

Theme Session B

The role of sea ice in polar ecosystems

ICES CM 2008/B:01

Sea ice algae—seeding the ice edge pelagic bloom?

D. M. Mikkelsen and S. Rysgaard

Short-lived pelagic blooms are commonly observed near the sea ice edge in spring. Though the combination of light availability and stratification is commonly assumed to facilitate the bloom, seeding by sea ice algae may be of great importance. A seasonal study of the pelagic and sympagic algae in Kobbefjord, West Greenland was conducted to elucidate the role of sea ice algae. During the sea ice season, there were indications that some sea ice algae (prasinophytes, the diatom *Chaetoceros simplex*) remained suspended and viable when released from the sea ice, a prerequisite for an influence on the pelagic. The pelagic bloom at the sea ice edge consisted mainly of small flagellates, which were already present in both sea ice and seawater. Several species which had not previously been observed either in sea ice or in seawater—*Thalassiosira* spp. and *Chaetoceros* spp.—also contributed to the bloom. Statistical analysis showed that the sympagic and pelagic community were two separate entities, and indicated that the bloom community in Kobbefjord was influenced by pelagic species rather than being seeded by sea ice algae.

Keywords: sea ice algae, pelagic bloom, seeding.

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ICES CM 2008/B:02

Relationships of sea ice extent and bottom water temperature with abundance of snow crab (*Chionoecetes opilio*) on the Newfoundland - Labrador Shelf

Earl Dawe, Don Parsons, and Eugene Colbourne

It is widely believed that recent increases in crustacean resources, including snow crab (*Chionoecetes opilio*), in Atlantic Canada are the result of reduced predation (top-down effects). We advance an alternative hypothesis that snow crab production and early survival are regulated primarily by effects of ocean climate variation (bottom-up effects) during early life history. We address this hypothesis by using time-series analysis to establish relationships between recruitment indices and ocean climate indices at various time-lags. We selected two indices of ocean climate variation: one to represent effects on epipelagic larval stages (ice coverage) and another to represent effects on early benthic stages (bottom temperature). Using catch per unit of effort (cpue) from the commercial snow crab fishery as our index of snow crab abundance, we applied an autoregressive, integrated moving average (ARIMA) procedure with environmental input (transfer function) to explore relationships between biological production or early survival and changes in ocean climate. The procedure facilitated cross-correlation analysis between cpue and each environmental index (corrected for autocorrelation) for each of four fishery areas. Our results showed consistent effects between the two ocean climate indices and across all four areas. Catch per unit of effort was positively correlated with ice cover for all three areas that are affected by ice, at lags of 7–10 years, approximating age at recruitment. These correlations were significant for the two longest time-series, while there was no relationship for a fourth, most-southern area that is unaffected by ice cover. Consistent negative relationships were found between cpue and bottom temperature for all four areas at lags generally one year shorter than the corresponding cpue–ice relationships, although none were significant. These consistent results indicate that abundance is regulated primarily by effects of ocean climate variation on early life history stages. Cold conditions in early life favour production or survival in both pelagic and benthic habitats. We also discuss mechanisms by which ice coverage or bottom temperature could regulate snow crab production.

Keywords: sea ice extent, bottom temperature, snow crab abundance, modelling.

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ICES CM 2008/B:04

Current sea ice conditions and trends

James E. Overland and Ken F. Drinkwater

Over the last decade overall Arctic sea ice extent has been reduced in both summer and winter, but sea ice behaviour in economically important marginal seas is still highly variable in response to shifts in the two

major climate patterns, the North Atlantic Oscillation (NAO) and the North Pacific Index (NP). In 2007, the summer minimum sea ice extent in the Arctic was 40% below the sea ice extents of the 1980s and over 20% below the previous record minimum of 2005. This loss was caused by a combination of greenhouse gas build-up, fortuitous timing in decadal atmospheric variability, and sea ice and cloud feedbacks. In March 2008 there was less multiyear sea ice than in 2007, and it seems improbable that summer Arctic sea ice could return to its climatological extent. Sea ice in marginal seas has responded to recent shifts towards a positive NAO and *La Niña*-weak Aleutian low conditions in the Pacific. March 2008 shows reduced sea ice in the Barents Sea, an increase in the Labrador Sea, an increase in the Bering Sea, and a reduction in the Sea of Okhotsk, relative to climatology. The NAO and NP tend to have multiple year persistence. Thus in the future when the NP reverses sign, combined with global warming, we predict that the Bering Sea will return to major sea ice reductions beyond those of 2000–2005. A future shift in the NAO may slow the rate of winter sea ice loss in the Barents Sea.

