

# BOOK OF ABSTRACTS

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ICES

International Council for  
the Exploration of the Sea

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## Theme Session A

### Joint ICES/PICES Session—Understanding, measuring and projecting the limits of resilience in marine ecosystem

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#### ICES CM 2012/A:01

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##### **Resilience and resistance in the foodwebs of Europe**

Maciej T. Tomczak, Sheila J. J. Heymans, Thorsten Blenckner, Alberto Barausse, Andy Kenny, Georgi Daskalov, and Alison Gilbert

Europe's marine ecosystems are perhaps the most used in the world, which means that the anthropogenic threats on these ecosystems are very high, with overexploitation and general use of the ecosystems well described. In this study we use previously published ecosystem models of the North Sea, the deep sea off the West Coast of Scotland, the Adriatic, the Baltic Sea, and the Black Sea to test the resilience and resistance of these ecosystems to both human and environmental perturbations. The models were run forward to stabilize and then used to test the resilience and resistance of the systems by giving them a pulse and then run until model stabilizes again. Different scenarios were tested, including increasing and decreasing primary production, increasing and decreasing fishing pressure on high trophic level and medium trophic level species, and combinations of these perturbations. The results show the differences in the ecosystem response, showing the resilience of these ecosystems. We tested the amplitude of the disturbance and time to recovery between these systems and describe the impact this has on the adaptive capacity and management of these systems.

Keywords: ecological model, foodweb, resilience, resistance.

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#### ICES CM 2012/A:02

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##### **Managing resilience of fish populations in principle and in practice: a multivariate analysis of Northeast Arctic cod**

P. Vasilakopoulos and C. T. Marshall

Concerns about food security in the face of climate change have highlighted the need to safeguard resilience of marine ecosystems so as to ensure stability in future production of fish protein. Resilience is often considered as a property of ecosystems or social-ecological systems, but a resilience perspective is also relevant at lower levels of biological organization, such as at an individual or population level. Assessing the resilience of a single fish population by quantifying how the population structure, life history traits, and abiotic and biotic factors interact to pull the population towards or away from desirable and stable states could provide useful information for fisheries management. Here, we use statistical tools that have been developed for the Integrated Ecosystem Analysis (IEA) of large marine ecosystems, in order to capture the multidimensional attributes that confer resilience to the Northeast Arctic cod stock. Over the past 60 years there have been dramatic shifts in life history traits, population structure, trophic interactions, and climate that may have mitigated or amplified the impacts of fishing mortality on population dynamics of this stock. The multivariate analysis clarified the respective synergistic or opposing roles of individual, population, exploitation, and environmental trends that allowed the stock to avoid collapse despite being harvested at comparatively high rates. We also investigated the development of the dominant eigenvalues of the system to identify possible "tipping points". Managing resilience by focusing on the factors that enhance the ability of fish populations to absorb disturbance is one means of managing the depletion risks associated with overfishing.

Keywords: ecosystem approach, integrated analysis, Northeast Arctic cod, resilience.

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### ICES CM 2012/A:03

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#### Fishing for resilience

Richard Law, Michael J. Plank, and Jeppe Kolding

The pattern and intensity of fishing affects the resilience of marine ecosystems. We use a simple model of steady-state dynamic size spectra to illustrate how size-at-entry fisheries can change the structure of exploited populations and alter their capacity to recover from perturbations. Heavy fishing from small sizes can cause hysteresis, where a small increase in fishing intensity leads to sudden stock collapse from which recovery is possible only with a substantial reduction in fishing. Heavy fishing starting from sizes close to maturity can destabilize the steady state, replacing it with a non-equilibrium attractor in which abundance fluctuates over time. We contrast size-at-entry fisheries with an alternative in which exploitation is balanced to productivity so that fishing mortality falls as fish get larger. Balanced harvesting has less effect on size structure, avoids destabilizing effects of starting fishing close to maturity, and can generate a larger biomass yield. These results lead to the surprising conclusion that there are advantages in harvesting small fish rather than large fish.

Keywords: balanced harvesting, size spectrum, stability, theory.

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### ICES CM 2012/A:04

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#### What determines intrinsic resilience and vulnerability of marine ecosystems to natural and anthropogenic forcing?

Skip McKinnell

PICES has embarked on a 10-year scientific programme called “FUTURE” that hopes to answer the question “What determines intrinsic resilience and vulnerability of marine ecosystems to natural and anthropogenic forcing?”. While it may never be answered to anyone’s satisfaction, it raises some fundamental issues that appear to be more philosophical than scientific. This presentation is a perspective on what is required to make progress on the question by considering its component parts. What is a marine ecosystem? What is resilience, in that context? Why should it be an intrinsic property of a marine ecosystem? These fundamental questions are grist for the philosophical mill that may take a pint or two to sort out.

Keywords: ecosystem, FUTURE, PICES, resilience.

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### ICES CM 2012/A:05

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#### Defining reference states for ecosystems: an approach through dynamic stochastic modelling

Benjamin Planque and Ulf Lindstrøm

Rapid and dramatic restructuring of an ecological community, often referred to as “regime shift”, is commonly interpreted as reflecting loss of ecosystem resilience. A common approach to detect regime shifts is to use long-term observation of ecosystem state as a reference baseline against which regime shifts can be detected. But such long time-series are rare for most ecosystems, in particular marine ones. In addition, ecosystems are defined with vague boundaries and there is no established theory that can be used to define the reference state of an ecosystem. For this reason it is not possible to clearly separate cases where an ecosystem has truly shifted from one state to another in response to external causes from cases where such large amplitude changes are part of

the internal dynamics of the ecosystem. Here, we present a dynamic stochastic modelling approach based on a small set of principles, which can reproduce realistic features of real-world foodwebs. We show that simulations from such models can serve as a baseline against which empirically observed regime shifts can be tested.

Keywords: dynamic stochastic foodweb model, regime shifts, tipping points.

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## ICES CM 2012/A:06

### Ecological resilience research in practice: the experience of the Barents Sea Ecosystem Resilience project (BarEcoRe)

Benjamin Planque, Grégoire Certain, Kathrine Michalsen, Magnus Wiedmann, Susanne Kortsch, Lis Lindal Jørgensen, Raul Primicerio, Michaela Aschan, Padmini Dalpadado, Mette Skern-Mauritzen, and Edda Johannesen

The BarEcoRe project was set up to investigate the resilience of the Barents Sea ecosystem under global environmental changes. It is important to be able to study the resilience of marine ecosystems in the current context of climate change and intense fishing pressure, but the theoretical framework and the practical tools to define, quantify, and monitor resilience are still being developed. So far, the BarEcoRe project has studied several aspects of the Barents Sea ecosystem structure and function with a view to forming a better understanding, monitoring, and projection of the resilience of this system. In this presentation we report on the aspects of resilience that are specifically addressed during the BarEcoRe project. We describe how some of the results of the BarEcoRe project can contribute to resilience research through either dynamic or structural approaches. This collection of research topics reveals the diversity of aspects that need to be considered for resilience studies conducted at the ecosystem level.

Keywords: community structure, ecosystem resilience, foodweb topology, functional diversity, macro-ecological models, spatial distribution models, taxonomic diversity.

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## ICES CM 2012/A:07

### Delineating marine ecosystem perturbation and recovery: theory and application of a trophic approach

J. S. Link, F. Pranovi, S. Libralato, M. Coll, V. Christensen, and C. Legault

The need to determine marine ecosystem resilience remains a prominent challenge. There are many proposed metrics to do this, but few, if any, have been tested with a broad range of applicable empirical examinations and simultaneously investigated for robustness to underlying theory. With the plethora of energy budget analyses and associated outputs now available, we were able to explore and indeed detect emergent patterns useful for such delineations. We examined a suite of biomass ( $B$ ), production ( $P$ ) and trophic level (TL) data from over 100 globally representative marine ecosystems. From these data we identified two sets of relationships: the first with  $B$  vs. TL and  $P$  vs. TL, used to build cumulative  $B$  and  $P$  vs. TL curves; the second set comprised the cumulative  $P$  vs. cumulative  $B$  curve. In the first set, common and general patterns consistently emerge. These patterns are readily explained by underlying dynamics of growth, mortality, productivity, transfer efficiency, and carrying capacity of marine ecosystems; known magnitudes and directions of perturbations can be predicted from them. From this underlying theory and observation, the second set emerges with consistent “hockey stick” cumulative  $P$  vs. cumulative  $B$  curves. As systems are perturbed, the hockey stick inflection and steepness parameters change, as one would expect, stretching and flattening out the curve and vice versa upon recovery. Simulations, sensitivity analyses, and empirical testing confirm the “hockey stick” dynamics,

leading us to derive potential ecosystem-level reference points. Our results expand knowledge about ecosystem functioning, ultimately helping in the implementation of ecosystem-based management.

Keywords: cumulative biomass, cumulative production, ecosystem-based management, hockey stick, reference points, resilience, trophic levels.

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#### ICES CM 2012/A:08

### Climate responses in fish: temperature dependence of physiological performance, consequences for growth and population resilience

Rebecca E. Holt and Christian Jørgensen

Climate change influences the marine environment, with a shift in water temperature being one of the main driving forces causing changes in the physiology and ecology of fish. At the individual level, increasing temperature can directly influence bioenergetics and numerous physiological and life history processes, and consequences are expected for populations, communities, and the functioning of marine ecosystems. We provide a model that predicts temperature-induced adaptations for life histories and population dynamics of a general fish, using parameters for Atlantic cod as a specific example. Temperature-dependent physiological functions such as active metabolic rate and metabolic scope are used as inputs within a conceptual model for predictions of survival, growth, and reproduction. The model differs from earlier work by including ecological parameters such as mortality rate, harvesting, and migrations, and challenges the concept of strict performance thresholds by showing how the effects of temperature adaptations depend on the ecological setting. The model is solved numerically using state-dependent dynamic programming with relationships for respiration and metabolism sourced from the current literature. Emergent life history strategies result through evolutionary optimization, and optimal individual strategies are simulated in populations to provide predictions of potential population growth and resilience to climate change.

Keywords: Atlantic cod, climate resilience, life history, physiology.

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#### ICES CM 2012/A:09

### Macro-ecological models of biodiversity metrics: how much can be explained by environmental change?

Grégoire Certain, Carsten F. Dormann, and Benjamin Planque

Ecological resilience is a multifaceted concept. Several of these facets relate to biodiversity. It is commonly assumed that diversity promotes resilience, and that diverse (in term of species, functions, habitats, genes) systems are usually more resilient. Taxonomy-based diversity indices might not relate as directly to resilience as metrics based on ecological function for example, but they are clearly defined, soundly documented, and highly repeatable across various systems. There are numerous taxonomy-based diversity indices, capturing various aspects of biodiversity such as commonness, rarity, evenness, diversity, or species richness. Investigations designed to “project the limits of resilience” can therefore be reformulated as “projecting changes in biodiversity”, under the paradigm that diversity promotes resilience, and bearing in mind that the relationships between the two is most likely non-linear. In this study, we used macro-ecological models (MEMs) to relate various biodiversity metrics describing the demersal fauna of the Barents Sea (82 species) to a set of 25 satellite-based and model-based environmental covariates (describing topography, temperature, salinity, stratification, current velocity, chlorophyll, ice coverage). These models show that the environment explains 15–30% of deviance in biodiversity metrics, and that the remaining

stochastic noise can be assimilated into a Gaussian, spatially autocorrelated, but time-independent, random field. Our MEMs identify the main biodiversity structure in the demersal fauna of the Barents Sea, and make it possible to predict structural changes in biodiversity according to climatic scenarios. They also show that a strong stochastic noise has to be expected on top of these predictions, and offer a way to quantify this.

Keywords: Barents Sea, biodiversity, demersal fauna, resilience.

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## ICES CM 2012/A:10

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### How does marine community resilience change with biodiversity loss?

Tak Fung, Keith D. Farnsworth, David G. Reid, and Axel G. Rossberg

Biodiversity is thought to be a major determinant of ecological resilience. While previous studies have found signs of increased resilience with higher species richness, they did not consider large marine communities, which are important in fisheries management. Thus, we study how resilience in large marine communities changes with biodiversity loss. First, a dynamic size-structured foodweb model was used to produce a population of large model communities, representing shelf communities in the Northeast Atlantic. A unique aspect of these model communities is that each has a realistically high fish species richness (>150). Experiments were performed on each model community, where fish species were randomly deleted until none remained. Following each deletion, the system was allowed to attain a new dynamic equilibrium through interspecific interactions. During biodiversity loss, four indicators of resilience were recorded: change in total fish biomass, change in total fish production, number of secondary extinctions and rate of return to equilibrium. Total fish biomass and total fish production both declined as fish species richness decreased, but slowly at high richness. Thus, resilience measured by these indicators decreased with decreasing richness, although with initial inertia, implying some functional redundancy among species. However, number of secondary extinctions decreased and rate of return increased with decreasing richness, such that the resilience measured increased with decreasing richness. The results were replicated when fish species were deleted in order of decreasing body mass, representing fishing down the foodweb. This study shows how different resilience indicators can reveal different aspects of marine community response to biodiversity loss.

Keywords: biodiversity, ecological resilience, ecosystem functioning, Northeast Atlantic.

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## ICES CM 2012/A:11

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### Resilience and thresholds in the Baltic Sea ecosystem

T. Blenckner, M. Llope, M. Lindegren, C. Möllmann, M. Casini, and N. C. Stenseth

Alterations in the structure and functioning of marine ecosystems have been increasingly reported around the world in relation to overfishing, changes in climate, and eutrophication. These pronounced and abrupt multitrophic level reorganizations of large-scale ecosystems are usually termed “ecosystem regime shifts” and happen when the ecosystem resilience is low. In the past, several regime shifts have been detected in the Baltic Sea, the largest brackish water body in the world ocean. To assess the existence of separated regimes (and hence regime shifts) in the Baltic Sea, we performed a state-of-the-art statistical analysis allowing the detection of non-linearities and thresholds in foodweb interactions and their relationship to drivers such as overfishing and climate. The analysis was applied to the large dataset of hydro-climatic, phyto- and zooplankton, as well as fisheries variables collected in the Central Baltic Sea during the period 1979–2006. This approach, by linking the different species-specific models to a foodweb model, enabled us to test for the cause of the observed regime shifts. A combination of fishery and environmental scenarios

has been applied to the foodweb model to test for the presence of thresholds, assess its resilience and detect hysteresis in this particular system. Our simulation results show that under the current environmental regime the Baltic Sea system presents hysteresis, as fishing should be reduced further below the pre-shift conditions to return to the previous state. The implications for management are discussed.

Keywords: climate, fishery, foodweb, hysteresis, regime shifts, resilience.

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## ICES CM 2012/A:12

### How is the resilience of fish populations affected by fishing-induced life history changes?

Katja Enberg and Christian Jørgensen

Fishing shapes not only the numbers and population structure of the harvested populations, but also the life history and behavioural traits of the targeted species. These adaptive changes can have consequences for the dynamics and the resilience of the population that is being fished. Intensive fishing has led to decreases in the maturation age and size of many fished stocks, including Northeast Arctic cod, the average maturation age of which has decreased several years during recent decades. Decreased age at maturation translates into decreased age at size, as a given amount of resources has already been diverted into reproduction at earlier ages. Northeast Arctic cod, like many other fished species, has a long and energetically costly spawning migration. As the age at maturation decreases, the cost of spawning migration for a fish of a given age increases, because swimming is more costly for smaller individuals. In this study we investigate, with the help of an individual-based evolutionary model, the following questions: Does increasing cost of spawning migration caused by decreasing size at age influence the resilience of the cod population? If the environment becomes more variable, are we likely to see larger fluctuations in the fish stock (and hence catches) as well? What is the interplay between fishing mortality causing life history changes and environmental drivers?

Keywords: cod, fishing-induced evolution, *Gadus morhua*, individual-based model, life history traits, resilience, spawning migration.

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## ICES CM 2012/A:13

### Functional diversity of the Barents Sea fish community: structure and drivers

Magnus Aune Wiedmann, Michaela Aschan, Grégoire Certain, Andrey Dolgov, Michael Greenacre, Edda Johannesen, Benjamin Planque, and Raul Primicerio

Functionally diverse systems are assumed to adapt more easily to environmental or structural changes than functionally poor systems. Therefore, functional diversity is often proposed to be an indicator of system resilience and robustness. Facing climate change and increasing anthropic pressure, northern ecosystems are currently experiencing major shifts in ecology and oceanography. To predict the probability that such shifts may occur in a given ecosystem, and subsequently to propose suitable management measures, tools such as functional diversity are needed to evaluate ecosystem state and functioning. However, functional diversity has mainly been developed in terrestrial systems. Therefore, we have applied the concept of functional diversity to a large marine ecosystem, the Barents Sea. We propose suitable functional trait selection and combine it with presence–absence data for each species in the area to produce a measure of functional diversity for the Barents Sea demersal fish community in the time period 2004–2009. We also show how the functional diversity of the demersal fish community varies in space and time in the Barents Sea, and give indications of some of its important drivers.

