent on phytoplankton than low nucleic acid (LNA) cells, showed a distinct seasonality with maxima (>80%) in April and minima (ca. 40%) in August. The apparent temperature-dependence of picophytoplankton abundance and biomass was greater than that of bacterioplankton. However, significant interannual variation in integrated microbial biomass was only detected for heterotrophic bacteria, with a 50% higher mean annual value at the end of the decade compared with 2002. Lack of microbial records prior to that date precludes concluding associations with observed increasing trends in oceanic temperature, but our analysis suggests that the smallest planktonic organisms will become increasingly important in North Atlantic waters. Given the importance of organism size for food web processes and carbon export, we anticipate profound changes in the functioning of pelagic ecosystems in the next decades.

Keywords: picoplankton, bacteria, warming, S Bay of Biscay

Contact author: X. A. G. Morán, Instituto Español de Oceanografía, Centro Oceanográfico de Xixón, Camín de L'Arbeyal s/n, 33212 Xixón, Spain [e-mail: xelu.moran@gi.ieo.es].

ICES/NAFO Decadal Symposium 2011/Ref. 67

Ecosystem Variability in NAFO Waters Adjacent to the Newfoundland and Labrador Shelf during the Decade of 2000–2009

E. Colbourne, P. Pepin, and G. Maillet

Systematic hydrographic observations on the Newfoundland and Labrador Shelf started in the late 1940s but it was not until the late 1990s, in response to the commercial collapse of groundfish stocks, that measurements were expanded to include lower trophic level observations through implementation of the Atlantic Zone Monitoring Program (AZMP). We present an analysis of inter-decadal changes in the meteorological and hydrographic climate variability along with intra-decadal variability in the physical, chemical and biological oceanographic environment for the first decade (2000-2009) of the AZMP. The results show significant variability at annual and decadal scales with the 1950s and 1960s the warmest decades during the latter half of the 20th century. The decades of the 1970s, 1980s and 1990s experienced extreme intra-decadal variability with the early years of each decade generally colder and fresher than normal and conversely during the latter half of each decade. The AZMP decade, while similar in many respects to the 1960s, was the warmest decade in the observational records but it also had among the lowest intra-decadal variability, reflecting the continuing warming trend throughout much of the region. During this period coherent trends in the timing, intensity, and duration of phytoplankton blooms over the shelf were observed. The inter-annual and regional zooplankton conditions were highly variable and complex with trends in secondary production often characterized by large changes in zooplankton abundance between adjacent years, which often persisted for several years. Although there was considerable inter-annual variability in plankton abundance on the Newfoundland Shelf, there appears to be considerable shelf-wide coherence when contrasted across other areas of Atlantic Canada.

Keywords: decadal, temperature, plankton, Newfoundland Shelf

Contact author:: E. Colbourne, Fisheries and Oceans, Canada. P. O. Box 5667, St. John's, NL A1C 5X1, Canada [e-mail: Eugene.colbourne@dfo-mpo.gc.ca].

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Variability in hydroclimatic conditions observed during the 2000–2009 period in relation to the last decades, in the southeastern Bay of Biscay

A. Fontán, V. Valencia, M. González, J. Sáenz, Á. Borja, and G. Esnaola

Trends, anomaly patterns and regime shifts, at different time-scales, in hydroclimatic conditions are analysed during the decade 2000-2009 on the basis of multidecadal datasets, in the southeastern Bay of Biscay. For this purpose, the Kolmogorov-Zurbenko adaptive filter is applied to identify discontinuities in time-series, induced mainly by natural variability.

A significant coupling between meteorological and oceanographic conditions is observed over the southeastern Bay of Biscay. In addition, the anomaly patterns and regime shifts observed over this marginal area are in agreement with those described for the NE Atlantic Ocean. In particular, the decade 2000-2009 is characterised by the prevalence of extremely warm summers (2003, 2006) together with cold winters (2005, 2006).

The present study is focused mainly on the freshwater balance (precipitation, evaporation and river flow) and its influence on the evolution of salinity, in addition to the thermal viewpoint, which is more evident and well-studied. The period 2000-2009 is characterised by several events, including a deep mixed layer in the winter of 2005, favouring the vertical mixing and the redistribution of anomalies accumulated during the previous years, through a deeper water column. In 2008, intense precipitation and high river flow contributed to counteract the increase in salinity and the advection of highly saline waters of previous years. Finally, in January 2009, the cyclone Klaus favoured strong and early vertical mixing of the water column; subsequently, haline stratification was observed in relation to intense precipitations. The confluence of both years resulted in a reduction of the heat and salt content of the upper waters of the Bay of Biscay.

Keywords: Water balance, Salinity, Climate, Southeastern Bay of Biscay.

Contact author: A. Fontán, AZTI-Tecnalia, Marine Research Division, Herrera Kaia - Portualdea z/g, 20110 Pasaia (Gipuzkoa), Spain [e-mail: afontan@azti.es].