Keywords: sea ice, Arctic, NAO, NP, climate patterns, Bering Sea, Barents Sea.

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ICES CM 2008/B:05

Lipid compositions of calanoid copepods and an ostracod from Kongsfjorden and the Marginal Ice Zone north of Svalbard: dietary influences

Catherine L. Scott, Stig Falk-Petersen, and John R. Sargent

The three dominant *Calanus* species—*Calanus finmarchicus*, *C. glacialis*, and *C. hyperboreus*—were sampled at different locations along the Arctic Marginal Ice Zone (MIZ) (different types and ages of ice) around Svalbard and in Kongsfjorden, an Arctic fjord. High-Arctic *Scaphocalanus magnus*, a calanoid copepod, and an ostracod, *Conchoecia borealis*, were sampled only at the MIZ sites. Changes and differences in lipid biochemistry (deposition of lipid classes and biomarkers) were used to investigate the different species under different physical regimes and potentially different food regimes. Stage V *C. hyperboreus*, for example, show greater lipid deposition at the MIZ-multiple-year-old ice site compared with other sites. Stage V *C. hyperboreus* sampled at the MIZ sites also have larger amounts of triacylglycerol (TAG) and wax esters than those at the fjord site. Site-specific differences in the fatty acid composition were evident in the three calanoid species, reflecting the variability in the phytoplankton composition. Diatom markers were more abundant at sites experiencing the bloom and flagellate markers were more abundant at sites where the seasonal bloom had passed. The dominant fatty acid biomarkers in the *C. borealis* wax esters and the *S. magnus* TAG suggest an omnivorous behaviour and, potentially, particulate feeding on material originating in the larger *Calanus* copepods. The importance of the ice habitat in maintaining high-quality particulate material is discussed.

Keywords: *Calanus*, zooplankton, Arctic sea ice, Lipids.

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ICES CM 2008/B:06

The role of sea ice in subarctic marine ecosystems

Ken Drinkwater

A brief review of the role of sea ice in the subarctic regions of the North Atlantic and adjacent Arctic is presented. Seasonal sea ice presently covers a large fraction of these northern regions from the Barents Sea, Nordic Seas, around Greenland, in Baffin Bay, the Canadian Archipelago, Hudson Bay, the Labrador Shelf, the Gulf of St Lawrence, and the Scotian Shelf. The variability in the extent of sea ice on time-scales from seasonal to centennial and beyond is presented, along with discussion on the underlying mechanisms responsible for this variability, with special emphasis on meteorological forcing and ocean current transports. In addition, the influence of sea ice on the underlying hydrography of these regions is outlined. In terms of the biology, the role of sea ice as habitat for organisms from ice algae to marine mammals, such as seals and polar bears, is described. Finally, how sea ice influences the amount and timing of primary production as well as how it helps to structure the underlying marine communities is discussed.

Keywords: sea ice, variability, physical oceanography, marine ecosystems, North Atlantic.

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ICES CM 2008/B:07

Projected changes in the physical environment of four Subarctic seas under climate change

W. Paul Budgell

Results from the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) from two climate scenarios: the climate of the twentieth century (20C3M) and conditions under carbon dioxide concentration stabilized at 720 ppm (SRES A1B), are downscaled to examine potential changes in ice and ocean conditions under climate change in four Subarctic seas: the Barents, Greenland, Labrador, and Bering Seas. The downscaling is carried out using a coupled ice–ocean version of the Regional Ocean Modelling System (ROMS) that covers the Arctic and North Atlantic Oceans with an average horizontal resolution of 10 km. Differences in how the sea ice distribution and ocean temperature and circulation may be altered under climate change in the four regional seas are discussed.

Keywords: sea ice, ocean circulation, ocean temperature, climate change, numerical model.