Keywords: adaptability, Barents Sea, community structure, functional diversity.



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**ICES CM 2012/A:14**

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**Resilience and functional redundancy: neutral model tests for ecological processes using North Sea survey data**

Jake Rice, Niels Daan, John Pope, and Henrik Gislason

Functional redundancy is a community property thought to contribute to ecosystem resilience. It is argued that trophic (or other) functional groups with more species have more linkages and opportunities to buffer variation in abundance of individual species. We explored this concept with a 30-year time-series of data on 83 species sampled in the International Bottom Trawl Survey. Our results were consistent with the hypothesis that functional redundancy leads to more stable (and by inference more resilient) communities. Over the time-series trophic groups (assigned by diet, size ( $L_{\max}$ ) group, or both factors) with more species had lower coefficients of variation (CVs) in abundance and biomass than did trophic groups with fewer species. These findings are also consistent with Bernoulli's Law of Large Numbers, a rule that does not require complex ecological and evolutionary processes to produce the observed patterns. Through iterative randomizations of the species' time-series into groupings of the same size as the functional groups, we developed expected pdfs of CVs in abundances and biomasses, assuming only the Law of Large Numbers was at work. The observed CVs of all groupings were not significantly different from these simulated distributions. These results do not prove the absence of ecological processes contributing to the greater stability of functional groups with more redundancy, however they do not justify invoking any such processes. The results support management approaches that maintain species richness, but do not require management to try to protect complex (and poorly understood) ecological processes.

Keywords: ecological process, functional redundancy, neutral model, resilience, stability.

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**ICES CM 2012/A:15**

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**Using rarefaction and species turnover analysis to detect marine fish species resilience**

Jamie M. Cournane, Christopher Glass, and Andrew A. Rosenberg

A diverse ecological community buffers against uncertainty from human and natural stressors. Biodiversity loss weakens ecosystem resilience, allowing an ecological community to become more susceptible to invasions and vulnerable to disturbance. Through extirpation, the functional roles of species may be replaced by other species, altered or eliminated. For example, overfishing and environmental change are two mechanisms in the marine environment that can diminish fish community diversity and alter fish functional roles. Measuring changes in ecological communities and understanding where, when, and how these changes occur provide insight on the use of best practices for biodiversity conservation (e.g. designing protected areas). This work traces the relationship of biodiversity, resilience, and disturbance from the ecological literature, applies modern biodiversity assessment methods to inspect for evidence of altered ecological community resilience, and provides advice on the use of this information for improved species conservation management. Using the case study of marine fish in the Gulf of Maine and Georges Bank, this study uses rarefaction techniques to test for changes in species richness and species turnover analysis to explore the species comprising those changes. Patterns of fish species richness and composition are examined to detect biodiversity changes in sub-areas of the study area and with respect to five large fishery closed areas, in a retrospective analysis of National Marine Fisheries Service bottom-trawl surveys (1971–2005). Outcomes of the analysis shape recommendations to improve the design of marine protected areas to buffer against the likely impact of overfishing and environmental change on marine ecological community resilience.

Keywords: biodiversity, marine protected areas, New England, resilience.

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## ICES CM 2012/A:16

### **Future climate projections provide insight into how the interaction of multiple drivers may affect Baltic Sea foodweb resilience**

S. Niiranen, T. Blenckner, O. Hjerne, M. T. Tomczak, and J. Yletyinen

Multiple driver interactions are known to affect ecosystem resilience. We used the best available information about future climate, nutrient loads, and fishery to study the Baltic Sea foodweb resilience under possible future combinations of these drivers. Foodweb projections were simulated for 2011–2100 using an Ecopath with Ecosim model of the Baltic Proper (BaltProWeb) that was run for two cod fishing, three nutrient load, and two regional climate scenarios (corresponding to IPCC scenarios A1B and A2), in all combinations. The system was considered resilient when changes in climate promoted no foodweb-wide regime shifts in future projections. Correspondingly, the lack of resilience was indirectly measured from regime-shift frequency and amplitude. These shifts were identified with the sequential regime-shift detection method STARS, applied on the first principal component of the PCA that compiles biomass information across the foodweb. Based on the criteria used, the foodweb was most resilient when both the cod fishing pressure and nutrient loads were low. These results suggest that regional actions, such as regulation of nutrient loads and fisheries, may be important in defining how vulnerable the Baltic Sea ecosystem is to changes in more global drivers. This was the first attempt to project the Baltic Sea foodweb resilience to future climate change using state-of-the art climate projections. We recognize that such modelling approaches involve large uncertainties, however, they are among the few tools that can provide long-term marine ecosystem planning with information about the ecosystem properties that may enhance ecosystem resilience under future conditions.

Keywords: Baltic Sea, climate change, ecosystem resilience, foodweb.

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## ICES CM 2012/A:17

### **Regime shifts and resilience in a eutrophic marine ecosystem: the Kattegat as a case study for ecosystem management**

Martin Lindegren, Thorsten Blenckner, Nils Chr. Stenseth, and Marcos Llope

Marine ecosystems worldwide have undergone large-scale changes in structure and functioning (i.e. regime shifts) in response to multiple external factors, including overfishing, eutrophication, and climate change. In order to prevent the associated loss of ecologically and economically important goods and services for human well-being, management actions to maximize ecosystem resilience has been advocated. While methods to detect ecosystem regime shifts have improved, our ability to characterize and explain the underlying causes, mechanisms, and ecological feedbacks of regime shifts are still limited. A crucial aspect for management is to detect ecological threshold beyond which recovery of an ecosystem (to a more favourable ecosystem state) is limited due to hysteresis. In this study, we present a statistical foodweb model for Kattegat, a eutrophied and heavily exploited marine ecosystem in the transition zone between the North and Baltic Seas. Using advanced non-linear threshold models (tGAM) on a comprehensive long-term dataset, covering abiotic factors and biotic variables across all trophic levels from phytoplankton to piscivorous fish, we here demonstrate a pronounced discontinuous regime shift involving hysteresis and multiple ecological thresholds primarily related to nutrient loads and temperature. Furthermore, we discuss and evaluate the limits to resilience and recovery on the narrow road from overexploitation and eutrophication.

Keywords: eutrophication, Kattegat, management, ecological thresholds, regime shifts, resilience.

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**ICES CM 2012/A:18      Withdrawn**

**ICES CM 2012/A:19      Poster**

### **A dynamic stochastic foodweb model for the Barents Sea ecosystem**

Ulf Lindstrøm, Benjamin Planque, and Samuel Subbey

Developing marine ecosystem models is inherently difficult because of the diversity and complexity of ecological processes to account for, the presence of non-linearities, and the broad range of spatial and temporal scales to cover. In general, the fundamental ecosystem processes involve several unknown components and parameters. Here, we adopt a parsimonious approach to model the dynamics of the Barents Sea ecosystem. By using a dynamic stochastic foodweb model (DSF), constrained by mass balance, inertia, and satiation, we simulate the foodweb dynamics of a simplified Barents Sea ecosystem. The aim is to generate realistic second-order properties of the Barents Sea foodweb, such as temporal autocorrelation, functional responses, integrated diet fractions and covariation between trophospecies/groups. The trophospecies/groups included in the model are minke whales, cod, capelin, krill, copepods, and phytoplankton. The model requires initial biomass values for each species and four species-specific parameters (satiation, inertia, metabolic efficiency, and ecotrophic efficiency). These were either taken from the literature or derived from existing models. Preliminary results from 100-year simulation show that the DSF model generates realistic species biomass trajectories, including pseudo cycles and consumer–resource relationships. Interestingly, despite fluxes of biomass between trophospecies being random (i.e. the consumption rates as a function of prey biomass are random), non-linear functional response relationships of some trophospecies emerge. Also, the analysis of covariation between various trophic levels suggests decadal fluctuation in top-down versus bottom-up controls. The same decadal fluctuations emerged when performing the analysis on real data.

Keywords: Barents Sea, dynamic, ecosystem, foodweb, model, stochastic.

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**ICES CM 2012/A:20      Poster**

### **Ecological resilience for ecologists**

Benjamin Planque, Grégoire Certain, Raul Primicerio, Kathrine Michalsen, Lis Lindal Jørgensen, Michaela Aschan, Padmini Dalpadado, Mette Skern-Mauritzen, Edda Johannesen, Susanne Kortsch, and Magnus Wiedmann

The term “resilience” is being used in a multitude of ways with meanings that can range from clearly defined descriptive ecological concepts to vaguely specified or normative management objectives. For examples, the terms “tipping points”, “resistance”, “functional diversity”, “modularity”, “sustainability”, “transformability”, and “panarchy” have all been associated with the concept of resilience, but these terms carry different meanings and may address distinct disciplines. Based on an extensive literature review, we map these concepts along major axes that separate normative from descriptive concepts, vague from precise concepts and transdisciplinary from ecology-specific concepts. We identify the concepts that provide a practical basis for empirical investigations and modelling of ecological resilience and the concepts that may be useful in communication between disciplines or with stakeholders but are generally of less relevance for ecological research.

Keywords: ecosystem dynamics, ecosystem structure, resilience, quantitative ecology, transdisciplinary research.

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**ICES CM 2012/A:21      Withdrawn**

**ICES C.M. 2012/A:22      Poster**

### **Impact of fish community types on ecosystem resilience**

Andrey V. Dolgov

The resilience of various marine ecosystems depends on peculiarities of fish communities in certain area. Dominance of one or a number of species belonging to different zoogeographic, ecological, and trophic groups can determine level of stability of various marine systems. Based on data on species composition, abundance, and biomass of commercial and other more abundant fish species in the Barents Sea and other areas of North Atlantic, the possible influence of fish community structure on ecosystem stability and resilience will be analysed and compared between different marine ecosystems.

Keywords: Barents Sea, ecosystems, fish communities, North Atlantic, resilience.

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**ICES CM 2012/A:23      Poster**

### **Foodweb topologies of the Barents Sea**

Susanne Kortsch, Michaela Aschan, Benjamin Planque, Magnus Aune Wiedmann, Lis Lindal Jørgensen, Padmini Dalpadado, Mette Skern-Mauritzen, Edda Johannesen, Kathrine Michalsen, Grégoire Certain, and Raul Primicerio

The vulnerability of ecosystems to environmental perturbations is influenced by their foodweb structure. Foodweb topology, which depicts and quantifies the ensemble of species and their network of trophic interactions, captures important aspects of foodweb structure influencing ecosystem dynamics. A better understanding of ecosystem vulnerability can be achieved via the description of topological properties, including species richness, connectedness, compartmentalization, and degree of omnivory. Each topological metric has implications for the dynamic properties of the foodweb communities, for example, via ecological theory and empirical evidence, metrics such as compartmentalization can be related to resistance and degree of omnivory to stability. Therefore, differences in vulnerability between ecological systems can be assessed by documenting differences in foodweb topology. Here we present the foodweb topologies for the Atlantic and the Arctic regions of the Barents Sea. The dissimilarities and similarities between the foodweb topologies for these two regions are discussed in the context of ecosystem vulnerability and resilience.

Keywords: Barents Sea, climate change, resilience, trophic interactions, vulnerability.

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**ICES CM 2012/A:24    Poster**

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**The Barents Sea fish community development during a decade of warming**

M. Fossheim, R. Primicerio, E. Johannesen, M. Aschan, and A. Dolgov

In the last decade the Barents Sea has experienced an unprecedented temperature increase, with positive anomalies every year since 2000. This is caused by an increased inflow of warmer Atlantic water and has led to a strong reduction of sea ice in the Barents Sea. Since 2004 Norwegian and Russian research vessels have covered the whole Barents Sea in autumn during a joint ecosystem survey, sampling the whole food chain, from plankton to fish, and including mammals and seabirds. In this period we have seen a build-up of a cod stock similar to the 1950s level in the Barents Sea, and many other commercial fish stocks, such as haddock and capelin, seem to be doing well. However, when taking an ecosystem approach to management we should ask how resilient the whole ecosystem is to these large changes. In this paper we investigate what happens to the whole fish community of the Barents Sea during such a climatic and ecological development. Over 100 fish species were identified during the surveys. Spatial and temporal changes in the Barents Sea fish communities were investigated by focusing on abundance and biomass patterns, driving factors and species' distribution change. This work is part of the BarEcoRe project, studying the resilience of the Barents Sea ecosystem under global environmental change.

Keywords: Barents Sea, climate warming, temporal change, uncommercial fish species.

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**ICES CM 2012/A:25    Poster**

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**Identifying thresholds of resilience within the benthos of the Barents Sea ecosystem**

L. L. Jørgensen, G. Certain, E. Johannesen, P. Lubin, B. Planque, R. Primicerio, T. Thangstad, and M. Wiedemann

The resilience of an ecosystem is the amount of disturbance that it can absorb while still maintaining its function. Benthic organisms, having limited mobility, are well-known integrators of the environmental condition. The degradation steps from a stable community with ecosystem services and goods, towards a disturbed end-community with large variation, are used as indicators of the environmental status. This poster describes the variation in community structure and diversity among areas in the Barents Sea and evaluates vulnerability. Areas expected to be exposed to external forcing are used as case studies on how resilience are measured in the field. Within these areas, stations along gradients of increasing natural (temperate, invasive species) and/or anthropogenic (bottom trawling) perturbations are evaluated. Changes including turnover in the species composition and frequency, the community structure, and functions along the gradients are used to identify and understand thresholds of resilience within the benthos subjected to different depth and oceanographic regimes. The natural history of the benthic species and their functions are combined with theoretical considerations to provide measures of resilience in marine systems. Our study provides examples on the use of the concept of resilience within a management context.

Keywords: Barents Sea, benthos, resilience, thresholds.

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**ICES CM 2012/A:26    Poster**

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**Operationalizing ecological robustness and resilience for ecosystem-based management**

Raul Primicerio, Michaela Aschan, Magnus Wiedmann, Susanne Kortsch, Benjamin Planque, Grégoire Certain, Edda Johannesen, Kathrine Michalsen, Andrey Dolgov, Lis Lindal Jørgensen, Padmini Dalpadado, Mette Skern-Mauritzen, and Maria Fossheim

The goal of an ecosystem approach to management is to preserve robust ecosystems that can cope with the environmental pressure imposed by human activities. Vulnerable ecosystems exposed to strong environmental perturbation are at high risk of large impact. Ecosystem-based management can mitigate impact by dealing with those ecosystem properties that influence vulnerability. The challenge is to identify relevant ecosystem properties that can be effectively integrated in assessment and decision-making so as to operationalize ecological robustness and resilience. Here we present the approach used in the BarEcoRe project to quantify, evaluate, and integrate an ensemble of structural properties affecting ecosystem adaptability and sensitivity to environmental change. The ecosystem properties, which include functional diversity and redundancy, and foodweb compartmentalization, were quantified based on data from the Norwegian and Russian Barents Sea ecosystem survey. The chosen structural ecosystem properties can be combined with early warning signals estimated from time-series to monitor robustness and resilience of managed ecosystems and guide decision-making.

Keywords: Barents Sea, foodweb compartmentalization, functional diversity, functional redundancy, resilience.

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## Theme Session B

### The contribution of acoustics–derived indices for ecosystem-based fisheries management: technological and analytical challenges and recent advances

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#### ICES CM 2012/B:01

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##### **Patchwork of the spatial distribution of small pelagics off Northwest Africa with non-linear geostatistics**

Cheikh Baye Isselmou and Nicolas Bez

In Northwest Africa, pelagic resources are an essential economic activity, particularly off Mauritania where they constitute about 90% of catches. To confirm that acoustic densities provide reliable observations of the order of magnitude of abundances rather than precise measurements of fish densities, we applied non-linear geostatistics to produce: (i) patchworks of classes of densities and (ii) indices of abundances from acoustic data collected during yearly surveys of RV “Fridjoff Nansen” from 1995 to 2006. This method, developed in the mining sector, has been rarely applied to fisheries previously. We show that it provides valuable and reliable results when applied to abundance indices for pelagic fisheries in Northwest Africa. Simple and cross-variograms of indicator variables based on four different thresholds of densities exhibit a stable year-to-year spatial pattern of density classes. Our results indicate also that (i) after a period of fluctuation between 1995 and 2000, abundance indices exhibit a slow and continuous increasing trend from 2001 to 2006, and that (ii) from 2001 to 2006 the geographical distribution of high abundance areas became wider through extending further offshore each year, roughly from 0.56 miles in 2001 to 0.92 miles in 2006.