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Atlantic Water - the main driver of the European Arctic marine ecosystem

Waldemar Walczowski

Significant variability in the properties of the Atlantic Water (AW) carried by the West Spitsbergen Current has been observed during the last ten summers. Changes in the AW temperature, heat content and northward transport have a strong influence on the Arctic climate and ecosystem, sea ice extension and Svalbard glaciers. The environmental effects of the northward propagating anomalous events of warm and saline water were clearly observed. In the European Arctic changes in the plankton community structure occurred. Arctic plankton in the Polar Front areas and Spitsbergen fjords were partly replaced by Atlantic ones, which led to modifications in the food web. The changes in living biota affected also fish: after 2007 large populations of cod were observed in the western fjords of Svalbard and even in the area north of Svalbard.

Summer-to summer variability of the Atlantic Water properties in the northern Nordic Seas, as well as changes in the West Spitsbergen Current structure and transports are presented. Feedbacks between air temperature on Spitsbergen, sea ice extension and Atlantic Water properties are analysed. Atlantic Water transformation, heat fluxes to the atmosphere and ambient waters are studied. Scientific projects investigating changes of Svalbard ecology and glaciology are presented.

Keywords: Atlantic Water, Climate, Ecology, European Arctic

Contact author: Waldemar Walczowski, Institute of Oceanology Polish Academy of Sciences, Powstancow Warszawy 55, 81-712 Sopot, Poland [e-mail: walczows@iopan.gda.pl].

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Properties and variability of the Denmark Strait Overflow in the 21st Century

S. R. Dye, S. Hall, K. J. Heywood, and M. R. Wadley

The plume of the Denmark Strait overflow has been measured since 1986 by an array of current meters on the continental slope of SE Greenland about 300km south-west of the Denmark Strait (the Angmagssalik array of Dickson, Meincke and Mälkki). Since 1998 the current meters have been augmented by the addition of moored CTD instruments. Here we examine the temporal variability of the watermass properties in the overflow plume both across the plume width and in their stratification. We place changes in the context of longer term change (Dickson et al, 2002) that saw the entire system of overflow and entrainment in the North Atlantic freshen by about 0.01 per decade between the 1960s and 1990s.

The dominant feature of the decade was a strong freshening event in 2004 that lasted more than 6 months with a maximum reduction in salinity of about 0.08. This event was evident across the entire width of the array (about 70km) at its freshest the temperature of the overflow was the coldest measured since the first array was deployed in 1986. We show results from a high resolution (1/12°) ocean model that suggest strong fresh events in the Denmark Strait overflow plume may be caused by variations in the East Greenland Current further north forced by meridional wind-stress over the Nordic Seas.

Keywords: hydrographic variability, Northeast Atlantic, Denmark Strait overflow

Contact author: S. R. Dye, Centre for Environment, Fisheries and Aquaculture Science, Pakefield Road, Lowestoft, Suffolk, UK [e-mail: stephen.dye@cefas.co.uk].

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Seasonal and interannual variation of two *Calanus* species off the east and west coasts of Scotland

M. J. Penston, K. Cook, J. Rasmussen, J. Fraser, S. Robinson, P. MacLachlan, J. Dunn, and S. Hay

Since 1997 plankton samples have been collected approximately weekly from 5.5 km off Stonehaven on the east coast of Scotland, and in Loch Ewe, on the west coast of Scotland, since 2002. The time series showed an increasing trend in the abundance of *Calanus finmarchicus* and *C. helgolandicus* (Copepoda, Calanoida) in coastal waters on the east and west coasts of Scotland up until around 2008. There was a decrease in the abundance of both species, on both coasts, in 2009/10. The seasonal abundance of *C. finmarchicus* and *C. helgolandicus* peak on the east and west coasts of Scotland in May and September, respectively. An additional peak in *C. helgolandicus* occurs on the west coast of Scotland in April/May, which is less apparent, although not absent, on the east coast of Scotland. This spring peak in *C. helgolandicus* has only been reported previously in more southerly waters, e.g. the Celtic Sea. *C. helgolandicus* was more abundant that *C. finmarchicus* on both coasts, except in 2009 on the east coast.

Keywords: plankton, *Calanus finmarchicus, Calanus helgolandicus*, Scotland

Contact author: M. J. Penston, Marine Scotland Science, Marine Laboratory, PO Box 101, 375 Victoria Rd., Aberdeen, AB11 9DB, Scotland [e-mail: m.penston@marlab.ac.uk].