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ICES CM2008/B:08

The effect of seasonal sea ice cover on the structure of the eastern Bering Sea pelagic foodweb

George Hunt, Jeff Napp, Ken Coyle, and Phyllis Stabeno

Seasonal sea ice cover is a defining characteristic of the eastern Bering Sea Shelf. Evidence suggests that the timing of ice retreat in spring has an important impact on the timing of the spring bloom and its fate. Early, ice-associated blooms occur in cold water, and late, open-water blooms in relatively warm water. Early blooms have been hypothesized to result in a larger portion of the production going to the benthos, whereas the late blooms supply more to the pelagic ecosystem. The timing of the bloom also affects the types of copepods that will predominate. In 1999, a cold year, sea ice was present in the southeastern Bering Sea until late May, and “large” crustacean zooplankton including *Calanus marshallae* and *Thysanoessa raschii* were abundant the following summer. In contrast, 2004 was a warm year in which sea ice retreated in early March, summer stratification was strong, and small shelf species dominated the summer mesozooplankton. These differences were reflected in the diets of age-0 walleye pollock (*Theragra chalcogramma*). The lack of large zooplankton in middle shelf domain waters in summer can be expected to affect the distribution, and possibly growth, of planktivorous groundfish, such as walleye pollock. There are also differences in the productivity of planktivorous and piscivorous seabirds that suggest that ice cover affects the availability of these classes of prey. As sea seasonal ice cover is lost with global warming there may be a major change in the structure and function of the southeastern Bering Sea ecosystem.

Keywords: sea ice, zooplankton, seabirds, ecosystem structure, climate change.

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ICES CM 2008/B:09

The effect of temperature and stock size on geographical distribution of capelin (*Mallotus villosus* Müller) in the Barents Sea

Randi Ingvaldsen and Harald Gjøsæter

During winter the capelin (*Mallotus villosus* Müller) is found near and south of the Polar Front. In the spring, the Barents Sea capelin migrate northwards and eastwards following a receding ice edge. The older capelin move further to the north and east than the younger capelin do. During the period 1972–2007 the spatial distribution of the Barents Sea capelin during autumn changed along a southwest–northeast axis. The position was partly determined by the environmental conditions and partly by the capelin stock size. In periods when the capelin stock is large, the feeding area is normally extended north- and eastwards. This is probably an adaptation necessary to meet the greater demand for food when the stock is more numerous. Better conditions for plankton growth in the northern areas, either resulting from a northward movement of the ice edge or the Polar Front or for other reasons, would be beneficial for the capelin stock. Since 2004, capelin has also been observed north and west of Spitsbergen and in the northwestern Barents Sea, even though the stock size during this period was low. Whether this is related to the increasing temperatures and the extremely low ice cover observed in the Barents Sea in the last years is investigated. Climate change scenarios have indicated that changes in the ice edge and the position of the Polar Front are expected in the future. The effect of these changes on the future spatial distribution of capelin is evaluated.

Keywords: Barents Sea, capelin, geographical distribution, environmental conditions. Contact author: Randi Ingvaldsen, Institute of Marine Research, Bergen, Norway [e-mail: randi@imr.no].

ICES CM 2008/B:10**Sea ice variations influence benthic community growth rates over decadal scales: evidence from bivalve population near the Barents Sea Polar Front**

Michael L. Carroll, William G. Ambrose, Ben Levin, Adam Ratner, Stuart Ryan, and Jeanette Hardy

We examined interannual patterns of growth in two Arctic bivalves species (*Clinocardium ciliatum* and *Hiatella arctica*) on either side of the Polar Front in the Barents Sea to assess relationships between environmental parameters and biological responses. Analysis of annually deposited growth rings in bivalve shells provides a means to assess these relationships over decades (*Clinocardium*) to more than a century (*Hiatella*), thus encompassing both warmer and colder climatic phases of the last century. Growth patterns of both species corresponded to hemispheric climatic oscillations represented by the Arctic Climate Regime Index (ACRI) and local parameters, especially ice cover and precipitation. There were, however, significant local variations in growth responses depending on proximity to the Polar Front and corresponding sea ice regime. Growth of *Hiatella* from locations near the Polar Front was positively correlated with the number of ice-free days and negatively correlated with maximum ice extent, while those in Atlantic water had the opposite response. Growth was related to the ACRI at stations in Atlantic water but not at Polar Front stations. Together, ice conditions and precipitation explained up to 82% of annual variation in *Hiatella* growth. *Clinocardium* growth was positively correlated with maximum ice extent in Polar Front and non-Front stations and to the ACRI at Atlantic water and some Polar Front stations. These results validate the use of growth-rate analyses of bivalves to reconstruct biophysical relationships over decades to centuries, thereby overcoming the limitations of interpreting climate change effects from the “snapshot” views afforded by traditional Arctic sampling campaigns.