Keywords: abundance index, non-linear geostatistic, Northwest Africa, small pelagic, spatial distribution.

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#### ICES CM 2012/B:02

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##### **Combining bottom-trawl and acoustic data to quantify expected biases in abundance estimates from bottom-trawl and acoustic surveys**

Stan Kotwicki, Alex De Robertis, Jim Ianelli, André E. Punt, and John Horne

Abundances of semi-pelagic fish are often estimated using acoustic-trawl and bottom-trawl surveys, both of which sample a limited fraction of the water column. Acoustic instruments have a near-bottom acoustic dead zone (ADZ), in which fish near the seafloor cannot be detected. Bottom-trawl surveys cannot account for fish that are located above the effective fishing height (EFH) of the trawl. We present a modelling method that combines acoustic and bottom-trawl abundance and habitat data to derive ADZ correction and bottom-trawl efficiency parameters. Our results show that predictions of fish abundance in the ADZ can be improved by incorporating bottom habitat features such as depth and sediment particle size, as well as pelagic habitat features such as water temperature, light level, and current velocity. We also obtain predictions for trawl efficiency parameters such as EFH, density-dependent trawl efficiency, and proportionality coefficients for trawl and acoustic data by modelling bottom-trawl catches as a function of acoustic measurements and the environmentally dependent ADZ correction. This method is applied to walleye pollock in the eastern Bering Sea to quantify expected biases associated with each survey method and the dependence of the biases on environmental variables. The catchabilities of acoustic and bottom-trawl survey methods are dependent on

environmental variables, and the sampling biases are not stationary in time and space as is commonly assumed for survey data. Applying models that combine both bottom-trawl and acoustic data can mitigate these problems for stock assessment as well as spatial dynamics studies.

Keywords: acoustic-trawl survey, bottom-trawl survey, acoustic dead zone, bottom-trawl blind zone, effective fishing height, catchability.

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### ICES CM 2012/B:03

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#### **High-resolution acoustic indices of Atlantic herring (*Clupea harengus*) paving the way for inclusion of migration patterns in management considerations of herring in ICES Divisions IIIa and SD 22-24**

Karl-Johan Stæhr and Lotte Worsøe Clausen

Herring catches in the Western Baltic, Kattegat and Skagerrak consist of a mixture of stocks; the two predominant stocks are the spring-spawning Western Baltic herring stock and the North Sea autumn-spawning herring (NSAS), and the mixing follows an age- and season-dependent pattern with high variability. The management is currently based on a single TAC and all catches are split into stock components prior to the single stock-assessment process. Given the complexity, knowledge of the magnitude of the mixing would improve the ability to perform sound forecasts of the herring stocks in the area. Thus a high-resolution stock-segregated survey index is highly warranted. Since 1991, DTU-Aqua have been acoustically monitoring herring in Skagerrak and Kattegat, ICES Division IIIa, as a part of the international acoustic survey for herring in the North Sea and adjacent waters. For the years 2006–2011 the two major herring stocks have been separated in the abundance estimate based on a combination of otolith microstructure and otolith shape. The abundance estimates by ICES rectangles have been used to describe the yearly geographical distribution of the herring stocks separately by age groups, mean length, and mean weight during June–July. This time-series (2006–2011) when analysed as a whole, gives a general picture of the distribution of the two herring stocks in Skagerrak and Kattegat during June–July and can ultimately be used as input to a description of the migration pattern for the two herring stocks.

Keywords: acoustic monitoring, herring, migration, Skagerrak, stock separation.

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### ICES CM 2012/B:04

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#### **Determining herring habitat quality from acoustically derived zooplankton abundance in the northern North Sea**

M. M. Sascha Fässler, Lorna R. Teal, Susan M. Lusseau, and Piet Ruardij

Acoustic fish surveys commonly collect data at a frequency range of 18–200 kHz. This is done primarily to facilitate target species identification and distinction from other fish based on differences in frequency-dependent scattering properties. Indeed, acoustic data contain qualitative and quantitative information on various trophic levels within an ecosystem, ranging from plankton to larger predators. Generally, however, backscatter information coming from plankton or other non-target fish species is discarded during the process of producing estimates of abundance and biomass of the target species. We applied a bi-frequency algorithm to multi-frequency data collected in the northern North Sea during acoustic surveys for herring from 2002 to 2012. This algorithm has previously been used on data from the Bay of Biscay and waters off



Peru to identify acoustic backscatter coming from macrozooplankton. Here, the same method allowed production of high-resolution maps of distributions, abundances, and biomass of macrozooplankton in the northern North Sea. These estimates were compared to outputs of the European Regional Seas Ecosystem Model (ERSEM) to determine whether the two approaches are in agreement with each other. Forage fish species such as herring feed directly on macrozooplankton, which are mainly composed of copepods or euphausiids. Knowledge about the location and abundance of food (macrozooplankton) and environmental conditions (temperature) may be used to identify preferable habitat for herring. A Dynamic Energy Budget (DEB) model was used to estimate food intake requirements of herring, given prey abundance and temperature, and consequently map the quality of the habitat in the survey area.

Keywords: North Sea, herring, dynamic energy budget, ecophysiology, habitat quality, ERSEM.

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### ICES CM2012/B:05

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#### **Going pelagic: how abiotic conditions force demersal Baltic cod into open water, and how this affects assessment**

Matthias Schaber, Hans-Harald Hinrichsen, and Joachim Gröger

Hydroacoustic measurements were applied to resolve seasonal distribution patterns of adult cod (*Gadus morhua*) in a physically challenging environment of the central Baltic Sea. Sampling was conducted biannually from 2006 to 2009 during the beginning and peak of the eastern Baltic cod spawning season on hydroacoustic transects covering the Bornholm Basin. Individual cod were identified using hydroacoustic single-target detection in combination with a fish-tracking algorithm. Distribution patterns of individual cod were related to ambient *in-situ* environmental conditions to identify possible abiotic driving mechanisms. Results showed a clear effect of salinity and ambient oxygen concentration marking the upper and lower boundaries of favourable cod habitats. Deteriorating oxygen levels in deep layers of the Bornholm Basin over the years investigated led to a seasonal upward movement of cod resulting in an increasingly pelagic distribution of large fractions of the local population. The results presented in this study highlight a significant shortcoming of the assessment survey design established for this species, as the observed shift in (vertical) distribution is not taken into account during the regularly conducted bottom-trawl surveys generating abundance indices, thus introducing a potential bias into a dataset used to tune the ICES standard stock assessment of this species.

Keywords: Bornholm Basin, environmental habitat thresholds, hydroacoustic single-fish detection, seasonal distribution patterns.

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### ICES CM 2012/B:06

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#### **Acoustic assessment of the effect of anchovy on bluefin tuna school structure: implications for acoustic estimation of tuna abundance and of predation of anchovy**

Nicolas Goñi, Igor Arregui, Guillermo Boyra, Iñigo Onandia and Haritz Arrizabalaga

Juvenile Atlantic bluefin tunas perform feeding migrations every summer to the Bay of Biscay, where juvenile anchovy constitutes their quasi-exclusive prey in the second half of the summer. Uncertainties regarding the stock abundance of bluefin tuna and their predation impacts on juvenile anchovy raised the need to develop reliable abundance indices for bluefin tuna in the Bay of Biscay. Due to the behaviour of this large pelagic predator (patchy distribution, fast

displacements, possible influences of feeding strategy on schooling behaviour), the possibility of acoustic surveys directed to bluefin tuna was assessed by an experimental survey. A set of three vertically and horizontally oriented echosounders was installed on board a baitboat targeting bluefin tuna in the Bay of Biscay during July and August 2011. The radius, volume, and density of each aggregation detected were calculated through a processing method combining information from vertical and horizontal echograms. The influence of anchovy abundance on tuna school structure (shape, volume, density) was tested on a large temporal scale and on a small temporal and spatial scale. The ratio between tuna catch rate and calculated abundance was also tested versus meteorological conditions and anchovy abundance. Our main result is a shift in school characteristics between July and August, schools being larger and denser in August than in July. This shift coincides with the local presence of juvenile anchovy in August (versus absence in July). The possibility of a transect-based acoustic survey directed to bluefin tuna is discussed according to the global results.

Keywords: acoustics, bluefin tuna, Bay of Biscay, feeding behaviour.

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### ICES CM 2012/B:07

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#### **Phytoplankton abundance and productivity impacts the distribution of herring in the North Sea**

Sven Gastauer, Mark Dickey-Collas, Narangerel Davaasuren, Niels Hintzen, Thomas Brunel, and Sascha Fässler

Almost all fishery stock assessments are carried out assuming a bounded spatial distribution of the exploited resource, although fish live and hence fisheries operate, in a highly dynamic environment. An understanding of the basic underlying patterns driving the distribution of herring, one of the most important commercial pelagic species in the North Sea, is crucial to a more ecosystem-based management approach and to achieve a better understanding of herring stock dynamics. North Sea herring is a planktivorous species that feeds on phytoplankton during its earlier life stages, switching to zooplankton later on. The present study assumes that zooplankton directly tracks phytoplankton. It will be shown if and to what degree primary production in the North Sea acts as a limiting factor for the distribution and seasonal migration of herring. The presented study will provide an insight into the spatial and temporal variability of phytoplankton standing stock, the associated primary production, and its impact on the exploitation and management of herring in the North Sea. Remote sensing chlorophyll data are used in combination with fisheries-dependent (VMS data) and fisheries-independent survey data (annual herring acoustic survey) to explore the relationship between fish, fisheries, and primary production.

Keywords: acoustics, herring, North Sea, plankton.

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### ICES CM 2012/B:08

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#### **Mesoscale eddies stimulate higher trophic level marine life – acoustically recorded density distribution creates understanding of the impact of physical forcing**

Olav Rune Godø, Gavin Macaulay, Annette Samuelsen, and Solfrid Sætre Hjøllø

Physical forcing shapes ecosystems and an understanding of interactions between drivers and biological responses is crucial for understanding ecosystem processes and potential impacts on harvested stocks. Combining satellite information with vessel-based acoustics is a cost-efficient way to study physical–biological interactions in mesoscale eddies. Anomalies in horizontal

distribution patterns demonstrate that fish feed along eddy peripheries. Therefore eddies also have an effect on the depth distribution patterns of fish species in eddies. However, data also indicate that the eddy-influenced signal in the acoustic record varies from very strong to absent, possibly because of eddy age, eddy rotation (cyclone or anticyclone), etc. The impact of the findings and suggestions for further work are discussed.

Keywords: acoustics, biomass distribution pattern, mesoscale eddies, physical-biological coupling, satellite imaging.

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**ICES CM 2012/B:10**

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**Assessing mackerel abundance indices extracted from opportunistically recorded acoustic data on board a bottom-trawl survey**

Jeroen van der Kooij, Sven Gastauer, Sascha M.M. Fässler, Beatriz O. Roel, and David Righton

Fisheries acoustic methodologies record continuous, high-resolution data of the water column. As acquisition of acoustic data is relatively autonomous, it can provide a valuable additional resource of information during expensive research surveys, irrespective of the main focus of the fieldwork. Here we present results of a case study which utilizes acoustic data, opportunistically recorded during the international bottom-trawl surveys (IBTS) in the North Sea, to extract information on the distribution and abundance of mackerel. Information about mackerel abundance and distribution in the North Sea is important because the spatial distribution of the stock and the fishery has changed in recent years. This has led to controversial changes in exploitation policy in more northern waters. In the absence of a dedicated North Sea mackerel survey at this time of year, we used a unique dataset of opportunistically recorded data. An algorithm based on the typical backscatter properties of mackerel was applied to a five-year time-series of multifrequency (38, 120, and 200 kHz) acoustic data collected during the IBTS across the North Sea. The acoustically derived information on the distribution and abundance of mackerel in the North Sea were combined with mackerel age and length data obtained from the routine bottom trawls to investigate the population dynamics. Patterns in mackerel dynamics over this five-year time-series were compared with those based on other sources, such as the triannual mackerel egg survey, to determine whether they were in agreement with each other and to assess whether routinely collected data could provide a supplementary in-year index. Our analysis has particular value because very few fisheries-independent data exist to describe mackerel distribution during the summer, yet scientific information is crucial to underpin management decisions.

Keywords: feeding, mackerel, North Sea.

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**ICES CM 2012/B:11**

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**Acoustic mapping of deep-water coral**

B. Ramiro Sanchez, F. McIntyre, F. Neat, and P. G. Fernandes

Little is known about the distribution of the deep-sea cold-water coral *Lophelia pertusa* in the Northeast Atlantic, although there are several closed areas which have been designated on the Rockall Plateau to protect this habitat and the species associated with it. Acoustic surveys have made it possible to locate and map more accurately areas with the occurrence of this species. In the Norwegian fjords and the west of Scotland, acoustic surveys using multibeam echosounders have been used in shallow waters to map *Lophelia*. In deeper water more specialized lower frequency multibeam sonar units are required, which are usually only available on the larger, more sophisticated research vessels. In this study we investigate the use of low-frequency single split-beam echosounders to detect *Lophelia*. These instruments are available on many fisheries and research vessels, and have the capacity to detect the seabed in deeper waters. We conducted an acoustic survey of the seabed in the closed areas on the Rockall Plateau in conjunction with a visual survey to groundtruth the acoustic characterization of coral habitat. Preliminary results from detections of deep-sea coral habitat are presented which make use of the phase information available from the split-beam echosounder, as well as the more traditional echo amplitude and envelope statistics.

Keywords: acoustic, coral, single split-beam echosounder.

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**ICES CM 2012/B:12**

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**Acoustic data from fishing vessels: what indicators can be obtained that research vessels cannot provide?**

François Gerlotto, Mariano Gutierrez, Erwan Josse, Anibal Aliaga, Jeremie Habasque, and Arnaud Bertrand

Large fisheries (e.g. jack mackerel in the South Pacific Ocean) are difficult to survey exhaustively through scientific surveys and the information obtained from the multiple international fisheries exploiting them are difficult to synthesize and do not always provide reliable indicators allowing correct ecosystem-based management. We propose to use direct acoustic information from fishing vessels, which is made possible nowadays because many vessels are equipped with professional echosounders similar to scientific echosounders. A study was done on the Peruvian fishery in March 2011 on a sample of acoustic data provided by the Jack mackerel fishers during the first trimester of 2011. Among the more than 150 000 data collected by the fishery we selected 25 trips made by vessels equipped with the most up-to-date echosounders, which represented 15 000 elementary distance sampling units of 0.5 nautical mile. Results showed that the acoustic information from fishing vessels is usable and could be obtained at very low cost from the fishery itself. The major findings were as follows: dimensions of fish school clusters and fishing vessels clusters were evaluated around 3 nautical miles diameter; as fishers applied an empirical density threshold below which fish was not considered exploitable, they concentrated their sampling effort on a third of the total fishing area; no clear relationship appeared between CPUE and acoustic density at small geographical scales, although a global correlation at the scale of a trip could be calculated. Finally, abundance estimates from scientific surveys could be dramatically improved when acoustic data from the fishing vessels were added.

Keywords: fisheries acoustics, fishing vessels, jack mackerel, South Pacific Ocean.

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**ICES CM 2012/B:13**

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**Assess spatial indicators from single-species acoustics estimates for ecosystem-based management: some possibilities from the eastern Mediterranean Sea**

M. Giannoulaki, A. Machias, P. Petitgas, M. M. Pirounaki, K. Tsagarakis, and M. Woillez

Spatial indicators based on acoustic surveys for anchovy and sardine, the two main target species in the Mediterranean, are used to describe species spatial distribution in relation to biomass variation. A series of spatial indicators (i.e. positive area, spreading area, equivalent area, inertia) was examined in two areas of the Aegean Sea (eastern Mediterranean) during summer (i.e. spawning period for anchovy and recruitment period for sardine). A significant relationship was found between the biomass and the spreading and equivalent area index for both species. In contrast to anchovy, sardine showed a highly aggregative behaviour in the study area, presenting biomass values that were not related to the positive area occupied by the population. Going a step further, the same relationship was examined using one-year lag difference in order to explore whether a spatial indicator could be used as an index to assess the status of the stock in the following year. Thus, during summer, which is the spawning period of anchovy, higher values of the equivalent and the spreading area, implying less heterogeneous distribution, can lead to lower biomass values in the next year. With regard to sardine, during the summer period—which largely coincides with the recruitment period of the species—the only significant relationship found was between inertia and the biomass of the next year. This denotes that higher inertia values and subsequently less aggregated population is likely to result in lower biomass in the following year. Thus the spatial behaviour of a population can be reflected in different spatial indices depending on the species and life stage.