ICES/NAFO Decadal Symposium 2011/Ref. 79

Long-term variability of the lower trophic levels in the Western English Channel

S. Ciavatta, C. Halsband-Lenk, C. Widdicombe, and T. Smyth

Climate and anthropogenic forcings can drive relevant changes in the dynamic of lower trophic levels, influencing the status and productivity of marine systems. These changes can be investigated through the analysis of time series collected at long-term monitoring stations. In this work, we investigate changes in the trend and phenology of phytoplankton and zooplankton for the years 1993–2009, at the long-term monitoring station L4 in the western English Channel. Time series of monthly observations of selected taxa were decomposed by using Dynamic Harmonic Regression (DHR) models, coupled with a Kalman filtering algorithm. The models pointed out significant differences in the trend and seasonal patterns in the last decade, as compared to the 1990s. Since 2002, the most abundant phytoplankton group, i.e phytoflagellates, had a significant negative trend and smoother seasonal oscillations, as were in part the oscillations of diatoms and dinoflagellates. Correspondingly, the copepods *Temora longicornis* and bivalve larvae had significant negative trends since 2002/03, whereas decapoda and *Centropages typicus* increased their relative abundance. The trend changes of total zooplankton and total phytoplankton were qualitatively in opposite phase in the 1990s and in phase since 2000, indicating potential modifications in the predator/prey interrelationships amongst the lower trophic levels. These changes are discussed with respect to the evolution of the climatic and anthropogenic driving forces, derived from the DHR decomposition of water quality and meteorological time series collected at the Western Channel Observatory.

Keywords: time series analysis, phytoplankton, zooplankton, Western English Channel

Contact author: S. Ciavatta, Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK [e-mail: s.ciavatta@pml.ac.uk].

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Study of the demersal fish community of the Flemish Cap (NAFO Div. 3M): Changes in community structure and common trends during the period 1988–2008

A. Pérez-Rodríguez, M. Koen-Alonso, and F. Saborido-Rey

The Flemish Cap fish community (NAFO Division 3M) has supported a high fishing mortality since the 1950s, and major changes in the biomass and abundance of its most important commercial species have been reported since late 1980's. Additionally, variations in the oceanographic conditions in the bank, with alternating periods of cold and warm weather, have also been described. This work examines and describes the changes in this community from 1988 to 2008 based on a suite of ecological indices (Abundance-Biomass Comparison –ABC- plots, size-based indicators, abundance, biomass and diversity indices). In addition, the existence of common trends in the biomass levels of main demersal species over time was studied using dynamic factor analysis (DFA); while the occurrence of the "occasional species" was studied to explore patterns in relation to environmental conditions. Overall, significant changes in size and community structure involving both commercial and non-commercial species were found. Three common trends were indentified in the biomass trajectories of the main demersal species. In the context of this analysis, fishing, as well as environmental and ecological variables (North Atlantic Oscillation –NAO-, and total piscivorous fish biomass) emerged as important drivers of the temporal dynamics. A trophic cascade mechanism, in combination with fishing pressure and oceanographic conditions, is proposed as a plausible hypothesis to explain the observed changes in the demersal community of Flemish Cap.

Keywords: Community structure, Common trends, Fisheries, Flemish Cap.

Contact author: A. Pérez-Rodríguez, Institute of Marine Research-CSIC, 6 Eduardo Cabello, 36208. Vigo, Spain [e-mail: fonsilei@iim.csic.es].

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Phytoplankton community structure analysed with molecular methods during late summers 2000 to 2008 obtained from sediment traps at the AWI deep-sea observatory HAUSGARTEN (79°N/4°E)

K. Metfies, S. Pfaff, B. Rajasakaren, E. Bauerfeind, E.-M. Nöthig, and S. Gaebler-Schwarz

Changes in phytoplankton community structure are mostly an expression of the changing environment. In order to provide a baseline for future evaluations of climate change consequences for the base of northern marine food webs we aim at elucidating the structure and variability of phytoplankton communities in the area of the "Hausgarten long-term observatory" in the eastern Fram Strait. Samples were taken from sediment traps that have been deployed at the central station of the "Hausgarten long-term observatory" (~79°01'N and ~4°21'E) in a depth of ~200-300 m during the years 2000–2008. We applied for the first time molecular methods in addition to traditional counting to get comprehensive information on the phytoplankton structure in the sedimented material.

Molecular methods have been established during the past two decades as valuable tools to facilitate and refine the assessment of phytoplankton diversity from environmental samples without previous cultivation. In this study we took advantage of the molecular fingerprinting method T-RFLP (Terminal Restriction Fragment Length Polymorphism), microsatellite analysis and 454-pyrosequencing of the highly variable V4 region of the 18S rDNA to elucidate seasonal patterns and inter-annual variability of the phytoplankton community in the eastern Fram Strait during the years 2000–2008. By applying these methods to sediment trap samples we are able to gain information on the presence of organisms, which can not to be assessed with conventional methods, but nevertheless can be key constituents of the sedimented matter.

Keywords: phytoplankton, sediment traps, molecular fingerprinting, Fram Strait, Hausgarten

Contact author: Katja Metfies, Alfred-Wegener-Institute for Polar & Marine Research, Am Handelshafen 12, D-27570, Bremerhaven, Germany [e-mail: Katja.Metfies@awi.de].

ICES/NAFO Decadal Symposium 2011/Ref. 95

Mixed layer depth (MLD) variability in the southern Bay of Biscay. Deepening of winter MLDs concurrent with generalized upper water warming trends?