Keywords: Barents Sea, bivalve growth, environmental forcing, sea ice, climate variability.

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ICES CM2008/B:11**Poster****The influence of sea ice dynamics on plankton abundance in the Northwest Atlantic inferred from the continuous plankton recorder survey**

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

The continuous plankton recorder (CPR) survey provides an assessment of long-term changes in the abundance and geographic distribution of planktonic organisms, ranging from small phytoplankton cells to larger macrozooplankton. The CPR survey can be used to address major marine management issues including fisheries and trophic linkages, biodiversity, phenology, invasive species, occurrence of harmful algal blooms (HABs), and climate change. Using data collected by the CPR survey, we review the spatial and temporal dynamics of selected CPR taxa in the Northwest Atlantic during the 1960s through to 2006 in relation to sea ice dynamics on the Newfoundland and Labrador Shelf. The retrospective analysis of plankton in relation to sea ice dynamics provides insight into the response of the lower trophic levels to climate change. Anticipated trends in phytoplankton and zooplankton abundance and community composition with predicted changes in sea ice conditions are also discussed.

Keywords: continuous plankton recorder (CPR), climate change, plankton, sea ice.

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ICES CM 2008/B:12**Changes in minke whale distributions in the Southern Ocean**

Bas W. P. M. Beekmans, J. Forcada, Eugene J. Murphy, J. W. Hein de Baar, and Ulrich V. Bathmann

This study explores the various relationships between distance from the sea ice edge and minke whale density distribution by means of a circumpolar spatial analysis. For almost 30 years, the International Whaling Commission (IWC) has conducted whale surveys in the Southern Ocean during austral summer months under the IWC/IDCR-SOWER programme. This has resulted in three circumpolar sets of surveys, with over 21 000 minke whale sightings. We used these sightings in spatial models of line transect data based on generalized additive mixed models (GAMMs). The GAMMs assumed an overdispersed Poisson error structure and log-link. In order to reduce possible bias caused by autocorrelation, the GAMMs also included an exponential

spatial correlation structure. Model selection was based on minimization of assignment index correction (AIC) and spatial autocorrelation effects, excluding GAMMs that had low explanatory power. The GAMMs were fitted independently by survey area and year. Selected GAMMs included combinations of the following covariates: closest distance of sighting to sea ice edge, closest distance of sighting to either the Southern Antarctic Circumpolar Current Front (SACCF) or the Southern Boundary of the Antarctic Circumpolar Current (SBACC), bathymetric depth, optimally interpolated sea surface temperature (OISST), and latitude. Minke whale densities did not show a consistent relationship with distance from the sea ice over the years, suggesting variability in minke whale distribution between years. In the most recent survey, however, moderate to high predicted minke whale densities tended to be closer to the sea ice edge and at higher latitudes within the Ross Sea sector (60°S 165°E–160°W).

Keywords: minke whales, distribution, sea ice edge, generalized additive mixed models.

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ICES CM 2008/B:13**Poster**

Monitoring the availability and quality of ringed seal pupping habitat in coastal Labrador

Becky Sjare

Relatively little is known about the adaptive capacity of ringed seals (*Phoca hispida*) to climate change in many parts of their range. However, because the species requires certain sea ice and snow conditions to successfully overwinter and rear a pup, ringed seals are thought to be sensitive to climatic variability that alters these required habitat characteristics. The pups are born in a protective snow cave (lair) constructed by the female near a well-drifted pressure ridge or ice hummock on landfast ice or relatively stable pack-ice. Adequate snow cover and/or appropriate ice roughness have been correlated with increased survival of ringed seal pups in the High Arctic and in Hudson Bay. The objective of this study was to map and quantify the available habitat for breeding ringed seals using RADARSAT imagery of ice conditions during February and March and data collected by on-ice teams of hunters from the communities of Nain, Hopedale, and Rigolet, Labrador. Ice and snow condition data from 2001 to 2007 at the Nain study area illustrated how expansive intrusions of highly deformed rough ice (2004), extensive sheets of smooth ice (2006, 2007), inadequate snow cover (2001), an abrupt and early spring melt (2003), and spring storm events (2005, 2006) impacted the availability of suitable pupping habitat. Although the occurrence and degree of ice deformation was the key determinant of quality habitat, persistent snow accumulation on the ice and the maintenance of a stable ice platform despite severe, unseasonable spring storms (i.e. high seas and rain) appeared to be critical.