Keywords: acoustics, anchovy, sardine, spatial indicators.

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**ICES CM 2012/B:14**

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**Extraction of zooplankton echoes in mixed aggregations**

Rolf J. Korneliussen, Egil Ona, and Hector Pena

When echoes from several organisms occur in the same acoustic pulse volume, as is the case in many fjord and oceanic layers, multifrequency analysis can seldom be directly used for target separation. A much stronger separator is sometimes needed for extrication of strong and weak targets. If a layer with zooplankton is contaminated by fish larva, small or large swimbladdered fish, the layer frequency response is always dominated by the strong scatterer, often disguising much more abundant zooplankton information. New thresholding and filtering methods enable a more accurate separation of the two dominating scatterers, enlivening the backscattering response from individual groups. New separator echograms may then further be used for standard single-target category abundance estimation.

Keywords: acoustics, mixed aggregations, zooplankton.

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**ICES CM 2012/B:16      Poster**

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**Oceanographic and physiological conditioning of the hydroacoustic survey results in the Canary upwelling region**

A. Sorokin, N. Barkova, N. Timoshenko, and G. Chernega

The hypothesis that acoustic biomass estimations in the Canary upwelling region are strongly dependent on oceanographic conditions was examined. Based on a long-term survey data, it was found that sardine shoals shifted northwards off the usual grounds in the years with positive temperature anomalies. The largest fish moved closer to the shore. Its availability for the survey as well as biomass assessment decreased. A contradicting growth of artisanal catches accompanied such situations, which is possible with high biomass levels. The areas around Cap Blanc abandoned by sardines became occupied by *Sardinella*, which in other years is stationed in shallow waters and is less available for surveys. Significant changes in individual weight which is determined by physiological condition affected biomass level of sardines. The relationship between those conditions and hydrological parameters was shown.

Keywords: availability for the survey, biomass, habitat conditions, indices, upwelling region.

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**ICES CM 2012/B:18      Withdrawn**

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**ICES CM 2012/B:19      Poster**

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**Density dependence in spatial behaviour of anchovy and sardine across Mediterranean systems**

M. Giannoulaki, P. Petitgas, M. Barra, P. Tugores, C. Vasapollo, M. Iglesias, I. Leonori, A. De Felice, A. Bonanno, G. Basilone, S. Mazzola, J. L. Bigot, A. Machias, and M. M. Pirounaki

A spatial indicator—the spreading area index—is used to describe anchovy and sardine spatial distribution in relation to biomass variation and to look for ecosystem differences within the Mediterranean basin. Specifically, the variation in the spreading area index in relation to biomass was examined for different areas of the Mediterranean Sea (i.e. Aegean Sea, western Adriatic Sea, Strait of Sicily, Gulf of Lion, and Spanish Mediterranean waters). In order to capture the spatial variability of the population at different levels of fish density, acoustic survey data for the years of highest, lowest, and intermediate abundance were used. In a subsequent step standardized values of spreading area and biomass were estimated to allow comparisons. Results showed pronounced area differences. A significant relationship was revealed in the case of anchovy for areas with extended continental shelf (i.e. Aegean Sea, Adriatic Sea, and Gulf of Lion), indicating an increase in biomass with an increase in the spreading area. No relationship was found for areas dominated by narrow continental shelf and strong currents (i.e. Spanish Mediterranean waters and the Strait of Sicily). With regard to sardine, an increase in biomass was followed by an increase in the spreading area when estimates from the Aegean Sea, the Adriatic Sea, and the Strait of Sicily were considered together. The relationship was even more

pronounced when analysis was limited to the Aegean Sea and the Strait of Sicily. No relationship was found for the Spanish Mediterranean waters and the Gulf of Lion. This clearly implies that spatial indicators should be integrated into ecosystem management, taking into account that they can be area- or ecosystem-dependent.

Keywords: anchovy, Mediterranean Sea, sardine, spreading area index.

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## Theme Session C

### Bycatch and discards: from improved knowledge to mitigation programmes

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#### ICES CM 2012/C:01

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##### **The effects of quota increases on discarding of common megrim (*Lepidorhombus whiffiagonis*) in the northern North Sea**

Angus Macdonald, C. H. Angus, and C. T. Marshall

The common megrim (*Lepidorhombus whiffiagonis*) is a commercially important, high-value flatfish species. It is occasionally targeted but more often a bycatch in the Scottish demersal trawl and seine fisheries in the northern North Sea. From the early 2000s discarding and high grading have been ubiquitous, primarily driven by what fishers have perceived as restrictive quotas. Market-driven discarding is also common as the soft flesh of megrim, which tends to bruise relatively easily in the trawl codend, reduces its commercial value. Since 2009, megrim quota in the northern North Sea has increased, primarily due to an increase in biomass reported from an annual fishery independent survey. In this study we compared megrim discard rates by Scottish trawl and seine vessels participating in the mixed demersal fishery in the northern North Sea prior to and following recent quota increases. Results indicate that discarding has reduced from an average of 56% of the total catch in 2009 to 11% in 2012. High grading and selectivity patterns evident prior to the quota increases have also changed significantly.

Keywords: common megrim, discards, high grading, *Lepidorhombus whiffiagonis*, North Sea, quota.

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#### ICES CM 2012/C:02

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##### **The impact of gear regulation changes on discard rates: the case of the Baltic Sea cod fishery**

Jordan Feekings, Niels Madsen, and Peter Lewy

Technical regulations have been introduced in almost all developed fisheries worldwide during the last 30 years. The main objective of these regulations has been to improve the state of the fishery or the stocks within by allowing juveniles and young individuals to escape. In the Baltic Sea, cod stocks have decline considerably over the past 30 years which has subsequently led to numerous legislations and policies being introduced to improving the state of the stocks. We evaluate whether the developments made to trawls used in the Baltic Sea cod fishery to improve selectivity and the increase in minimum landing size (MLS) have had any marked effect on the discard rates of the target species, cod. Results show that the gear regulation changes enforced in the Baltic demersal trawl fishery have had diverse effects on discard rates and are largely dependent on the gear, recruitment, and compliance by the fishermen.

Keywords: Baltic Sea, cod, demersal trawl, discards, MLS, selectivity.

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**ICES CM 2012/C:03**

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**Estimating discard mortality of flatfish using reflex impairment predictors**

Adam Barkley and Steve Cadrin

In many commercial fisheries, bycatch and discards contribute a large portion of the total catch, and in many cases are assumed to die upon release. Stock assessments for yellowtail and winter flounder currently assume 100% and 50% discard mortality from commercial fisheries, respectively. We estimated discard mortality rates of yellowtail and winter flounder for demersal fisheries off the coast of the US, using Reflex Action Mortality Predictors (RAMP). Predictive relationships between RAMP observations and long-term mortality were developed for each species through experimental holding studies. Once the RAMP–mortality relationships were established, discard mortality was estimated for various fisheries using direct observations aboard fishing vessels during normal fishing operations. The results indicate that the mortality rate of yellowtail flounder is approximately 85%, and discard mortality of winter flounder is approximately 36%, which are both significantly less than current assumptions. The estimates of discard mortality found in this study indicate that the current assumptions of discard mortality may be overestimated for both yellowtail and winter flounder, and revised discard mortality rate assumptions are expected to improve stock assessment and fishery management.

Keywords: bycatch, discard mortality rate, North Atlantic.

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**ICES CM 2012/C:04**

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**Mixed fisheries management: protecting the weakest link**

J. Batsleer, J. J. Poos, P. Marchal, Y. Vermard, and A. D. Rijnsdorp

The cod (*Gadus morhua*) stock in the eastern English Channel is still outside safe biological limits and single-species total allowable catch management has proved ineffective to rebuild the stock. The European Commission is considering imposing a discard ban partly to preserve vulnerable and economically important fish stocks. We explore the potential effects of a discard ban in mixed fisheries management using the French mixed fisheries in the eastern English Channel as a model system. The performance of two different management scenarios—traditional individual quota management that allow over-quota discarding and individual quota management in combination with a discard ban—is explored using a dynamic state variable model. The model evaluates a time-series of decisions taken by fishers to maximize profits within constraints set by management regulations. Compliance to management was tested by applying an in height varying fine for exceeding the quota. Consequences of individual quota for cod in both scenarios were studied. Individual quota management barely influences our fishers. Fishers fully exploit cod quota and continue fishing while discarding their over-quota catches. In contrast, individual quota management with a discard ban causes fishers to reallocate effort to areas and weeks when cod catch is low, at expenses of lower revenues. In general, a restrictive policy for individual quota for cod needs to be combined with a discard ban and a high fine in order to have large effects on fishing effort and net revenues.

Keywords: discard ban, dynamic state variable modelling, eastern English Channel, effort allocation.

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**ICES CM 2012/C:05**

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**The impact of catch quotas on a European fishing fleet: will they work?**

H. M. Condie, A. Grant, and T. L. Catchpole

Discarding of unwanted or unmandated catch wastes both food and economic resources, and represents a major source of unaccounted mortality, contributing to the overfishing of stocks. Under growing public and political concern, the European Commission is seeking to reduce unwanted catches and eliminate discarding by 2016. One proposed approach is to implement catch quotas, in which all catches are landed and counted against species-specific quotas. The impact of such a management tool on an entire fishing fleet has not been evaluated. We use detailed observer and logbook data to predict the potential impact of catch quotas on fishing mortality and total operating profits for the English North Sea otter trawler fleet. Fishing mortality should be reduced, but initial increases may be observed where the fleet discard rate is lower than the estimate used to derive the catch quotas. The economic impacts could vary substantially between vessel segments; larger whitefish trawlers are likely to see an increase in profits, while those of vessels under 10 m may fall. The economic benefit of using more selective gear to avoid low-value individuals and increase catches of marketable fish of the catch quota species is likely to be substantially offset by a loss of other marketable catch, indicating how fishing behaviour may or may not be altered under catch quotas.

Keywords: catch quotas, economic impact, fishing mortality, North Sea otter trawlers.

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**ICES CM 2012/C:06**

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**Socio-economic and institutional incentives influencing fishers' behaviour in relation to fishing practices and discards**

Søren Q. Eliassen, Nadia Papadopoulou, Vassiliki Vassilopoulou, and Tom Catchpole

Discards of unwanted catches are common in European fisheries. The proposal for reforming the Common Fisheries Policy by 2013 gives high priority to reducing or even banning discards. Various measures are already in use. However, there is no in-depth understanding of the incentives causing discards at the individual fisher level. In an attempt to improve our knowledge we have proposed a framework to understand the underlying socio-economic and institutional incentives influencing fishers' behaviour in relation to fishing practices and discard caused by three different drivers: the state (primarily the management system), market (demand and price formation), and community (norms and identities). The framework is applied on three case studies: the trawl fishery in northeast England, the nephrops trawl fishery in Kattegat (Denmark), and the Greek otter trawl fishery. The paper concludes with a qualitative comparison between the three cases and points to the various types of incentives influencing discard practices in trawl fisheries across the European Union.

Keywords: case study comparison, drivers for discards, institutional and socio-economic incentives.

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**ICES CM 2012/C:07**

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**UK cross-industry Discard Action Group (DAG) champions joined-up approach to tackling discards**

Mike Park

The Discard Action Group (DAG) was set up by the Sea Fish Industry Authority (Seafish) three years ago in the light of the many initiatives being adopted by the fishing industry to reduce discards. It is a prime example of an integrated, interdisciplinary, cooperative approach to the

issue, and is the only UK cross-industry group addressing the discards issue from all perspectives. The group is indicative of the whole seafood supply chain, with representatives from the catching sector, environmental non-governmental organizations, legislators, regulators, technologists, scientists, retailers, foodservice, and, where appropriate, the media. It is a key forum to allow individual interests to have a voice in the debate and to explore means by which discarding can be reduced to the minimum level practicable. Most importantly, by working to join up the dots in a highly complex area, it is also helping to accelerate the process of defining practical solutions. The DAG works in four key areas (selectivity, regulation, markets, and data collection) and has a clear remit to provide factual information on discards that is both accessible and understandable. It is helping each sector to understand the perspectives of others and build consensus on issues relating to discarding; it is helping to define and promote best practice in discard reduction; it has been, and continues to be, instrumental in looking for novel ways of incentivising the adoption of best practice; it informs its members and the wider community of new developments on a national basis, and to the highest level in Europe.

Keywords: DAG, Seafish, UK.

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## ICES CM 2012/C:08

### Characterizing the pressures and impacts of fisheries selectivity on marine communities by combining survey and commercial fisheries data

Laurence Fauconnet, Marie-Joëlle Rochet, and Verena Trenkel

To develop an ecosystem approach to fisheries management, indicators of the pressures and impacts of fishing on marine communities are required. Specifically, the selectivity of fisheries, defined as the ratio between what is caught and what is available, is thoroughly examined. Improving the selectivity of fisheries is considered as one of the main goals in current fisheries management to limit the impacts of fisheries. However, this concept has been recently reassessed and may not be suitable when considering fishery impacts on the whole marine community. The objectives of this study are to understand how the diversity of the harvest affects the diversity of the ecosystem and how a selective harvest affects marine communities compared to an unselective one. A variety of data sources can contribute to this. Data from the national onboard observer programme (2003–2011) have been used to characterize the pressures exerted by fisheries by providing catch composition by species and size for the whole catch, as well as data on the fishing métiers. Catch composition and length structures from French scientific survey data have been used to characterize the state of marine communities and were compared with commercial catches. The case study presented here is from the southern Bay of Biscay, where a southern area was considered "selective" in contrast to another one further north. Several metrics of selectivity were calculated for both data sources, by area and by gear and compared between the two areas to highlight systematic differences.

Keywords: Bay of Biscay, marine communities, onboard observer programmes, selectivity indicators.

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## ICES CM 2012/C:09

### Marine recreational fisheries in Europe—does only harvest matter?

Keno Ferter, Marc Simon Weltersbach, Jon Helge Vølstad, and Harry Vincent Strehlow

The potential impact of marine recreational fisheries on fish stocks has largely been neglected until recent years in Europe. While the landings of European commercial fisheries in marine ecosystems have been assessed over decades, there has been relatively little effort to estimate marine recreational fisheries catches. However, since 2009 the European Union has demanded that

Member States monitor the catches of stocks subject to recovery plans by recreational fisheries. To do this in a reliable and systematic manner, an ICES working group has been established to develop common survey methods across Member States. As recreational fisheries are often regulated through minimum landing sizes and bag limits, anglers often release part of their catch. The survival rates of these releases are generally unknown, but are probably less than 100%, and hence will cause bias in estimates of the fishing mortality based on landed catches only. Post-release mortalities can vary significantly by species, and depend on many factors, including water temperature, fishing depths, and handling time. To get an overview of the practice of catch-and-release (C&R) among marine recreational anglers in Europe, the existing knowledge on C&R and its potential associated release mortality was collected during a workshop of the ICES working group. This meta-analysis revealed that large proportions of the catch are released in several European marine recreational fisheries, and that post-mortality of released fish may need to be accounted for in the estimated fishing mortality.

Keywords: catch-and-release, European recreational fisheries, fishing mortality, post-release mortality.