R. Somavilla, C. González-Pola, M. Ruiz Villarreal, and A. Lavín

Mixed layer depth (MLD) variability from seasonal to decadal timescales in the Bay of Biscay is studied in this work. A hydrographic time-series running since 1991 in the study area, a climatology of the upper layer vertical structure based on the topology of this temperature profile time-series, and a one dimensional water column model have been used for this purpose. The prevailing factors driving MLD variability have been determined with detail, and agreement with observations is achieved. Tests carried out to investigate climatological profile skill to reproduce the upper layer temporal evolution have demonstrated its ability to simulate variability at seasonal timescales and reproduce the most conspicuous events observed. This has enabled us to carry out a reconstruction of the MLD variability for the last sixty years in the study area. Favourable sequence of intense mixing events explains interannual differences and cases of extraordinary deepening of winter mixed layer. The negative phase of the Eastern Atlantic pattern seems to determine important interannual variability through intense episodes of cooling and mixing as in winter 2005 in the Bay of Biscay. Low frequency variability is also observed. A very striking and unexpected shallower winter MLD during the 1970s and 1980s than those observed from 1995, concurrent with the reported warming trends, is supported by simulation results. The long term trends in MLD seem related with decadal variability in the North Atlantic Oscillation (NAO), being in phase and opposition with other deepening-shallowing cycles found from subtropical-to-subpolar areas in the North Atlantic.

Keywords: MLD variability · upper ocean climatology · one dimensional model · warming trends · North East Atlantic

Contact author: R. Somavilla, Instituto Español de Oceanografía, C.O. de Santander, Promontorio de San Martín sn. CP 39080, Santander, Spain [e-mail: raquel.somavilla@st.ieo.es].

ICES/NAFO Decadal Symposium 2011/Ref. 100

Stable isotope evidence for the rate at which climate-driven variations in phytoplankton growth influence higher trophic levels

C. N. Trueman and K. M. MacKenzie

Common patterns in time series of climate parameters, plankton and fish abundance demonstrate the influence of climate on ecosystem function in the North Atlantic. Such comparisons depend on reliable abundance records for each species studied. Crucially, data are only available for a few ecosystem components, whereas mechanisms linking climate to ecosystem function are spread across many species. Alternatively, the influence of climate variables on nutrient transfer through food webs may be assessed via stable isotope analysis of top consumer tissues. Carbon isotopes reflect phytoplankton growth rates, while nitrogen isotopes reflect the number of trophic steps between fixation and tissue production. Long term records of C and N isotopes in high trophic level generalist predators thus reflect variations in phytoplankton growth and subsequent effects on ecosystem trophic level.

Using a 20 year record of stable isotopes from Atlantic salmon migrating to different regions of the North Atlantic, we show climate-driven influences on phytoplankton growth rates with a periodicity of 11-15 years in one stock and 8-10 years in another. Trophic level indicators vary with changes in plankton growth with a 2-3 year lag. This suggests that causes of variations in carbon isotope values (likely temperature) result in either greater availability of high TL prey (bottom-up control) or a reduction in availability of low TL prey (top-down control). Coincidences of periods of high nitrogen isotope values and herring biomass implies bottom-up control. Time series analysis of stable isotopes in consumer tissues provides new information on the interaction between climate and ecosystem dynamics.

Keywords: Ecosystem, biogeochemistry, fish, NE Atlantic

Contact author: C. N. Trueman, School of Ocean and Earth Science, University of Southampton. National Oceanography Centre, Southampton, SO143 ZH, UK [e-mail: trueman@noc.soton.ac.uk].

ICES/NAFO Decadal Symposium 2011/Ref. 106

Atlantic water flow through the Faroe area 2000–2009

K. M. H. Larsen, B. Hansen, and H. Hátún

The inflow of Atlantic water to the Nordic Seas across the Greenland-Scotland Ridge controls both physical and biological conditions in much of the downstream region through its transport of heat and salt. The two main branches of this flow pass on either side of the Faroe Islands: The Iceland-Faroe inflow (IF-inflow) and the Faroe-Shetland inflow (FS-inflow). The Faroe area is dominated by water from the IF-inflow, which flows eastwards in a boundary current north of the Faroes, after which it bifurcates and follows two different pathways: Some of the water continues eastwards over the deep parts of the Norwegian Sea. The rest rounds the eastern corner of the Faroe Plateau and flows south-westwards into the Faroe-Shetland Channel where it turns again and joins the FS-inflow.

Since the late 1980ies, the temperature and salinity of this water has been monitored by regular CTD cruises along four different standard sections, crossing the flow and velocity and transport have been monitored since the mid-1990ies. Based on these observations, we present the variations in both properties and transport of this water up to and during the last decade. The mechanisms driving the inflow are discussed as well as the bifurcation process that separates the IF-inflow into a baroclinic open-ocean component and a more barotropic component.