Keywords: ringed seal, pupping habitat, landfast ice, climate change.

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ICES CM 2008/B:14

Macrobenthos distribution patterns on a sea ice-affected continental shelf, Canadian Beaufort Sea

Kathleen E. Conlan, Alec E. Aitken, Ed Hendrycks, Christine McClelland, Steve Blasco, and Humfrey Melling

Variation in macrofaunal composition was analysed in nine regions of the Beaufort Shelf and Amundsen Gulf. We hypothesized that benthic community composition: (i) was distinctive in a recurrent polynya in the Amundsen Gulf, (ii) was distinctive in upwelling regions (Mackenzie Canyon, Cape Bathurst), and (iii) changed in a linear gradient across the Beaufort Shelf. (i) No significant change in community composition was measured inside the polynya in the Amundsen Gulf. (ii) The Mackenzie Canyon macrofauna were similar to the shelf community at similar depths, but there was a ten-fold increase in inshore abundance in the upwelling region at Cape Bathurst owing to large numbers of the amphipod *Ampelisca macrocephala* and the polychaete *Barantolla americana*, species that were not abundant elsewhere. (iii) In the inshore fast ice and flaw lead regions of the Beaufort Shelf, under the influence of ice scour, storm effects, coastal erosion, and the Mackenzie River, the macrofauna were dominated by the bivalve *Portlandia arctica* and the polychaete *Micronephthys minuta*. Offshore, where these influences are less pronounced and upwelling of Atlantic water occurred, the polychaete *Maldane sarsi* dominated. Faunal distribution across the Beaufort Shelf correlated with depth, bottom temperature and oxygen content, and sediment texture but was not significantly linear. Benthic habitat anomalies such as mud volcanoes, pingo-like features, artificial drilling islands, and drowned beaches modified community composition locally.

Keywords: macrobenthos, community composition, Beaufort Sea, Amundsen Gulf, sea ice.

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ICES CM 2008/B:15

Possible impacts of ice-related mortality on trends in the Northwest Atlantic harp seal population

M. O. Hammill and G. B. Stenson

The harp seal is a highly migratory, medium-sized phocid distributed over continental shelf regions of the North Atlantic. The Northwest Atlantic population currently numbers around 5.5 million animals and is harvested commercially and for subsistence reasons. Harp seals use pack ice to haul out on, to give birth, and to nurse their young. After weaning, the young of the year remain with the ice, which they use as a resting platform. In the Gulf of St Lawrence, poor ice conditions, which are thought to lead to increased mortality among young animals, have been observed in six of the last ten years. The harp seal population is assessed approximately every four years via aerial surveys of pup production. The harvest is focused on juvenile animals. This means that the impact of any management action or unusual conditions will not be reflected in the assessment until at least four years later. For management considerations, taking into account possible changes in natural mortality owing to ice conditions would appear to be important. A factor to account for increased mortality during poor ice years has been incorporated into the harp seal assessment model, but the impacts of this factor on model predictions have not been evaluated. Under scenarios of a constant harvest, an annual ice-related mortality of 20% or higher would result in significant changes in the population trajectory within a decade, but these changes would not be detected as changes in pup production for at least 20 years. Mortality of 10% had limited impact on the population trajectory and pup production unless it occurred in four or more winters within a decade. Variability in the magnitude or frequency of this ice-related mortality made little contribution to the uncertainty associated with population projections within a time-frame of 20 years or less. Although attempts to capture the uncertainty in this mortality may be less important, at least within a framework of 20 years, it is important to consider ice-related mortality during the assessment of this pagophilic species.

Keywords: harp seals, ice, mortality, population assessment.