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## ICES CM 2012/C:10

### Estimated bycatch of harbour porpoise (*Phocoena phocoena*) in two coastal gillnet fisheries in Norway, 2006–2008. Mitigation and implications for conservation

Arne Bjørge and Mette Skern-Mauritzen

Based on catch and bycatch data from 2006 to 2008 from a monitored segment of the fleet of coastal gillnetters targeting monkfish and cod, we used general additive models (GAMs) to model bycatch rates, with number of harbour porpoises entered as the response variable and catch by the fisheries entered as offset. Landings statistics of target species were used to extrapolate to entire fisheries. The two best models predicted the total number of porpoise bycatch to 20 719 and 20 989 porpoises, with CVs 36.05% and 27.33%, respectively. Thus, the models predict total annual bycatches of about 6900 porpoises in the two fisheries. The minimum fishing depths ranged from 5 to 200 m for cod and from 20 to 400 m for monkfish nets. In cod nets porpoise bycatch rate decreased rapidly with increasing depth from 5 m to 50 m and then levelled off. The bycatch rate decreased linearly with increasing depth throughout the depth range for monkfish nets. According to the criteria advised by ASCOBANS (bycatches should not exceed 1.7% of the best population estimate), a population in excess of 400 000 is required to sustain an annual bycatch of 6900 porpoises. One third of the Norwegian coast borders the North Sea where the abundance of porpoise is estimated at approximately 1/3 million. The abundance along the remaining Norwegian coast is not known. However, mitigation is required and our mitigation recommendations include the prohibition of large-mesh nets set shallower than 50 m. For large-mesh nets deeper than 50 m we recommend the use of acoustic deterrent devices (ADDs).

Keywords: bycatch, harbour porpoise, mitigation.

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## ICES CM 2012/C:11

### Inferring the drivers of discarding practices from observer data to identify appropriate fishery-specific solutions

Tom Catchpole, Marie-Joëlle Rochet, Niels Madsen, Natacha Nikolic, Andreas Palialexis, Teresa García, and Vassiliki Vassilopoulou

Discard patterns are affected initially by catch compositions, which are determined by environmental factors, the fishing gear used, and fishing tactics, and finally by fishers, when they decide which parts of the catch to retain. An understanding of the drivers of discard practices is essential in developing successful discard mitigation measures. A simple model is applied to

European observer data to infer the main causes of discarding by partitioning the discards into four categories based on the length at which the fish are discarded and principal legislative restrictions. These are: (i) fish below the legal minimum landing size (MLS); (ii) fish with no associated legal MLS that are below the minimum length landed (includes protected species and non-commercial species); (iii) fish with no associated quota that are above the MLS or minimum length landed; (iv) fish with associated quota that are above the MLS or minimum length landed. The model is applied to data from the full English observer programme and to French, Danish, Greek, and Spanish case study métiers. The proportionate contribution of the different categories is determined, the differences between métiers and areas established as well as any changes over time. The results are used to assess the most appropriate discard mitigation reduction strategies in each case, such as selectivity improvements, markets developments, and aligning fishing opportunities with quota availability.

Keywords: CFP, discards, minimum landing size, observer, quota.

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## ICES CM 2012/C:12

### A mitigation programme for reducing mortality caused by slipping in purse-seine fisheries

Bjørnar Isaksen, Jostein Saltskår, Bjørn Totland, Aud Vold, Jan Tore Øvredal, and Mike Breen

The release or “slipping” of schooling species such as mackerel (*Scomber scombrus*) and herring (*Clupea harengus*) in the later phases of hauling during purse-seine fishing may lead to unacceptably high rates of unobserved fishing mortality. Excessively large catches, as well as wrong species, size, and/or quality of the catch are the main reasons for slipping in these fisheries. As new national regulations put a ban on slipping at a late stage of pursuing, a mitigation programme has been launched in order to give the fishers tools to identify their target schools before shooting the net or at an early stage of seining, as well as to design seine nets that make early, rapid, and gentle release of fish possible. The programme focuses on three main areas of development: (i) acoustic instrumentation for improved pre-catch identification of fish schools (quantity, species, and fish size) to prevent catching unwanted fish; (ii) methods and equipment to estimate the catch volume, fish size, and quality at an early stage of pursuing while slipping is still acceptable; (iii) seines where fish could be slipped at an early stage of seining, without any significant mortality. While the purse-seine gears used today are built with the goal of maximizing catch, the new gears should be designed to minimize unnecessary stress, physical injury, or damage resulting in mortality.

Keywords: North Atlantic, purse-seine, mitigation, mortality

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## ICES CM 2012/C:13

### Double Dutch: implications of using both observer- and self-sampling techniques to quantify discards in the Netherlands

Sebastian S. Uhlmann, Aloysius T. M. van Helmond, Ronald A. Bol, and Rosemarie R. Nijman

The technique of commercial catch sampling by fishers (“self-sampling”) has been proposed as an alternative to traditional observer-based sampling of discards in meeting the needs of data-hungry stock assessments, seafood certification schemes, and management regulations. The planning and implementation of reliable procedures to control data collection and quality, however, can be a challenge. This study reviews the lessons learned from setting up a self-sampling programme within the requirements of the European Data Collection Framework (DCF) in the Netherlands. Since 2009, a preselected and initially growing number of commercial bottom-trawl fishers were asked to retain a fraction of their discards to complement an existing observer-based programme

under the DCF. This resulted in a >10-fold increase in the number of sampled trips, ultimately improving the spatio-temporal spread of sampling. However, despite this success and the improved collaboration between scientists and fishers, promoting the independent use of two different sampling techniques generated haul-, trip-, and fleet-level estimates of species-specific discard rates which precluded their evaluation by direct comparison. To better allow for this, in mid-2011, so called “matched trips” were introduced, where an observer sampled the same hauls as the crew member(s) on board a vessel participating in the Dutch DCF self-sampling programme. Detailed comparisons revealed (i) patterns among mean lengths of discarded fish at the sample, trip, and vessel level of self-samples, and (ii) differences in length-frequency distributions of several minimum-landing-size regulated fish discarded during matched trips. Nevertheless, the judgement call whether self-sampling is an appropriate technique within the context of sampling discards is yet to be made.

Keywords: collaboration, demersal fisheries, North Sea, participatory research, sustainable resource management.

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## ICES CM 2012/C:14

### Consequences of change in selectivity versus the establishment Marine Protected Areas on the hake–nephrops fishery in the Bay of Biscay

S. Méhault, S. Mahévas, and M. Bertignac

The mixed trawl fishery targeting nephrops (*Nephrops norvegicus*) and hake (*Merluccius merluccius*) in the Bay of Biscay is characterized by high discards rates. Although the fishing community has already made efforts to reduce these, development of more selective gears is still needed. Therefore, four innovative selective devices fitted to an experimental bottom trawl (square mesh cylinder, T90 codend, grid, and short selvedges) were tested on board a scientific vessel. The catches-at-length obtained with the selective gears were compared to those of a standard commercial trawl (twin-trawl configuration). The selectivity parameters of the gear used were based on both catch data collected on board commercial vessels and previous scientific experiments. We propose (i) to assess by simulation the consequences of change in selectivity on both stocks and fishing fleet dynamics and (ii) to compare the performance of such technical measures with the implementation of Marine Protected Areas (over two key zones of the hake lifecycle). We used ISIS-fish, a simulation tool describing the spatial dynamics of the fishery. The population model is structured by length for both hake and nephrops stocks and fishing mortality is parameterized in terms of effort and selectivity at length. Sensitivity analyses are carried out to provide conclusions robust to uncertainties.

Keywords: fleet dynamic, *Merluccius merluccius*, *Nephrops norvegicus*, technical measures, trawl selectivity.

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## ICES CM 2012/C:15

### Bycatch reduction devices: development, adoption, and implementation?

Christopher W. Glass, Stephen Eayrs, and Jamie M. Courneau

Despite a plethora of conservation engineering research initiatives over the past decade, bycatch and discarding continues to be a problem in fisheries in the northeast US and worldwide. While a number of successful bycatch-reduction devices have been developed and introduced into fisheries regulations, there are many more examples of devices or strategies that have been either unsuccessful or have not been adopted by fishers or managers. The reasons underlying lack of adoption are complex but may include factors such as reluctance of fishers to accept any loss of target catch, reticence of managers to change status quo, concerns regarding suitable enforcement

measures, and lack of clear, unequivocal, scientific evidence of the efficacy of the device or strategy. Here we provide examples illustrating where bycatch-reduction devices and/or strategies have been successfully introduced, examples where devices exist but have not been implemented, and others where devices and or strategies have been introduced and subsequently dropped from use. We include examples of, gear design and modification, discussion of bycatch-reduction strategies such as quantification of temporal and spatial distributions of fish and introduction of bycatch caps or quotas that create incentives to avoid bycatch. We discuss potential reasons for the apparent general lack of adoption of bycatch-reduction devices worldwide and make recommendations regarding mitigation measures and reduction programmes that could be used to address this issue.

Keywords: bycatch reduction, discard, northeast US.

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## ICES CM 2012/C:16      **Withdrawn**

## ICES CM 2012/C:17

### **Bycatch and discards: from improved knowledge to mitigation programmes. Evaluating success of bycatch-mitigation measures**

Catherine E. O'Keefe, Steven X. Cadrin, and Kevin D. E. Stokesbury

Designing effective bycatch-mitigation programmes requires an understanding of the life histories of target and non-target species, interactions of fish and fishing gear, effects of spatial and temporal shifts in fishing effort, socio-economic impacts to the fishery, and incentives of fishery participants. The effects of mitigation measures (including fishing gear modification, time/area closures, bycatch quotas and caps, incentive programmes, and fleet communication programmes) have been extensively evaluated globally with respect to reducing bycatch and discards. Less attention has been focused on evaluating unanticipated results related to shifts in fishing effort, changes in catch-at-size of non-target species, reduced catch of target species and socio-economic costs to fishing fleets. We review mitigation measures to evaluate overall effectiveness in reducing bycatch without causing unintended biological and socio-economic impacts. Our results suggest that wide-ranging studies of species' life histories, potential changes in fleet behaviour, and individual incentives are important for developing and implementing mitigation programmes. Combining mitigation techniques, such as gear modifications paired with fleet communications, has been successful in meeting biological and socio-economic fisheries goals. In addition, collaborative programmes that utilize the skill sets of fishers, scientists, and managers have been more effective in meeting bycatch-reduction objectives.

Keywords: bycatch mitigation, fishing fleet behaviour, incentive programmes.

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## ICES CM 2012/C:18

### **Ecosystem-based management and the discard ban: reforming the Common Fisheries Policy**

Richard Curtin and Raúl Pallezo

This paper seeks to analyse whether the proposed discard ban by the European Union in the upcoming reform of the Common Fisheries Policy will help to achieve ecosystem-based management objectives. From investigating the causes of discarding, the role of incentives has been widely acknowledged as being of fundamental importance. This paper analyses the new incentives that will be created by the discard ban in Europe. Among other effects, discard bans have been

known to encourage behavioural changes in the exploitation of areas and seasons of high bycatch. However, the uncertainty related to the beneficial ecosystem effects of increased selectivity has been increasing in the literature. How these incentives interact with and alter the traditional incentives at work in fisheries will be investigated, with the focus of the study on their effects on the achievement of ecosystem-based management objectives.

Keywords: discard ban, ecosystem-based management, Europe, incentives.

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## ICES CM 2012/C:19 Withdrawn

## ICES CM 2012/C:20 Poster

### Can groundgear modifications minimize bycatch of flatfish in the New England trawl fishery?

Sally Roman, Steve Cadrin, and Pingguo He

The groundfish fishery in the New England region of the Northwest Atlantic has transitioned to a catch-share management system with annual catch limits for regulated groundfish. Within this management scheme, the ability to reduce bycatch of sublegal and non-retention flatfish could allow for optimization of catch allocations while promoting sustainable fishing practices. A modified groundgear with “escape windows” was tested during two separate projects to examine if the catch of American plaice (*Hippoglossoides platessoides*) and winter flounder (*Pseudopleuronectes americanus*) could be reduced. The objective of the first project was to reduce the catch of sublegal American plaice while maintaining commercial catches of legal plaice; that of the second project was to minimize the catch of winter flounder, a non-retention stock, while retaining Atlantic cod. Comparative fishing sea trials were conducted on board commercial otter trawl vessels in March 2011 and April 2012. Dimensions of the “escape windows” differed between the projects based on the varying project objectives. Results indicated that the window sizes tested to reduce the catch of sublegal American plaice were ineffective, and the use of the groundgear in conjunction with a large-mesh panel resulted in a significant loss of Atlantic cod. Modified escape windows without a large-mesh panel showed a reduction in the catch of the flatfish and juvenile Atlantic cod while maintaining catch rates of legal-sized cod. Continued research is warranted to refine groundgear modifications for effective bycatch reduction.

Keywords: bycatch, discards, technical mitigation measure.

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## ICES CM 2012/C:21

### Quantifying and reducing river herring bycatch in the US northwest pelagic trawl fisheries

N. David Bethoney, Bradley Schondelmeier, Kevin Stokesbury, and William Hoffman

Midwater trawling, the primary method of harvesting Atlantic herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) in the US, can capture hundreds of tons of fish in a single tow. Vessels using this fishing gear are efficient but have the potential to catch large amounts of non-target species that are difficult to quantify. Decreases in the number of anadromous river herring (*Alosa pseudoharengus*, *A. aestivalis*) and American shad (*A. sapidissima*) returning to spawn has led to speculation that these fish are incidentally caught in large numbers by midwater trawl vessels. Although the role of bycatch in the decline of river herring and American shad is unclear, midwater and bottom-trawl Atlantic herring and mackerel fishers collaborated with the University of Massachusetts Dartmouth School of Marine Science and Technology and the Massachusetts



Division of Marine Fisheries to quantify and minimize bycatch. This collaborative project increased portside sampling of vessels landing in Massachusetts and Rhode Island from  $\leq 15\%$  to 50% and created a near real-time communication system to notify vessels of areas with high bycatch. Portside sampling is an efficient, cost-effective method to estimate catch of river herring and American shad, which are pumped aboard vessels with targeted catch. Industry cooperation and the appearance of small-scale spatial and temporal bycatch patterns suggest rapid communication may be effective for reducing bycatch. As managers of the Atlantic herring and mackerel fisheries consider adding regulations to reduce bycatch, this project provides fishers with a tool to achieve this goal without increased regulation.

Keywords: bycatch, collaborative research, Northwest Atlantic.

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## ICES CM 2012/C:22      Poster

### Precision in estimates of marine species bycatch: the case of tuna purse-seine fisheries of the Indian Ocean

Justin Monin Amandè, Emmanuel Chassot, Pierre Chavance, Hilario Murua, Alicia Delgado De Molina, Martin Hall, and Nicolas Bez

Estimating bycatch (i.e. the incidental catches of non-target marine animals and undersized individuals of target species) by extrapolating observer data to the whole fishery is routine practice. However, some important issues such as precision and accuracy in bycatch estimates are often ignored, as observer programmes are established for political, compliance, or certification aims. An analysis of variability in the precision of estimates based on generalized linear models and Monte-Carlo simulations showed that the current sampling coverage of the European tropical tuna purse-seine fishery observer programme, that is 4.6% of fishing trips, resulted in large uncertainties around bycatch estimates by species (none of the estimates get a relative root mean square error smaller than 50%). Although the overall magnitude of bycatch for the fishery appeared to be small, the current sampling coverage was insufficient to give any reliable estimate for low-occurring species such as marine turtles, some oceanic pelagic sharks, and some billfish. Increasing the sampling coverage would certainly improve bycatch estimates. Meanwhile the cost of the sampling increases linearly so that there is an optimal sampling coverage where the costs induced by the increase of the sampling coverage are balanced by the gains in precision. However, this optimum is dependent on the value (in euros) associated with the precision of the estimates. Simulation outputs were produced to define trade-offs between the species to be monitored in priority, the estimation precision and accuracy expected, and the associated sampling costs.

Keywords: bycatch, fishery observer programme, precision, purse-seine, tropical tuna.

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## ICES CM 2012/C:23      Poster

### Spatial and temporal variability of discards indicators and fishery factors affecting the otter trawl fishery in the Spanish Mediterranean Sea

A. Carbonell, A. Mir, T. García, X. Valeiras, V. Rubio, E. Olafsson, M. Gonzalez, B. Guijarro, N. Pérez, and J. M. Bellido

A set of diversity indices were studied from data of observers on board two Mediterranean trawlers from 2001 to 2009. These diversity indices comprise relationships between total catch, landing and discard fractions to explore the accuracy of the estimates and to analyse the series trends using different methods, such as ARIMA. The hypothesis tested was that diversity indicators give a good representation of the changes produced in impacted bottom-trawl areas,

providing a reasonable fit of the data. ARIMA models are useful because they handle time-correlated modelling and forecasting. These techniques can also reveal changes in total catch as well changes in catch composition, probably induced by changes in effort fishery, seasonal (time) fluctuations, and environmental or climatic processes. Contrasted trends were also compared with survey data by MEDITS Mediterranean trawl survey time-series indicators.

Keywords: bycatch, discards, Mediterranean trawl Spanish fisheries, state indicators.