Keywords: Atlantic inflow, heat transport, bifurcation, Faroe area

Contact author: K. M. H. Larsen, Faroe Marine Research Institute, P.O.Box 3051, FO-110 Tórshavn, Faroe Islands [e-mail: karinl@hav.fo].

ICES/NAFO Decadal Symposium 2011/Ref. 107

On the role of freshwater forcing on the convection intensity in the central Irminger Sea between 2002 and 2011

J. Karstensen, M. Visbeck, T. Müller, U. Send, and H. Valdimarson

The Central Irminger Sea has long been identified as one of the open ocean deep convections regions in the North Atlantic Ocean. Here surface waters may reach densities that are high enough to contribute to the re-ventilation the Labrador Sea Water density range which is part of the North Atlantic Deep Water. The "efficiency" of the deep convection has been found to depend on local (Greenland Tip Jet) as well as large scale (North Atlantic Oscillation) atmospheric forcing. Most likely because of unavailability of data the role of the salinity in the near surface waters have been ignored in the investigations of deep convection in the Irminger Sea.

Based on temperature and salinity time series data from late 2002 to now from an open ocean mooring in the central Irminger Sea (nominal 60°N/40°W) the convection depth at this location is derived. The time series are used to estimate the heat and freshwater fluxes and their respective contribution to the buoyancy budget. It is shown that the freshwater fluxes can have a significant influence on the evolution of the buoyancy budget and thus in setting the convection depth. In the period 2002 to 2007 the convection depth was less than 500m. In the last winters from 2007 onwards particular higher upper layer salinity contributed to a much deeper convection depth down to about 700m. However, the buoyancy flux was not strong enough to ventilate the NADW density range at this location. As the mooring is equipped with a real time data transmission buoy an estimate for the current (2010/2011) winter convection intensity is presented.

Keywords: Deep convection, freshwater, bouyancy, ventilation, Irminger Sea,

Contact author: J. Karstensen, Leibniz-Institute for Marine Sciences (IFM-GEOMAR), Düsternbrooker Weg 20, 24105 Kiel, Germany [e-mail: jkarstensen@ifm-geomar.de].

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Decadal variability of hydrodynamics and productivity in North- and Baltic Sea, relating 2000–2009 to the earlier decades

C. Schrum, U. Daewel, D. Pushpadas, and S. Svendsen

Both, the North Sea and the Baltic Sea experienced pronounced changes in hydroynamic-, biogeochemical and higher trophic conditions during the past decades. In the middle of the 80´s positive SST trends accelerated (e.g. Meyer et al., 2010) and a variety of pronounced and partly dramatic changes have been reported for the different levels of the marine ecosystem, which have been frequently discussed in the literature and been identified as regime shifts (e.g. Alheit et al, 2005). Here we aim to relate the hydro-biological situation in the North Sea and the Baltic Sea from 2000–2009 to these changes and the multi-decadal variability of the marine ecosystems in both seas.

We will present results of a coupled physical-biological model for the North Sea and the Baltic Sea. The model identifies a long term multi-decadal trend, likely forced by a multi-decadal oscillation of the climatic conditions in the North Sea and Baltic Sea region. Here, we will identify the most important climatic drivers, illustrate the interplay of forcing and the variations in dominance over the decades. Moreover, the role of changes in river nutrient loading and marine nutrient transports are assessed and related to the role of the climatic drivers.

Keywords: North Sea, Baltic Sea, Barents Sea, biogeochemistry, hydrodynamics, modelling

Contact author: C. Schrum, Geophysical Institute and Bjerknes-UiB, University of Bergen, No-5007-Bergen, Allégaten 70, Norway [e-mail: corinna.schrum@gfi.uib.no]

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Ocean Weather Ship Station M 1948–2009 - the end of the North Atlantic Weather Ship era

S. Østerhus and T. Gammelsrød

Having performed daily oceanographic measurements in the deep Norwegian Sea since 1 October 1948 until the end of November 2009, Ocean Weather Ship Station (OWS) M, at 66°N, 2°E, can present the longest existing homogeneous time series from the deep ocean.

With the expansion of civil aviation and growing understanding of the impact of aerological observations on weather forecasts after World War II, ICAO (The International Civil Aviation Organization) demanded a greater network of aerological stations, primarily in the North Atlantic.

In 1946 a plan for a network of 13 ocean weather stations in the North Atlantic was set forth under the auspices of ICAO. The Stations were to supply meteorological services, search and rescue services, and navigational aids to aircraft. The USA, Canada and eighth European countries should be responsible for operating the stations, which were referred to by letters from A to M. Norway was to operate station M (phonetic name Mike), with financial backing from Sweden and Great Britain.

ICAO attempted to organize an international oceanographical research programme for the weather ships, but failed due to lack of interest, shortage of money and difficulties in procuring the necessary scientific equipment. In Norway, a country which held great traditions in oceanographical research, a small group of three scientists, led by the oceanographer Håkon Mosby, took upon themselves to implement an extensive research programme on station M.