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ICES CM 2008/B:16

Variability of oceanographic and ice properties of the Canadian Arctic Archipelago

Ingrid Peterson, Simon Prinsenber, James Hamilton, and Roger Pettipas

Year-long moorings have been in place since August 1989 in Lancaster Sound to measure pack ice properties and oceanographic transports of the Arctic surface waters passing through the Canadian Arctic Archipelago. In addition, ice charts provide a 30-year time-series on the interannual variability of mobile and land-fast pack ice conditions. The mooring time-series data demonstrate large interannual variability, with a major transport peak in summer and a minor peak in winter. Regression analysis with the Arctic Ocean windfield has shown that the highest correlation between the transports in Lancaster Sound is with the winds at grid location along Banks Island in the Canadian Beaufort Sea some 1000 km from the mooring site. This suggests that it is the far-field winds rather than local winds that cause the variability in transports. The north-south winds over the shelf at the western entrance to the Northwest Passage set up the pressure gradient in Lancaster Sound, which in turn causes the variability seen in the observed transports. In contrast, local atmospheric conditions determine the mobile and land-fast ice variability in Lancaster Sound. Expected atmospheric changes resulting from global warming will increase the length of the mobile ice season and increase the oceanographic transport variability, thereby changing physical environments controlling the ecosystem of the Canadian Arctic Archipelago.

Keywords: Lancaster Sound; measured pack ice properties; Arctic Surface Waters & Canadian Arctic Archipelago.

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ICES CM2008/B:17**Poster****Polynyas and tidal currents in the Canadian Arctic Archipelago**

Charles G. Hannah, Frédéric Dupont, and Michael Dunphy

A tidal model of the Canadian Arctic Archipelago was used to map the strength of the tidal currents, tidal mixing (h/U^3), and the vertical excursion associated with the tidal currents driving water up and down the slope. The hotspots in these quantities correspond to the location of many of the small polynyas in the Archipelago, supporting the idea that the tidal currents make an important contribution to the dynamics of

many of these recurring polynyas. The potential link with tidal mixing means that these locations may have enhanced plankton production in summer.

Keywords: Arctic Archipelago, polynyas, tidal currents, tidal mixing, tidal mixing fronts.

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ICES CM/B:18 Poster**On the extent and variability of sea ice on the Scotian Shelf**

Ken Drinkwater

The southernmost extent of seasonal sea ice in the North Atlantic is on the Scotian Shelf offshore of Nova Scotia. Primarily using the ice records from the Canadian Ice Service from the 1960s to the present, the mean seasonal sea ice extent and concentrations are presented, along with their interannual variability. The sea ice is principally transported from the Gulf of St Lawrence and persists on the Scotian Shelf for approximately two to three months of the year, mostly during January to March. While normally confined to the northeastern Shelf region, on occasion it will reach Halifax, and very rarely points even further south. The primary mechanisms controlling the timing of first and last presence of ice, as well as the areal extent of the sea ice on the Scotian Shelf, is also presented.

Keywords: sea ice, seasonal variability, interannual variability, Scotian Shelf.

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ICES CM 2008/B:19 Poster**TUNU-MAFIG: Marine fishes of northeast Greenland—diversity and adaptation**

Jørgen S. Christiansen, Oleg V. Karamushko, and Svein-Erik Fevolden

The TUNU-MAFIG programme (2002–2012) is endorsed by the International Polar Year (IPY ID: 318) and comprises about 35 scientists and research students from ten countries. The Arctic marine fish fauna, in particular the fish of east Greenland north of Scoresby Sund Fjord (70°N), is little studied. Furthermore, the distribution and amount of sea ice (“Storisen”) along the northeast Greenland coast has fluctuated widely with, for example, almost no ice in 2003 and heavy ice in 2005. This makes the area a key Arctic site at which to study the effects of climate change on the marine biota. The TUNU-MAFIG programme focuses on the interaction between fish diversity (zoogeography, taxonomy, and genetics), physiology (blood chemistry, metabolism, and cardiovascular adaptations), and ecology (trophic relationships, pollutants, and fish parasites). At present, a net of 90 key stations has been established from the innermost part of the fjords to the continental slope. This provides first-hand information on the interannual variability of both the fish fauna and concurrent hydrographical regimes. A museum collection of northeast Greenland marine fish species has also been established. The logistic backbone of TUNU-MAFIG consists of five expeditions headed by the University of Tromsø. Three expeditions were conducted successfully in autumn 2003 (TUNU-I), 2005 (TUNU-II), and 2007 (TUNU-III) with the ice-strengthened RV Jan Mayen as the operational base. The TUNU-IV and -V expeditions are planned to take place in autumn 2009 and 2011. Here, we present an overview of the main activities and results to date.