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## ICES CM 2012/C:24      Poster

### Evaluation of the impact of pulse fishery on a selection of North Sea fish and invertebrates

Marieke Desender, Maarten Soetaert, Bart Verschueren, Hans Polet, Koen Chiers, and Annemie Decostere

Demersal trawl fisheries are known to produce large amounts of discards and to disturb the seafloor habitat of benthic organisms. In order to increase the sustainability of these fisheries, technical adaptations are necessary to avoid these problems. Electric pulse fields have proven to be the most promising option for alternative stimulation in fishing gear, replacing the mechanical stimulation. Since 2008 the Belgian ILVO research institute has been successfully testing their Hovercran electropulse trawl for brown shrimp fishery. In this device the bobbin rope is replaced by lightweight electrodes, creating a low-intensity electric field which selectively induces a startle response in the shrimps. Other benthic organisms are left untouched and can escape underneath the hovering trawl, which collects the jumping shrimps without disturbing the seabed. Nevertheless, the effects of such an electric pulse field on marine organisms are largely unknown. Preliminary exposure and survival experiments indicated that the use of this low-frequency pulse has no immediate significant effects on most adult fish and invertebrate species. However, electrosensitive fish, such as sharks and rays, and polychaete species were not included in these studies. In addition, the influence on different life stages has never before been investigated; electrofishing over active spawning grounds may affect the survival of embryos, larvae, or juveniles if exposed during their more sensitive stages. To re-evaluate the standing ban on electric fishing in Europe, recent research has been focused on filling these gaps in knowledge and determining safety margins, enabling further development of and legislation on pulse fisheries.

Keywords: impact, North Sea, pulsed direct current, pulse fishing.

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## ICES CM 2012/C:25      Poster

### Pressure indicators describing bycatch and discards in selected Spanish fisheries

M. Mendoza, J. Valeiras, T. Garcia, N. Pérez, S. Mallol, A. Carbonell, R. Goñi, and José M. Bellido

Discard data from onboard sampling were analysed to study spatial distribution and abundance of species in relation to fishing variables. A multivariate analysis on abundance data was performed to characterize discard patterns. Nine species account for 62% of total discards by the Spanish otter trawl fishery targeting megrims (*Lepidorhombus* spp.) and anglerfish (*Lophius* spp.) in western Ireland. The most discarded species were of three species: a non-commercial sea anemone (*Actinauge richardi*), boardfish (*Capros aper*), and Atlantic horse mackerel (*Trachurus trachurus*), which have a discard ratio of 100% of the capture. The fourth group of discarded species—starfish and sea cucumbers (Echinodermata)—are also entirely discarded. Other important discarded species have ratios ranging from 26 to 100%: the small-spotted catshark (*Scyliorhinus canicula*), megrim (*Lepidorhombus whiffiagonis*), blue whiting (*Micromesistius poutassou*), mackerel (*Scomber scombrus*), and haddock (*Melanogrammus aeglefinus*). Hake (*Merluccius merluccius*) and ten other

low-value or non-commercial species comprise slightly more than 1% of the total discard. The spatial distribution and seasonal abundance show differences for several species related to species ecology and fishing patterns. Indicators play a key role in gauging the exploitation and state of marine ecosystems and they are required for an understanding of the effects of fishing on marine ecosystems and to address ecosystem approach to fisheries (EAF) objectives. In this work we present pressure indicators describing catch and discards as well as state indicators describing the ecosystem or fish community. Several key indicators have been calculated from discard data: métier catch mean size, métier discard mean size, métier discard rate, minimum mesh size/minimum landing size (MMS/MLS), relative landing diversity (Simpson landings/discards), and threatened species relative abundance.

Keywords: bycatch, discard, indicators, trawl fishery.

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## ICES CM 2012/C:26      Poster

### Review of existing knowledge on fishery discards in the Mediterranean Sea

K. Tsagarakis, A. Palialexis, and V. Vassilopoulou

Bycatch and discarding have been acknowledged globally as important issues for fisheries management, their mitigation being a major concern to governments, conservation bodies, and the wider public. In this study a considerable amount of the existing information concerning discards quantities and practices in the Mediterranean Sea was collected, highlighting the extended spatio-temporal gaps, particularly at the métier level. The majority of the studies took place in the northern Mediterranean, and concerned bottom trawling. Among fishing practices, bottom-trawl fisheries, especially those targeting deep-water shrimps, were characterized by the highest discards ratios. Midwater trawling presented lower discard rates, and even lower rates have been reported for purse-seiners, with both fisheries sharing the same target species (small pelagic fish). Artisanal fisheries are usually characterized by low discards (<10%). It should be noted, however, that despite the low discards ratios of purse-seiners and artisanal fisheries, these practices still produce considerable amounts of discards since they are responsible for the bulk of the catches in the Mediterranean. Discarded quantities have been related to bottom depth, fishing duration, and the availability of fishery resources as a result of the exerted fishing pressure. The multispecies nature of most Mediterranean fisheries seems to affect discarding since depending on the composition of the catch and the respective value of the different components it gives fishers the incentive to highgrade low-value species. Regional differences, with generally lower discard rates in southeastern Mediterranean countries, were established and seemed to be related to cultural traits.

Keywords: bycatch, discards, Mediterranean Sea, observer programmes.

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## ICES CM 2012/C:27      Poster

### Potential role of blue whiting exploitation patterns in the success of improving hake selectivity in Spanish Atlantic coastal OTB mixed fisheries

Juan Santos, Itxaso Salinas, Francisco Velasco, and Nélida Pérez

Increasing minimum mesh size (MMS) to match codend  $L_{50}$  to species minimum landing size (MLS) can be seen as a straightforward solution to reduce juvenile mortality, but this strategy may yield short-term economical losses in multispecies fisheries as a result of catch reductions of others target species with lower MLS. The alternative of species selection approach may also fail when escape behaviour information to drive species to specific selectivity devices is unknown. Large quantities of hake (*Merluccius merluccius*) below MLS (27 cm) are still caught and subsequently discarded in Spanish North Atlantic (ICES VIIIc, IXa) otter bottom-trawl (OTB) mixed fisheries, suggesting that an improvement of hake selectivity is needed to reduce juvenile mortality. Blue

whiting (*Micromesistius poutassou*) is a mesopelagic commercial species also presented in OTB mixed-catch profiles. Its low MLS (15 cm) and close biological and ecological relation to hake makes it a paradigm of the selectivity challenges faced by mixed fisheries. A descriptive analysis found high variability in the blue whiting onboard retention rate, suggesting lower commercial interest than hake in this métier. This study explores the underlying factors conditioning blue whiting retention/discarding probability in OTB mixed fisheries, and simulates different scenarios, varying this species retention probability as an expression of its relative value for crews. Identifying scenarios that minimize blue whiting as a target interest for OTB mixed fisheries can be a useful tool for envisaging optimal conditions that promote commercial adoption of new technical measures aiming to reduce discards of juvenile hake.

Keywords: blue whiting, discards, hake, OTB mixed, selectivity.

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**ICES CM 2012/C:28      Withdrawn**

**ICES CM 2012/C:29      Poster**

**A new method for estimating net volume during purse-seine fishing—towards improved guidelines for slipping operations**

Maria Tenningen and Héctor Peña

In purse-seine fisheries slipping appears to be commonly practised to release unwanted catches. There is currently a need to regulate slipping so that the slipped fish survive. One alternative is to determine a “point of no return” after which slipping is no longer allowed, but to optimize this value, continuous information is needed on both the fishing gear and school densities while hauling the net. This information is currently lacking. The aim of this study was to examine the use of omnidirectional fishery sonar combined with accurate acoustic underwater positioning system (HiPAP) to study purse-seine volume and shape during commercial fishing. Data were collected during the Northeast Atlantic mackerel fishery in 2011 and used to reconstruct the three-dimensional shape of the net and to estimate its volume. It was assumed that purse-seine volume is the main factor determining the density within the school. The preliminary estimates of the net volume indicate that critically high fish densities should not occur before a relatively late phase of the hauling process of the net. The results also suggest that with some further development this method should be a very useful tool for observing the purse-seine while fishing, with potential for developing a system that provides real-time information about the net performance. Such a system would be useful both for the authorities regulating slipping practices and for the fishers to improve capture efficiency.

Keywords: fishery sonar, HiPAP, Northeast Atlantic, purse-seine.

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**ICES CM 2012/C:30      Poster**

**Comparison of fishing-induced stress response and post-release mortality between sandbar (*Carcharhinus plumbeus*) and dusky (*Carcharhinus obscurus*) sharks (Family Carcharhinidae)**

H. Marshall, R. Brill, P. Bushnell, G. Skomal, and D. Bernal

In recent years, exploitation of many shark species has incited management organizations to revise commercial fisheries management plans (FMPs) with the hopes of conserving shark populations. Specifically, in the western Atlantic, amendments to the Consolidated Highly Migratory Species FMP demand the post-capture release of several coastal species, including the sandbar

(*Carcharhinus plumbeus*) and dusky (*C. obscurus*) sharks (Family Carcharhinidae). Although these FMPs are designed to conserve populations, they result in an increased number of sandbar and dusky sharks being released after capture. Research on fishing-related stress indicates that the survival of released fish after capture is not well understood. This study investigates stress response in sandbar and dusky sharks after longline capture, and subsequent post-release mortality. Pop-up satellite archival tags were used to determine post-release survival of sharks after capture on longline gear, and blood stress parameters (electrolytes and metabolites) were collected from each fish. Post-release mortality appears to occur more often, after shorter capture times, in the dusky versus the sandbar shark. In addition, at-vessel mortality occurs after ~3 hours on the longline in the dusky shark. Regression analysis reveals a significant ( $p < 0.05$ ) correlation of increasing levels of sodium, potassium, glucose, and lactate with soak time in the dusky shark, whereas the sandbar shark did not show any correlation. Physiology of the dusky shark seems greatly affected by capture, relative to sandbar sharks, resulting in higher rates of at-vessel and post-release mortality.

Keywords: elasmobranch, fishery, physiology, survival.

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#### ICES CM 2012/C:31     Poster

##### A wasted resource: cod discards in the North Sea

Jordan Feekings, Jan Jaap Poos, Geert Aarts, Niels Madsen, Edwin van Helmond, Tom Catchpole, Marie-Joelle Rochet, Alastair Pout, Jens Ulleweit, Sofie Vandemaele, and Clara Ulrich

The public, political, and stakeholder perception of fisheries discards is that they are a waste of a valuable resource. In the North Sea, fisheries discards are some of the highest in the world. Cod (*Gadus morhua*) has contributed considerably to the amount discarded. The declining cod stock within the North Sea has resulted in changes in technical measures, effort restrictions, closed areas, and the establishment of a recovery programme for cod; all which have attempted to reduce the amount discarded. Here, we combine European Union discard data from seven Member States to describe the trends, spatially and temporally, in discarding over the past decade while pinpointing the major reasons to why it occurs. We discuss how such information can be used to improve future fishing activities and their subsequent catch compositions under a discard ban.

Keywords: none

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#### ICES CM 2012/C:32     Withdrawn

#### ICES CM 2012/C:33

##### Gear Solutions to Minimize Discards in the Gulf of Maine Shrimp Trawls: A Decade of Research to Reduce Finfish Bycatch and Small Shrimps

Pingguo He

The Nordmøre Grid may be one of the most successful fishing gear devices for reducing fish bycatch in trawls targeting northern shrimp *Pandalus borealis*. However, Nordmøre Grid cannot eliminate small finfish and small shrimps that can pass through the 25 mm spacing currently regulated in the northeastern US. During the last decade, the author and his colleagues conducted several gear-related research projects to further reduce finfish bycatch and small shrimps. The new Rope Grid

reduced finfish bycatch by 36-50% without loss of targeted shrimps. The topless shrimp trawl with a cutback headline reduced Atlantic herring bycatch by 87% and with modest increase in shrimp catch (14%). Simply replacing regular steel bridles with floating synthetic bridles reduced flounder bycatch by about 20%. The new size-sorting grid installed in front the Nordmøre grid reduced small shrimps below 22 mm carapace length without lost of large shrimps 23 mm and larger. However, the installation of water-borne kites to expend codend meshes did not reduce small shrimp or finfish bycatch. This paper will review and summarize these projects and provide fishing technologists, fishery managers and fishing industry the state of art in gear design and modification available for the Gulf of Maine shrimp trawl fishery. Discussions will also be made on possible applications of these designs in other shrimp and prawn fisheries around the world.

Keywords: trawl, northern shrimp, discard, USA

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### ICES CM 2012/C:34

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#### **Magnitude and causes of mortality of Atlantic herring (*Clupea harengus*) induced by crowding in purse seines**

Aud Vold, Bjørnar Isaksen, Ragnhild Svalheim, Maria Tenningen, Rolf-Erik Olsen, and Mike Breen

Releasing, or "slipping" all or part of a catch has traditionally been used as a method for catch regulation in purse seine fisheries. During the last decade it has been documented that the mortality of fish crowded to densities experienced in the later phases of purse seine fishing may be substantial. To study the effects of crowding on Atlantic herring (*Clupea harengus*), large scale field experiments were carried out off the Norwegian coast between 2008 and 2012. These were conducted under conditions comparable to those experienced under commercial fishing. Eight different experiments involving one control group and two or three test groups that were crowded to different densities were made. The mortality observed in each experiment was directly correlated with crowding density, although the level of mortality varied somewhat between experiments. Crowding densities below 150 kg m<sup>-3</sup> did not result in any additional mortality compared to the control groups, while the mortality after hard crowding (>400 kg m<sup>-3</sup>) exceeded 50 %. The mortality was size and condition related, where smaller herring and herring with a lower condition factor were more vulnerable. Oxygen starvation, scale loss and/or energy depletion are possible explanatory variables for the observed mortality. Quantification of scale loss indicated that this factor alone could not account for the observed mortality. Blood parameter analyses showed that herring experienced elevated levels of stress and were approaching physiological exhaustion.

Keywords: Norwegian Sea, mortality, purse seine, herring.

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## Theme Session D

### Joint ICES/AOSB Session—The role of the Arctic and Subarctic in a climate change perspective

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#### ICES CM 2012/D:01

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##### **The long-term variation of global and Arctic temperatures. Are they predictable?**

L. B. Klyashtorin and V. M. Borisov

Heightened interest in changes in the Arctic temperature regime is justified by its established role in influencing the climate of the whole northern hemisphere, but also in recent years in connection with development of the northern sea route from Europe to Asia and offshore oil and gas fields. Temperature anomalies ( $dT$ ) of both global and Arctic indices undergo some 60-year synchronous fluctuations. It should be emphasized that while global  $dT$  shows a clear age-long ascending trend, the Arctic  $dT$  is subject to 60-year quasi-periodic fluctuations but without a visible ascending trend. The multi-year dynamics of the most important ocean surface temperature indices in the North Atlantic (AMO) and North Pacific (PDO) sectors show a roughly 60-year periodicity and descending trend after the 2000s. Some recent models of climate change, including those based on solar activity dynamics, also predict a probable decrease in the Arctic  $dT$  in the early twenty-first century. An empiric forecast by the Arctic and Antarctic Institute (AARI, S. Petersburg, Russia), based on time-series from 100-year observations, suggests that the Arctic  $dT$  will probably decrease in the next 10–20 years. The authors discuss probable trends in the Arctic climate and possible variation in the sea ice area, taking into account its historically proven 8–10 years delay in relation to air and sea temperature dynamics in the region. Given this prospect, the probable effects on commercial fish populations in the Arctic region are considered.

Keywords: Arctic, climate, fish populations, temperature anomalies.

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#### ICES CM 2012/D:02

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##### **The role of the Barents Sea in the climate system**

R. B. Ingvaldsen, L. H. Smedsrud, I. Esau, V. Lien, V. Semenov, A. Omar, B. Risebrobakken, A. B. Sando, S. Sorokina, T. Eldevik, H. Haugan, O. H. Otterå, V. Li, and A. Olsen

Global warming is amplified in the Arctic and accompanied by unprecedented sea ice decline. Located at the major pathway of Atlantic Water entering the Arctic, the Barents Sea is important in the decadal scale Arctic and northern hemisphere climate variability. The atmosphere steadily cools the warm Atlantic inflow to the Barents Sea through intense heat exchange, and coupled feedback processes operate in the air–ice–ocean system. Warm periods, like today, have a high northward heat transport, a small Arctic Sea ice cover, and high surface air temperatures. The cooling of the Atlantic inflow creates dense water sinking to great depths in the Arctic basins, and two-thirds of the Arctic Ocean carbon uptake is removed from the carbon-saturated surface this way. High ocean heat transport has recently decreased the Barents Sea winter ice cover, a strong contributor to recent winter Arctic sea ice loss. The heating of the Barents atmosphere plays a role in the “Arctic amplification” and is important in the Arctic seasonal heat budget. The heating also perturbs the large-scale circulation through expansion of the Siberian High northwards, with a possible link to recent continental winter-time cooling. During the last 2500 years the air–ice–ocean variability was larger than that observed today. However, the Barents Sea is projected to be largely

ice-free throughout the year by 2050, with a 4°C summer warming in the formerly ice-covered areas.