Håkon Mosby implemented a routine programme within physical oceanography, including serial observations of temperature, salinity, and (since 1953) oxygen weekly at standard depths to 2000 meters, and serial observations of temperature and salinity at standard depths down to 1000 meters 3 or 4 times a week. This programme has been running continuously since 1 October 1948 until the end of November 2009 when the weather ship service on the station was terminated. The method of obtaining temperature and salinity observations (Nansen bottles with reversing thermometers) has not changed significantly either so the time series are indeed homogeneous.

Here we will present the history of the weather ships in the North Atlantic, and scientific results from station M with emphasis on the last decade.

Keywords: History of the Ocean Weather Ships, Hydrographic Time Series, Climate, North Atlantic, Norwegian Sea

Contact author: Svein Østerhus, UNI Bjerknes, Bjerknes centre for Climate Research and Geophysical Institute, University of Bergen, Norway [e-mail: svein.osterhus@uni.no].

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Multi-year variability in zooplankton on the West Spitsbergen Shelf in relation to hydrography, and its consequences for planktivorous seabirds

S. Kwasniewski1, M. Gluchowska, W. Walkusz, K. Wojczulanis-Jakubas, D. Jakubas, N. Karnovsky, A. Harding, I. Goszczko, A. Beszczynska-Moeller, W. Walczowski, J. M. Weslawski, and Lech Stempniewicz

The Arctic is experiencing climate-induced environmental change. In order to understand the effects of this change on Arctic marine ecosystems, we examined the influence of hydrographic conditions on zooplankton communities on the West Spitsbergen Shelf (WSS), and chick diet composition of zooplanktivorous little auk *Alle alle* from large colony in Hornsund (SW Spitsbergen).

The WSS at the south west tip of Spitsbergen (77 °N, 15 °E) is a part of Polar Front zone between Atlantic Waters (AW) of the West Spitsbergen Current (WSC) and Arctic Waters (ArW) of the Barents Sea. Zooplankton on the shelf consists of Atlantic and Arctic species but little auks from Hornsund prefer as food for their chicks more energy-rich Arctic copepod *Calanus glacialis*, over less lipid-rich Atlantic *Calanus finmarchicus*. Observations from single years suggest that influxes of Atlantic waters on the WSS are associated with increasing of numbers of warm-water *C. finmarchicus* and decreasing of its cold-water counterpart *C. glacialis*.

Here we present observations on hydrography, distribution and abundance of zooplankton and chick diet composition of little auks in Hornsund area, made on a quasi-synoptic scale in summers 2001–2008. We investigate whether the year-to-year variability arranges in a pattern of significant trend. The local variability is compared with regional variability in atmosphere and ocean climate. We make an attempt to comprehend links between climate change, variation in hydrography, response of zooplankton and effect on little auk's chicks diet, and discuss scenarios of development of the present day situation towards different climate changes.

Keywords: Zooplankton, seabirds, climate change, Spitsbergen

Contact author: S. Kwasniewski, Institute of Oceanology, Polish Academy of Sciences, Powstancow Warszawy St. 55, 81-712 Sopot, Poland [e-mail: kwas@iopan.gda.pl].

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Seasonal to interannual variability of temperature and salinity in the Nordic Seas: heat and freshwater budgets

K. Latarius and D. Quadfasel

Ten years of autonomous profiling float data from the Nordic Seas are used to detect changes in temperature and salinity of the water column on time scales from seasonal to interannual. In the Greenland Sea Gyre the effect of ocean-atmosphere and internal ocean fluxes on heat and freshwater is largely (about 90%) confined to the upper 700m. Throughout the water column a warming at a mean rate of 0.05 K/year is observed, while the freshwater content is dominated by interannual changes not containing trends. In the annual mean the gyre exports freshwater across its boundary throughout the water column. Import of freshwater takes place only in the upper 50 m during summer. Heat is exported in the upper 50 m, while below the gyre cools the surrounding. The net effect of the gyre on the water mass conversion in the Arctic Mediterranean is small and the gyre does not re-enforce the Nordic Seas overturning circulation.

Keywords: Argo floats, hydrographic variability, heat and freshwater budgets, Nordic Seas

Contact author: K. Latarius,Institut für Meereskunde, KlimaCampus, Universität Hamburg, Bundesstrasse 53, 20146 Hamburg, Germany [e-mail: katrin.latarius@zmaw.de].

ICES/NAFO Decadal Symposium 2011/Ref. 114

Decadal changes in ocean chlorophyll

H. Wehde

Aside the decadal scale fluctuations linked to climate forcing, a decreasing trend within ocean chlorophyll was observed in the world oceans during the last decades. Simultaneously a decrease of penetration depths of oceanic convection in higher latitudes in winter was observed. The main assumption of the actual study is that it is the decrease of the strength of oceanic convection that causes the decrease in ocean chlorophyll. The assumption is based on the hypothesis on the strong relationship between oceanic convection and primary production, i.e. the support of production by oceanic convection in winter.