Keywords: East Greenland, marine fish, diversity and adaptation.

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ICES CM 2008 /B:20 Poster**Distribution and movement patterns of killer whales (*Orcinus orca*) in the Northwest Atlantic**

T. S. Stevens and J. W. Lawson

Killer whales (*Orcinus orca*) occur throughout the Northwest Atlantic. A sightings database and photographic catalogue, created mostly from opportunistic sources, is used to examine the occurrence of killer whales in Atlantic Canada. A majority of the sightings are from the Newfoundland and Labrador region, despite comparable observer coverage in adjacent areas such as the Gulf of St Lawrence and Scotian Shelf, which suggests greater abundance in and habitat preference for Newfoundland and Labrador waters. Killer whales occur in all months of the year and in both near- and offshore regions, although particular sighting patterns may represent local observer effort and awareness. The distribution, movement, and residency patterns of killer whales may be closely linked to that of their prey; they have been observed harassing, attacking, and eating marine mammals, including minke whales (*Balaenoptera acuterostrata*),

dolphins, and seals, and potentially eating fish. Some killer whales appear to remain year-round in the Newfoundland and Labrador area and have been sighted during spring within pack ice, potentially in association with breeding harp seals (*Phoca groenlandica*). Based on photographic records, individual killer whales in this area have been shown to travel hundreds of kilometers within a year. Conversely, although there is no spatial or temporal evidence of seasonal migration, killer whales may be reliably seen in certain areas during particular times of the year, suggesting that long-term site fidelity patterns may exist within this population.

Keywords: killer whale, distribution, movement, residency, site fidelity, Northwest Atlantic, Newfoundland and Labrador.

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ICES CM 2008/B:21 Poster

Antarctic sea ice habitat and minke whales

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In the Southern Ocean, biological production in sea ice is thought to be a major driving force for Antarctic animal population sizes and biodiversity. Understanding the importance of sea ice to the related foodweb is critical for a proper evaluation of the potential impacts of climate change. It has been thought that Antarctic minke whales (*Balaenoptera bonaerensis*) only stay in Antarctic waters during the austral summer and spend the winter breeding season in tropical and subtropical waters. Sightings of minke whales during the austral winter in the pack ice were considered atypical. It is known that sea ice forms an important habitat for the Antarctic minke whale during summer when production is high. Continuing food availability under the sea ice during winter, however, might also allow them to overwinter in the deep pack ice. Data on minke whale occurrence in Antarctic winters are scarce, because of limited observation effort during this time, as well as difficult sighting conditions. To investigate the hypothesis that Antarctic minke whales regularly overwinter in the pack ice, we compiled year-round information on historical references, published sightings, and observations from non-dedicated shipboard surveys as well as from dedicated helicopter surveys in Antarctic waters. The analysed data cover a range of different seasons, including winter months, and records over the last decades. The results indicate that sea ice is used year-round as a habitat by the Antarctic minke whale.

Keywords: Antarctic, minke whales, climate change, habitat use.

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North Pacific Research Board and National Science Foundation partner in comprehensive study of eastern Bering Sea ecosystem

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The North Pacific Research Board (NPRB) and the National Science Foundation (NSF) are studying the response of the eastern Bering Sea shelf ecosystem to climate change and sea ice loss. The programme includes three field seasons (2008–2010) and two years of analysis and is based on the NSF's 2005 Bering Ecosystem Study and the NPRB's Bering Sea Integrated Ecosystem Research Program. Funds for the \$52 million partnership include \$16 million from the NPRB, \$21 million from the NSF, and matching funds from the National Oceanic and Atmospheric Administration (NOAA), the US Fish and Wildlife Service, and the US Geological Survey. Over 90 federal, state, and university scientists are involved, many from Alaska, Washington, Oregon, and British Columbia. NSF researchers are studying atmosphere, ocean physics, and lower trophic levels, including physical and biological sampling around sea ice and on the seabed; primary production near sea ice; nutrients and stratification; and energy transfer through zooplankton. NPRB-funded research emphasizes forage fish, commercial fish species such as pollock, Pacific cod, and arrowtooth flounder; northern fur seals, walrus, and whales; and thick-billed murres and black-legged kittiwakes. Foraging patterns of marine mammals and seabirds will be studied within large prey aggregations near the Pribilof, Bogoslof, and St Lawrence Islands. Local and traditional knowledge research involves the coastal communities of Akutan, St Paul, Togiak, Emmonak, Savoonga, and Nelson Island. Federal matching funds from the NOAA, the US Geological Survey, and the US Fish and Wildlife Service will support trawl surveys, seabird telemetry, and studies of fur seal pups and persistence of foraging hotspots. An innovative ecosystem modelling activity will tie the programme components together.