Keywords: Arctic, Barents Sea, climate variability, feedback cycles.

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### ICES CM 2012/D:03

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#### Variability, forcing, and fate of the inflow of Atlantic Water to the North Icelandic Shelf

Steingrímur Jónsson and Héðinn Valdimarsson

The North Icelandic Shelf is an area that shows highly variable hydrographic properties. This variability to some extent determines the productivity and the living conditions on the shelf north of Iceland. To determine the flow along the shelf, the Marine Research Institute has been monitoring the flow with current meters on a section north of Iceland since 1994. Up to 2010 the flow consisted on average of 68% of Atlantic Water with its transport being 0.88 Sv and associated heat transport estimated to be 24 TW. Since 1994 there has been a positive trend in both the transport of Atlantic Water and the heat transport. The increase in the heat transport is mainly caused by an increase in the temperature of the Atlantic Water. The variability of both the transport and the water mass composition of the current are closely correlated with the National Centers for Environmental Prediction (NCEP) wind data over the area. The transport responds very quickly to changes in the wind whereas the water mass composition takes longer to adjust. Thus the local wind is a primary force driving at least the shorter term variability of the two parameters. However the direct wind forcing does not explain the mean flow of Atlantic Water to the North Icelandic Shelf. Some of the Atlantic Water is deflected into the deeper parts of the Iceland Sea along the Kolbeinsey Ridge. Some of this water recirculates back to the west whereas the rest becomes entrained into an anticyclonic gyre east of the ridge.

Keywords: Atlantic Water, circulation, Iceland, North Icelandic Irminger Current.

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### ICES CM 2012/D:04

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#### Submarine estimates of Arctic turbulence spectra—SEATS

Charlotte Marcinko, John Allen, Adrian Martin, Garry Dawson, Tim Clarke, and Yvonne Mather

The Arctic is undergoing rapid climatic change. Currently ice cover over the Arctic isolates much of the water column from the atmosphere and prevents direct wind forcing on the upper ocean. Future ice retreat will expose more of the upper water column to direct atmospheric forcing for longer periods throughout the year. Increased atmospheric forcing has the potential to significantly change the properties and dynamics of the Arctic Ocean and its circulation. It is important to fully understand current conditions in ice-covered and marginal ice regions to predict future changes in physical processes and feedbacks brought about by these rapid changes in climate. Historically, it has been difficult to study the physics of the ocean beneath permanent or seasonal ice cover, although recent instrument developments have begun a sparse database of observations. The Submarine Estimates of Arctic Turbulence Spectra (SEATS) is a new project which aims to use previously unavailable data from UK submarine missions to assess the characteristics of mixed layer and sub-mixed layer variability in marginal, permanent, and seasonally ice-covered regions. Here we introduce the project and present the first preliminary results demonstrating the variability spectra of physical parameters within the Arctic Ocean.

Keywords: Arctic, spectra, turbulence.

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**ICES CM 2012/D:05**

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**A mechanism for fluctuations between Atlantic inflow branches to the Arctic**

Vidar S. Lien, Frode B. Vikebø, and Øystein Skagseth

Atlantic Water inflow to the Barents Sea ensures a steady flow of heat, nutrients, and plankton to one of the most productive shelf seas of the world. We utilized direct current measurements and a numerical ocean model to quantify the mean and variability of the flow pattern on the northern slope of the Barents Sea opening, and discuss the results in terms of climatology and ecology. We found that a dominating westward flow is interrupted by transient flow reversals following a reduction of the downstream sea surface height through Ekman transport off the northern Barents Sea shelf, caused by a northward shift of the storm tracks. The subsequent cross-slope sea surface height gradient induces a compensating barotropic current, which advects more heat into the Barents Sea, where it is lost to the atmosphere, leaving less heat to enter the Arctic Ocean through the Fram Strait, where it effectively gets insulated by the cold halocline. Furthermore, the heat is made readily available to melt sea ice, a key process in the marginal ice zone ecosystem dynamics.

Keywords: Arctic, Atlantic inflow, Barents Sea.

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**ICES CM 2012/D:06**

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**Changes in the properties and distribution of the intermediate and deep waters in the Fram Strait**

Helene R. Langehaug and Eva Falck

The Fram Strait is the only deep connection between the Arctic Ocean and the Nordic Seas, with a sill depth of approximately 2600 m. Consequently, observations from this area reflect changes in the deep waters of the Arctic Mediterranean. Possible changes in the properties and distribution of the intermediate and deep-water masses passing through the Fram Strait have been studied for the period 1982–2008 at a zonal section at 79°N, with special emphasis on the period from 1997 to 2008. The temperature of the Arctic Intermediate Water shows large interannual variability, with the period from 2002 to 2004 being especially cold, indicating a strong winter convection in the Nordic Seas prior to those years. The deep water originating from the Norwegian Sea has become warmer (by about 0.10°C) during the study period. The changes in the properties of the Norwegian Sea Deep Water are caused by changes in its composition (i.e. an increasing fraction of the Eurasian Basin Deep Water and a decreasing fraction of the Greenland Sea Deep Water). A prominent feature seen in the  $\Theta S$ -diagrams from the deep Fram Strait is the disappearance of water with the characteristics of Greenland Sea Deep Water. This very cold water (temperature below  $-1.1^\circ\text{C}$ ) was not observed after 1997, and the minimum temperature in the strait increased by 0.24°C between 1982 and 2008. In the Fram Strait the fraction of intermediate waters has increased, while the fraction of deep waters from the Nordic Seas has decreased.

Keywords: Fram Strait, interannual variability, intermediate and deep water masses.

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**ICES CM 2012/D:07**

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**Topographically controlled flow on the West Spitsbergen Shelf with special emphasis on the Atlantic Water transport towards Isfjorden**

Frank Nilsen, Juni Vaardal-Lunde, and Ragnheid Skogseth

A single-layer numerical model is developed that demonstrates how the Atlantic Water (AW) from the West Spitsbergen Current (WSC) is topographically steered onto the West Spitsbergen Shelf (WSS) with a special emphasis on the Isfjorden Trough. Model results show that the WSC connects more easily to the Isfjorden Trough than anywhere else on the shelf, exposing the trough to warm

and salty AW. The simple one-layer barotropic model gives a good approximation of the dynamic processes on the WSS that play a significant role in the cooling process of the WSC on its way towards the Arctic Ocean. The intrusion of Atlantic Water on Arctic shelves and into fjord systems also represents a transition from Arctic-type water masses to Atlantic-type water masses, and a complete change in the biomass and species composition. Estimates of oceanic heat transport on the shelf and towards fjord systems are presented, which has the potential to increase the melt rate of glaciers and has been identified as a likely mechanism leading to the acceleration, thinning, and retreat of glaciers.

Keywords: Arctic Shelf, Atlantic Water intrusion, barotropic circulation model, heat transport.

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## ICEC CM 2012/D:08

### Downscaling IPCC models using the Regional Ocean Modeling system (ROMS) with focus on the Barents Sea

A. B. Sandø, A. Melsom, and W. P. Budgell

The gain of downscaling ocean components of two global coupled climate models has been evaluated in terms of hydrography in the Barents Sea, and heat and volume transports. The global models used were the GISS AOM (GISS-G) and the NCAR CCSM3 (NCAR-G), while the Regional Ocean Modeling system (ROMS) was used for downscaling. The two downscaled models (GISS-R and NCAR-R, respectively) were integrated with forcing from the present climate and from a future scenario of the respective global models. This study reveals that the GISS-R model gives a better reproduction of the observed salinities than the NCAR-R model, while the NCAR-R model performs better with respect to sea ice cover and concentration, despite higher and more realistic transport of heat into the Barents Sea in GISS-R. A major deficiency in the regional results from GISS-G is a cold bias by 4–5 K in the upper 50 m in the interior of the Barents Sea, because of too extensive regional ice cover. The NCAR-G model has an unexpected strong negative drift in salinity in large parts of the Atlantic Ocean which especially affects the downscaled future scenario through initial and boundary conditions. The stratification in the ocean resulting from vertical gradients in temperature and/or salinity has an impact on marine life. This study shows that the projected changes in stratification of the respective models diverge, so changes in the conditions for marine life in this region are very uncertain. Nevertheless, differences in the biases of upper level temperature and salinity are much smaller between the regional models than between the global models, and biases are significantly reduced in the downscaling simulations of the control climate case. Hence, our work strongly suggests that a better understanding of the regional climate of shelf seas is provided by regional downscaling.

Keywords: Barents Sea, downscaling, future, ocean stratification, ROMS.

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## ICES CM 2012/D:09

### Heat and fresh-water content in the Nordic Seas, 1950–2000

Kjell Arne Mork, Victor Ivshin, Vladimir Ozhigin, and Øystein Skagseth

Hydrographic data from the Nordic Seas during spring over the period 1950–2000 are investigated in terms of relative heat and fresh-water contents. The hydrographic data used in the studies are the combined ICES and PINRO datasets. The anomalies of heat and fresh-water contents are calculated above a specific volume surface. This approach allows us to better distinguish between change caused by local air–sea flux variations and that caused by depth variation of the specific volume surface derived from ocean current changes. The different contributions to the interannual variations in heat and fresh-water contents are investigated in relation to both air–sea fluxes and wind forcing (e.g. the North Atlantic Oscillation).

Keywords: advection, climate, heat flux, Nordic Seas.

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**ICES CM 2012/D:10**

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**Sources and propagation of anomalous fresh-water content in the Nordic Seas**

Mirjam S. Glessmer, Tor Eldevik, Jan E. Ø. Nilsen, and Kjetil Våge

The fresh-water content of the Nordic Seas is expected to increase as a result of, for example, melting of sea ice and Greenland glaciers and an amplified hydrological cycle under global warming. Hence anomalous fresh-water content in the Nordic Seas, the gateway between the Arctic Ocean and Atlantic proper, is an indicator for climate change. There are two oceanic sources for fresh-water anomalies in the Nordic Seas: the Arctic Ocean to the north and the North Atlantic to the south. We use a comprehensive dataset of hydrographic observations to determine sources and propagation of anomalous fresh-water content in the Nordic Seas over the last 60 years. In addition, we use a state-of-the-art 600-year climate model simulation for a closed and quantitative assessment. We conclude that the Atlantic Inflow determines most of the variability of the Nordic Seas fresh-water content, and that anomalies propagate from the Atlantic Inflow through the Norwegian Sea into the Greenland Sea and then to the Iceland Sea.

Keywords: fresh water, Nordic Seas.

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**ICES CM 2012/D:11**

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**Time to revise the role of the Faroe–Shetland Channel in the heat transport between the Atlantic and Nordic Seas after 16 years of observations?**

B. Berx, B. Hansen, K. M. Larsen, S. Østerhus, T. Sherwin, and S. M. Olsen

The exchange of water, heat, and salt across the Greenland–Scotland Ridge (GSR) is a two-way coupling between the Nordic Seas and the Atlantic Ocean and is important for the Atlantic Meridional Overturning Circulation and conditions in the Nordic Seas and the Arctic. A significant portion (3.0 Sv) of Atlantic Water inflow across the GSR flows through the FSC, with a similar amount crossing between Iceland and the Faroes (3.5 Sv) and a minor contribution (0.9 Sv) occurring west of Iceland. In the FSC region, acoustic Doppler current profilers have been deployed since autumn 1994 to measure velocities. Combined with time-series of water mass properties, these have been used to estimate the transport of Atlantic Water masses through the FSC. The Atlantic Water present in the FSC can be separated into two water masses, each with a different origin: the Slope Current on the Scottish side transporting North Atlantic Water (NAW) and a recirculation of Modified North Atlantic Water (MNAW), which had previously crossed the Iceland–Faroes Ridge. Combined with observations from altimetry and meteorology, the relative contributions of these two sources to the net volume (as well as heat and salt) transport of Atlantic Water to the Nordic Seas through the FSC can be estimated. Thus, changes in the strength of recirculation and its influence on transport estimates can be quantified. Together with data from an additional three mooring sites, these data allow us to present more accurate estimates of the mean transport and its variations and to assess the quality of the long-term monitoring system.

Keywords: heat transport, Northeast Atlantic, recirculation.

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**ICES CM 2012/D:12**

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**Propagating hydrographic anomalies in the Norwegian Atlantic Current**

Øystein Skagseth, Tor Eldevik, and Kjell Arne Mork

The Norwegian Atlantic Current is the major conduit between the North Atlantic and the Arctic Ocean. Based on oceanographic monitoring, anomalies in both temperature and salt have been reported to propagate through this system. However a fundamental understanding of this propagation (e.g. what sets the mean propagation speed) is lacking. The focus here is to develop some conceptual models of relevance for the propagation of anomalies toward the Arctic. These are tested against observations including oceanographic section data from the ICES Working Group on Oceanic Hydrography that capture the along-stream extent of the Norwegian Atlantic Current and gridded fields covering the entire Nordic Seas during the spring from 1995 to 2011. Special issues that will be discussed include modification en route by air–sea fluxes, the different characteristics of how anomalies propagate through the Norwegian and Lofoten basins, and the predictability of these anomalies in general.

Keywords: Atlantic water, anomalies, interannual variability, propagation.

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**ICES CM 2012/D:13**

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**Seasonal and interannual variability of the slope current and its possible impact on the Barents Sea opening**

Léon Chafik, Øystein Skagseth, and Johan Nilsson

The Norwegian Atlantic Slope Current provides the most direct link connecting the North Atlantic to the Arctic. The focus of this study is on the large-scale variability of the slope current and its forcing mechanisms. We utilize satellite altimeter data from 1992 to 2011 on a weekly basis to estimate the local sea level gradient from about 55° to 80°N in order to resolve the spatio-temporal factors along a constant  $f/H$  contour corresponding to the main core of the slope current. One principal question we will attempt to answer is how the mean seasonal cycle changes along the stream of the slope current. This approach helps to diagnose where the Norwegian Atlantic Slope Current loses or gains mass. In addition, a particular emphasis will be on the splitting of the slope current into the Barents Sea and the Fram Strait branches, which in turn will be related to the atmospheric forcing controlling the slope current variability using a topographic Sverdrup relation. The study is extended to investigate how wind forcing has changed over interannual and longer time-scales, and to further relate this to observed hydrographic variability. Finally, in relation to climate change we briefly discuss the sensitivity of these results to possible future changes in the forcing.

Keywords: climate change, satellite altimetry, slope current variability.

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**ICES CM 2012/D:14**

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**Quantifying the influence of Atlantic heat on Barents sea ice variability and retreat**

Marius Årthun, Tor Eldevik, Lars H. Smedsrud, Øystein Skagseth, and Randi Ingvaldsen

The recent Arctic winter sea ice retreat is most pronounced in the Barents Sea. Using available observations of the Atlantic inflow to the Barents Sea and results from a regional ice–ocean model we assess and quantify the role of inflowing heat anomalies on sea ice variability. The interannual variability and longer term decrease in sea ice area reflect the variability of the Atlantic inflow, both in observations and model simulations. The last decade (1998–2008) the reduction in annual (July–June) sea ice area was  $218 \times 10^3 \text{ km}^2$ , or close to 50%. This reduction has occurred along with an increase in observed Atlantic heat transport, caused by both strengthening and warming of the

inflow. Modelled interannual variations in sea ice area between 1948 and 2007 are associated with anomalous heat transport ( $r = -0.63$ ) with a  $70 \times 10^3 \text{ km}^2$  decrease per 10 TW input of heat. Based on the simulated ocean heat budget we find that the heat transport into the western Barents Sea sets the boundary of the ice-free Atlantic domain and, hence, the sea ice extent. The regional heat content and heat loss to the atmosphere scale with the area of open ocean as a consequence. Recent sea ice loss is thus largely caused by an increasing "Atlantification" of the Barents Sea.

Keywords: Arctic sea ice retreat, Barents Sea, general circulation model, ocean heat transport, observations.