To support this, a coupled convection-phytoplankton model and a phytoplankton mixed layer model were applied for the North Atlantic region. The analysis of the model simulations in comparison to the available observations display that the decreased convective activity support the hypothesis that convection can act as a mechanism that explains the decadal changes in ocean chlorophyll. In addition to that, the impact of that decline in ocean chlorophyll on the higher trophic levels will be estimated.

Keywords: Ocean Chlorophyll, Oceanic Convection, Climate variability, North Atlantic

Contact author: H. Wehde, Institute of Marine Research, Nordnesgaten 33, 5005 Bergen, Norway [e-mail: henning.wehde@imr.no].

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Zooplankton variability on the Faroe Shelf and in the surrounding oceanic area in relation to phytoplankton and physical conditions

E. Gaard, H. Debes, B. Hansen, H. Hátún, and K. M. H. Larsen

On the Faroe Shelf and in the surrounding oceanic area, zooplankton abundance and composition, phytoplankton biomass and physical conditions have been monitored in late April (pre-bloom), mid May (spring bloom) and late June (summer conditions) since the early 1990ies. In the oceanic environment surrounding the Faroe Shelf, the copepod community is dominated by *Calanus finmarchicus*, while it on the shelf basically is neritic, with variable influence of *C. finmarchicus* from outside the shelf. Both on the Faroe shelf and in the oceanic area surrounding the Shelf, clear variations are observed in copepod biomass, abundance and stage composition with cycles over several years. Especially, there have been clear fluctuations in stage composition of *C. finmarchicus*, with a pronounced shift in the mid 2000ies. The paper explores potential influences from large-scale and local oceanographic conditions and phytoplankton on abundance and phenology of *C. finmarchicus*, and local oceanographic influences on copepod advection on/off the shelf.

Keywords: Zooplankton, *Calanus finmarchicus*, phytoplankton, hydrography, Faroe Islands

Contact author: E. Gaard, Faroe Marine Research Institute, Tórshavn, Faroe Islands [e-mail: eilifg@hav.fo].

ICES/NAFO Decadal Symposium 2011/Ref. 125

Impact of climate variability on the North Sea ecosystem

J. Alheit, T. Pohlman, and C. Wagner

During the period from the late 1980s to 2000, the North Sea ecosystem experienced massive climatic and hydrographic impacts. The strengthening of the NAO in the late 1980s elevated particularly winter temperatures and led to an ecosystem regime shift with dramatic changes in the composition of plankton and benthos communities. In contrast, conspicuous changes were observed particularly in the fish community, when, after the mid-1990s, the NAO index became rather neutral or negative again, but spring and summer temperatures increased, probably due to the entry of the AMO into a positive phase and/or the contraction of the subarctic gyre drawing warmer subtropical waters to the north. As a consequence, Lusitanian species such as anchovy invaded the North Sea then and began to spawn regularly in the German Bight. In addition, phenological relationships were destroyed. Community changes observed during the last decade were much less dramatic. They will be discussed in the light of observations made in previous decades.

Keywords: Climate variability, zooplankton, fish, North Sea

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

ICES/NAFO Decadal Symposium 2011/Ref. 128

Concurrent recruitment failure in gadoids and changes in the planktonic community along the Norwegian Skagerrak coast after 2002

T. Johannessen, E. Dahl, and L. J. Naustvoll

Since 1919 an annual beach seine sampling programme has been carried out along the Norwegian Skagerrak coast with main objective to measure the abundance of 0-group gadoids. Repeated incidents of abrupt and persistent recruitment collapses in the gadoids have been observed locally. These collapses have been liked to gradual cultural eutrophication which has resulted in abrupt changes in the planktonic community and deprivation of adequate pray for the 0-group gadoids.

Since 2002 recruitment in the 0-group gadoids have been very poor along the Skagerrak coast on a regional scale. At the same time major changes in the planktonic community have been observed in these waters. The standing stock of phytoplankton as measure in terms of Chl *a* three times a week has decreased during summer, and a regular and pronounced autumn bloom has practically vanished. The autumn bloom was dominated by red-tide forming dinoflagellates such as large *Ceratium* spp. and the toxic *Karenia mikomotoi*. Furthermore, a linear decrease in oxygen concentrations at intermediate depths (30 m) which have been going on since the 1960s, was revered around 2002. Reduced algal biomass, disappearance of the red-tied dominated autumn bloom and reversal of the negative oxygen trend would normally be interpreted as improved environmental conditions. However, recruitment failure in the gadoids does not support this perception. Rather, the evidence points towards a potential regime shift in the planktonic community which has resulted in recruitment failure in the gadoids. Interestingly, the recruitment failure along the Skagerrak coast concurs with recruitment problems for many fish stocks in the North Sea.

Keywords: Recruitment, plankton, oxygen, regime shift, Skagerrak, the North Sea

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

ICES/NAFO Decadal Symposium 2011/Ref. 130

The serial recruitment failure to North Sea fish stocks during the 2000s, is climate to blame?