Keywords: ecosystem, Bering Sea, partnership.

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Interannual pack ice properties of the St Lawrence Gulf and their effect on the mortality of harp seal herds

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Sea ice habitat is an important component of the ecosystem to which harp seals belong, as they require specific sea ice conditions to successfully rear pups. Once they haul out on the pack ice to rear their pups, the security of their habitat (pack ice) is at the mercy of the weather conditions that alter between years and may permanently alter owing to global warming. Little is known about the vulnerability, sensitivity, or adaptive capacity of ice-breeding seals to perturbations of their habitat. Changes in the pack ice evolution and the timing or geographic distributions of seals, perhaps induced by climate change, could strongly influence their natural mortality. Ice thickness and ice roughness profiles were successfully sampled in the southern Gulf of St Lawrence during the harp seals' early whelping stage on 2 and 3 March 2007 and again on 3 and 4 March 2008. Helicopter-borne sensors collected ice property and video data for transect lines covering the pack ice the herd preferred and avoided. In both years, four satellite-tracked ice beacons were placed on the ice to track the herd and follow the ice signature seen in synthetic aperture radar (SAR) imagery around the herd. The pack ice upon which the 2007 herd hauled out did not remain within the Gulf for more than a week, resulting in a high seal pup mortality rate. In contrast, most of the pack ice the 2008 herd selected lasted more than four weeks, resulting in a low mortality rate. The pack ice durability selected by the seal herd and thus the rearing success of the Gulf harp seals depends on the succession and strength of storms during the whelping season as well as the total ice extent (winter severity) of the specific year; these environmental parameters are expected to change as a result of global warming.

Keywords: sea ice habitat; harp seals; sea ice conditions; pack ice; Gulf of St. Lawrence.

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A new high-resolution, unstructured-grid, finite-volume model system for Arctic Ocean research: A nesting experiment with global ocean models

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A high-resolution, prognostic, unstructured-grid, finite-volume, free-surface, three-dimensional primitive equation model for the Arctic Ocean (FVCOM-Arctic) has been developed and tested by our UMASS-WHOI team. The unstructured triangular grid makes this model capable of resolving accurately the complex coastal geometry and bathymetry of the Arctic Ocean, including the narrow straits in the Canadian Archipelago and steep bottom topography over continental slopes and ridges. The finite-volume discrete method solves the integral form of the governing equations using control volumes, which ensures mass conservation in both individual volumes and the entire domain. FVCOM-Arctic is configured in terrain-following spherical coordinates, with uniform layers near the surface and bottom. It is driven by atmospheric forcing (windstress, surface heat flux/shortwave irradiance, precipitation via evaporation, air pressure gradients), river discharge, water exchange with the Pacific and Atlantic Oceans, and tides. The open boundary conditions are specified using a global ocean model through a one-way nesting approach. The ocean model is coupled with the Community Ice Model (CICE) modified for the FVCOM-Arctic unstructured grid. The FVCOM-Arctic model has been validated for tidal simulations and also tested for a 50-year spin-up run with climatologic forcing. With guarantee of mass conservation, FVCOM-Arctic can run continuously with no need of "restoration". With better resolving of coastal geometry and high horizontal resolution in shallow regions and continental slope, this model has successfully reproduced major features of the Bering, Chukchi and Beaufort Seas. Tidal forcing included in the model dynamics allows us to represent correctly ocean mixing and vertical temperature-salinity structure. The process-oriented experiments suggest that the open boundary conditions (either specified or nested within the global ocean model) have a significant impact on ice, water property, and currents in the Arctic Ocean for a long-term simulation. A new unstructured-grid nesting approach is proposed to avoid the problem of deep-water gravity wave energy accumulation at open boundaries due to inconsistency of grid sizes that occur in current structured-grid Arctic Ocean models.

Keywords: ice model, mid-ridge circulation, water exchange.

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