G. Ottersen, E. Moland Olsen, T. Falkenhaug, Priscilla Licandro, and M. Llope

Recruitment to several of the ecologically and commercially important fish stocks in the North Sea became strongly reduced from the early 2000s compared to earlier years. Long-term decreasing trends as well as more abrupt drops continue to cause concern for fishers, managers and scientists alike. The stocks affected include herring (*Clupea harengus*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), Norway pout (*Trisopterus esmarkii*) and sandeel (*Ammodytes marinus*). While the spawning stock was, and still is, at a critically low level for cod and sandeel, no such decline was seen for herring and haddock. A general reduction in the size of the spawning stocks is therefore not the only explanation for the observed successive recruitment failure. Simultaneously sea temperatures were increasing throughout the North Sea and the zooplankton community was shifting from a boreal towards a more temperate composition. With this backdrop we give an overview of some of the recent work exploring links between the described environmental changes and recruitment. While drawing upon the work also of colleagues, the presentation focuses on our own findings. Our results indicate changes in temperature, changes in zooplankton composition, and long-term changes as well as interannual variations in the relative abundance of Calanus *finmarchicus* vs *Calanus helgolandicus*. A new stock-recruitment model for North Sea cod combining the Beverton-Holt and Ricker models by utilizing temperature and zooplankton data is introduced. We find that food availability (i.e. zooplankton) in essence determines which model applies and that recruitment is strengthened during cold and weakened during warm years.

Keywords: Recruitment, cod, herring, North Sea

Contact author: G. Ottersen, Institute of Marine Research, Gaustadalle`en 21, 0349 Oslo, Norway [e-mail: geir.ottersen@bio.uio.no].

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Contrasting the Variability of Northwest Atlantic Fish Populations During 2000–2009 with 1960-2010 as Influenced by Physical Forcing and Fishing

B. J. Rothschild, Y. Jiao, and E. F. Keiley

Research survey data comprising c.200,000 tows taken during 1960–2010, covering the continental shelf from Georges Bank to off-of-Newfoundland were studied. The abundance of many species declined. However, remarkably, cluster analysis revealed that this decline was not gradual, but sudden, occurring from the mid-1980s to the 1990s. This remarkable change was driven by key species and reflected mid-1980s to the early 1990s decreases in cod, plaice, and yellowtail and increases in herring, mackerel, capelin and sand lance. Correlation analysis of the ensemble of species reflected a small proportion of significant Bonferroni adjusted correlations. Most of the correlations were positive, indicating that the dynamics were driven by factors not associated with competition between the species. Furthermore, the correlation plots suggested that the dynamics could be described as multiple stable states where the shift between the states occurred in the mid 1980s. The depth and spatial extent of each key species is studied along with surplus production, fishing, and physical forcing. The paper discusses the dynamics of the stocks in 2000–2009 relative to the 1960–2009 time series.

Keywords: variability, fish population, Northwest Atlantic

Contact author: B. J. Rothschild, University of Massachusetts Dartmouth, School for Marine Science and Technology, 706 South Rodney French Boulevard, New Bedford, MA 02744-1221, USA [e-mail: brothschild@umassd.edu].

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Long-term variability (1958–2009) in the plankton in Northwest Atlantic shelf and oceanic regions in relation to hydrography

E. J. H. Head and P. Pepin

Continuous Plankton Recorder sampling results were analysed for eleven plankton taxa in four shelf and four oceanic regions of the Northwest Atlantic. For shelf regions, phytoplankton abundances increased in the early 1990s, mainly in winter, as the contribution of Arctic-derived freshwater to the Newfoundland (NLS) and Scotian shelves (SS) increased. In the sub-polar gyre, phytoplankton levels increased with rising temperatures during the 1990s and 2000s. The changes in both shelf and oceanic regions can be explained by increased stratification. The increased influx of arctic water to the NLS in the 1990s also led to increased abundances for two arctic copepod species, *Calanus glacialis* and *Calanus hyperboreus*, while the sub-arctic species, *Calanus finmarchicus* declined. On the SS the arctic *Calanus* abundances increased in the 2000s, probably due to increased transport from the Arctic via the Gulf of St Lawrence. A slight decrease in pH since the early 1990s and 2000s, has not led to decreases in the abundance of two acid-sensitive taxa.

In the deep ocean, phytoplankton and zooplankton seasonal cycles were synchronised and changed little over the decades: increasing phytoplankton levels in the 2000s were accompanied by increasing abundance for some zooplankton taxa, implying bottom-up control. In shelf regions, phytoplankton increases in the 1990s were in winter and young stage *C. finmarchicus* appeared earlier in spring than in previous decades. Zooplankton levels did not change overall however, probably because the taxa used in this analysis were mainly inactive during winter and could not respond to the increased winter phytoplankton production.

Keywords: Phytoplankton, zooplankton, inter-decadal variability, Northwest Atlantic

Contact author: Erica Head, Fisheries and Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, B2Y 4A2, Canada [e-mail: Erica.Head@dfo-mpo.gc.ca].