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## ICES CM 2012/D:15

### Imprint of the North Atlantic climate on long-term changes in the Gulf of Mexico hydroclimate

A. Roldán-Heredia, J. C. Molinero, M. Marín-Hernández, and C. Meiners

Climate teleconnections link large-scale regions through the transient behaviour of atmospheric waves. In the Atlantic Ocean, one of the most prominent teleconnections is the North Atlantic Oscillation (NAO), which is related to the Arctic Oscillation (AO) and closely linked to the leading pattern of sea surface temperature (SST). Here we have examined the potential influence of such meteorological phenomena on patterns of low-frequency variability in hydroclimate and fish catches in the Gulf of Mexico. Statistical analysis were performed based on three datasets: (i) annual standardized time-series of hydroclimatic variables of the Gulf of Mexico, (ii) catch-based time-series of fish in the Gulf of Mexico (1980–2010), and (iii) the NAO/AO index. Results show significant correlations between hydroclimate variability of the Gulf of Mexico and the North Atlantic climate over the period 1950–2010. Significant direct correlations were found between the first component of PCA hydroclimatic variables and the NAO/AO. The oscillation frequency of some hydroclimatic variables, the NAO/AO, and some catch time-series showed common peaks. The relationship, however, shows a transient behaviour led by the varying dominant period of the climatic teleconnection. The close link between large-scale atmospheric forcing and regional environmental conditions suggests cascade down effects on plankton communities and/or changes in reproductive habitat for fish. The long periods of alternating low and high SST, probably coupled to the Atlantic Multidecadal Oscillation, may alter the structure of zooplankton populations, subsequently affecting food sources for fish larvae. On the other hand it may also affect the thermal window for mass reproduction of fish.

Keywords: Arctic Oscillation (AO), climate variability, Gulf of Mexico, North Atlantic Oscillation (NAO), time-series.

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## ICES CM2012/D:16

### Is the oceanic heat transport with Atlantic water towards the Arctic changing?

B. Berx, B. Hansen, S. Jónsson, S. M. Olsen, S. Østerhus, T. Sherwin, and H. Valdimarsson

The flow of Atlantic water (Atlantic inflow) across the Greenland–Scotland Ridge (GSR) is critical for conditions in the Nordic Seas and Arctic Ocean by importing heat and salt. All three branches crossing the GSR have been monitored since the mid-1990s and the transports of water and heat have been estimated. The Atlantic inflow that forms the surface part of the thermohaline circulation in the North Atlantic is affected by wind forcing and fresh-water input but the most important driver appears to be the cooling of the ocean by the atmosphere in the Subarctic seas and increase of salinity in the Arctic Ocean through freezing of seawater. This results in the sinking of the surface waters that subsequently flow out of the area close to the bottom over the GSR. This removal of water from the Arctic region by the overflow generates sea level slopes that drive a

northward transport of water and heat. With global climate change, the Arctic atmosphere is expected to warm and fresh-water input to the Arctic to increase, both of which may act to slow the mechanism that drives these flows, and climate models predict a weakening of the North Atlantic thermohaline circulation. This presentation addresses the question whether the weakening has already been initiated and what regions may have been affected. Based on observations and model results, we conclude that the volume transport of the Atlantic inflow has not weakened consistently whereas the temperature has increased.

Keywords: Arctic, Atlantic Ocean, currents, heat transport.

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## ICES CM 2012/D:17

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### **Changes in temperature and salinity in the eastern Eurasian Basin and its implications for Arctic Ocean heat and fresh-water balance**

Bert Rudels, Meri Korhonen, Ursula Schauer, Sergey Pisarev, Benjamin Rabe, and Andreas Wisotzki

Observations from icebreakers in the eastern Eurasian Basin are used to determine the relative importance of the Fram Strait branch and the Barents Sea branch downstream of their confluence area at the Kara Sea slope. The largest reduction in temperature and salinity takes place between the Kara Sea and the Laptev Sea. This implies that, in addition to cooling, a substantial amount of fresh water is injected into the core of the Fram Strait branch Atlantic layer. This makes a heat loss from the Atlantic water to the surface water and to ice melt unlikely and a mixing with the colder, less saline Barents Sea branch more plausible. The influence of the Fram Strait branch is mainly confined to the Eurasian Basin, especially the Nansen Basin, and the heat given up by the Fram Strait branch to the Arctic is largely limited to the melting of sea ice north of Svalbard. This information is used together with observations from the Fram Strait and some recent estimates of the inflow through the Barents Sea opening and the outflow through the Canadian Arctic Archipelago to formulate an average volume and fresh-water balance for the Arctic Ocean and to estimate heat transport through the Fram Strait.

Keywords: Arctic Ocean, fresh-water balance, heat transport, mixing.

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## Theme Session E

### Bridging the distance—Understanding habitat (and life stage) connectivity

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#### ICES CM 2012/E:01

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##### Assessing replication requirements for an MPA network using a basic model of connectivity

Alejandro Gallego, Fiona M. Gibb, Peter J. Wright, and Morten D. Skogen

The establishment of networks of Marine Protected Areas (MPAs) to protect vulnerable habitats and species is becoming a widely used approach to promote resilience in marine ecosystems throughout the world. Scotland is currently developing its contribution to an international network of MPAs to help meet UK obligations to OSPAR and achieve Good Environmental Status under the EU Marine Strategy Framework Directive. Several search locations for Scottish MPAs have been identified and will be subject to further refinement and stakeholder consultation. However, in order to consider the level of site replication needed to offer protection for priority species and afford wider ecosystem benefits of export out of MPAs, it is important to have a good understanding of connectivity. For vulnerable sedentary benthic species identified as nature conservation priorities, connectivity depends on the largely passive transport of eggs and larvae. In this study, priority benthic species were grouped into a few broad categories, based on their life history characteristics (timing of spawning, pelagic phase duration, behaviour). A simple (in terms of biological realism) biophysical model, using an annual flowfield climatology, was then used to estimate transport patterns to and from potential MPA locations. The results will be used to consider the level of site replication needed for the different priority species and thereby inform the choice of MPA locations. Consideration will also be given to import and export potential. This approach, although basic, is likely to be more relevant than the even distribution of MPAs planned for some other EU regions, especially given the prevailing circulation patterns in Scotland's seas.

Keywords: connectivity, biophysical model, MPA, Northeast Atlantic.

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#### ICES CM 2012/E:02      **Withdrawn**

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#### ICES ASC 2012/E:03      **Withdrawn**

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#### ICES CM 2012/E:04

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##### Genetic relationships between North Atlantic populations of *Pseudocalanus moultoni*, *P. elongatus*, and *P. minutus*

Ole Nicolai Staurland Aarbakke, Ann Bucklin, and Fredrika Norrbin

Calanoid copepods of the genus *Pseudocalanus* are very abundant and widespread throughout the northern hemisphere. The genus is represented by at least five species in the North Atlantic Ocean, some of which overlap considerably in their geographic ranges. This makes *Pseudocalanus* well suited as a bioindicator genus because shifts in abundance and/or distribution of one or more species could be connected to forcing factors. Current knowledge holds that *P. newmani* and *P. moultoni* are natives of the North American east coast, but *P. moultoni* was recently discovered in the Northeast Atlantic and in several fjords of Svalbard. *P. minutus* and *P. acuspes* are widespread throughout the Northeast Atlantic and in the Arctic, while *P. elongatus* is the dominant species in the southern North Atlantic. Using the genetic barcoding gene mitochondrial cytochrome oxidase

subunit I (COI), we investigated species composition of *Pseudocalanus* sp. in several locations throughout the North Atlantic Ocean. We present observations of *P. moultoni* and *P. elongatus* in Icelandic waters, as well as *P. moultoni* in Norwegian and Svalbard waters. Genetic distances between the different populations of *P. elongatus* (i.e. English Channel–Iceland), *P. moultoni* (i.e. Gulf of Maine–Iceland–Norwegian Sea–Svalbard), and *P. minutus* (i.e. Iceland–Norwegian Sea–Svalbard) were investigated using two mitochondrial genes, COI and cytochrome B (CytB), and one nuclear marker, internal transcribed spacer (ITS). We discuss the genetic relationships and connectivity between the different populations.

Keywords: barcoding, bioindicator, copepod, phylogeography.

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## ICES CM 2012/E:05

### Importation of baitworms and their live algal packing materials to the Mid-Atlantic: vector characterization and management

Amy Fowler, A. Miller, A. Whitman, Fredrika Moser, April Blakeslee, Joao Canning-Clode, and Gregory Ruiz

Maine polychaetes (*Glycera dibranchiata*) are used extensively as bait in the Mid-Atlantic (New Jersey, Maryland, Delaware, Virginia, and North Carolina, USA) and abroad, and dealers ship live baitworms from Maine, USA, packed in live algae (mainly *Ascophyllum nodosum* *ecad* *scorpioides*) globally overnight. Packing algae used are associated with numerous organisms (mostly small invertebrates), which can hitchhike with bait shipments, thus providing opportunities for possible introductions. For example, three key invasions on the US West Coast have been attributed to this vector—European green crab (*Carcinus maenas*), rough periwinkle snail (*Littorina saxatilis*), and the packing algae itself. Little is known regarding possible impacts of this vector in the Mid-Atlantic, nor is there any baseline information regarding diversity and abundance of organisms transported to the region. Therefore, our study assessed diversity and abundance of macroorganisms associated with baitworms/packing algae at three levels along the vector pathway: (i) Maine source habitats; (ii) bait-boxes shipped from Maine distributors; and (iii) bait-boxes sold in the Mid-Atlantic (in the five States listed above). Organisms were counted and identified to lowest taxonomic level seasonally from 2011 to 2012, and preliminary results indicate that diversity and abundance of associated biota decreases along this stepwise operation. However, there remains a large number and diversity of viable invaders arriving in recipient regions. Given the active nature of this vector, results from our study reflect the risk of introduction to other recipient regions, including destinations such as Europe, and serve as a model system for understanding live bait vectors around the world.

Keywords: introduced species, live bait, Mid-Atlantic (USA).

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## ICES CM 2012/E:06

### Reconstructing a recent, climate-assisted colonization of an oceanic archipelago by a coastal fish

S. Mariani, S. Stefanni, M. Sala-Bozano, J. Robalo, S. M. Francisco, R. S. Santos, R. Castilho, N. Marques, A. Brito, and V. C. Almada

To understand ocean-wide changes in the distribution of marine species it is necessary to consider the biological traits of the species and their environmental context. The mid-Atlantic volcanic archipelago of the Azores, located more than 1000 km off the European continental shelf, offers ideal opportunities to investigate alternative biogeographical scenarios in coastal fish. The common two-banded sea bream, *Diplodus vulgaris*, is a benthopelagic fish of the family Sparidae with a geographical distribution that extends from the Bay of Biscay to Senegal and the Canary Islands,



including the Mediterranean and Black Seas. In the last decade, this species changed from virtually absent to relatively abundant in Azorean waters. Here we employed a multiple marker approach to test whether this recent appearance is more likely to be evidence of the demographic explosion of a relict population or rather the result of recent colonization from western continental/island populations. The collective use of genetic diversity data, life-history traits, climatic records, and historical information allows us to reconstruct a scenario according to which the Azorean population is most likely the result of a recent colonization event, possibly from the other Macaronesian island of Madeira, occurring within the last two or three decades. This study may provide an interpretive framework for the increasing number of recent climate-driven range expansion cases in coastal fish.

Keywords: dispersal, genetic drift, islands, Mediterranean–Atlantic boundary, mitochondrial DNA, nuclear DNA.

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### ICES CM 2012/E:07      **Withdrawn**

### ICES CM 2012/E:08

#### **Multivariate analysis of features and patterns across estuarine, coastal, and oceanic ecosystems in the northeast US**

Robert J. Gamble, Jason S. Link, Andre Buchheister, Christopher M. Martinez, Jeremy S. Collie, Michael G. Frisk, Thomas J. Miller, Howard M. Townsend, and Robert LaTour

Connectivity between contiguous oceanic ecosystems, estuaries, and coastal bays is an important consideration in ecosystem based fisheries management. Many species of commercially important fish are dependent on estuaries in their early life history before they recruit to oceanic ecosystems. Seasonal migrations and changing climate can cause fish populations to move among areas that might be considered separate management units. We used multivariate analyses between and among 10 estuarine, coastal, and oceanic ecosystems in the Northeast US Continental Shelf Large Marine Ecosystem. The oceanic ecosystems included were the Gulf of Maine, Georges Bank, Southern New England, and the Middle Atlantic Bight. The estuaries and bays that connect to them were Narragansett Bay, Delaware Bay, the Connecticut shoreline, Long Island Sound, and the Hudson River. Biomass, abundance, and landings of commercially and ecologically important species were the primary response data examined. Environmental covariates, both large scale (e.g. Atlantic Multidecadal Oscillation, North Atlantic Oscillation, etc.), and local (e.g. temperature, salinity, etc.) were also utilized. Using multivariate analyses, we found that ecosystems exhibited some obvious connectivities and synchronicities among contiguous areas, but also that broader patterns of connectivity and synchronicity, although counter-intuitive, were observed. We conclude by noting how the measures of connectivity obtained here could inform fisheries management.

Keywords: coastal, connectivity, ecosystem-based fisheries management, ecosystems, estuaries, multivariate, Northeast US, Northwest Atlantic, oceanic, synchronicity.

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### ICES CM 2012/ E:09

#### **Genetic connectivity between Moroccan stocks of *Mytilus galloprovincialis* populations across Gibraltar strait**

Yassine Ouagajjou and Pablo Presa

Previous studies using microsatellites have shown the existence of two differentiated population sets of *Mytilus galloprovincialis* in southern Europe, one extending in continuity from the Cantabric

Sea (NE Iberia) to the Alboran Sea (SE Iberia), and another one in the Mediterranean. The oceanographic properties of the Almería–Oran Oceanographic Front (AOOF) have been proposed as a causative barrier to gene flow between those population sets. The present work aimed at clarifying whether northern Moroccan populations of *M. galloprovincialis* fit into the biogeographical pattern characterized by two gene pools distributed on both sides of the AOOF exclusion zone. Seven microsatellite loci were tested on 12 Moroccan samples and two representative ones from the Mediterranean or the Atlantic Iberia. All differentiation parameters have revealed a conspicuous differentiation between Alboran and Atlantic samples ( $F_{ST} = 3.8\%$ ), this latter being larger than within any of those basins ( $F_{SC} = 1.02\%$ ). Present data suggest the existence of a phylogeographic discontinuity at Gibraltar Strait where limited gene flow occurs between Alboran mussels and Atlantic mussels in northern Morocco. A wide genetic connectivity has been so far described in this species along Iberian coasts, well across Gibraltar Strait and up to the AOOF. The distinct population genetic scenarios observed with the same markers in Iberian and Moroccan coasts seem to be due to the specific directionality of the turbulent currents in the Alboran Sea. Knowledge of the biogeography of this area allows for a better understanding of connectivity patterns, interspecific comparisons, and management of local stocks.

Keywords: gene flow, genetic connectivity, Gibraltar strait, microsatellites, *Mytilus galloprovincialis*.

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#### ICES CM 2012/E:10

##### **Influence of climate on connectivity and recruitment in the Pacific oyster: a case study in the Charentais sounds (Charente Maritime, France)**

I. Bernard, F. Dumas, O. Le Moine, M. Plus, S. Pouvreau, D. Mille, and P. Boudry

Spat supply is of increasing concern for the French oyster industry since 2008 due to the severe impact of summer mortality. As a result, better understanding and quantification of factors affecting recruitment of *Crassostrea gigas* are now a key issue. In this context, we studied Pacific oyster recruitment patterns in the Charentais Sound, a major area of spat collection in France. Our aim was (i) to verify if patterns of connectivity are correlated to the spatial variation of spatfall and (ii) to identify the main factors affecting the pattern of connectivity for different spawning events. Potential larval connectivity between 25 different oyster beds was calculated for the period 1998–2009 with the hydrodynamic model "MARS-3D". Simulation of larval dispersal was launched at the recorded spawning dates for each year, according to oyster larval fishing data, with realistic larval duration, tide, wind and river flow. Twenty-six matrices of potential larval connectivity were therefore calculated. These matrices were then weighted by oyster stocks and compared to the observed spatial pattern of recruitment. Our results shows that the supply of larvae, as described by the hydrodynamic model, explain a significant part of the spatial variability of recruitment. Cluster analysis on the set of matrices allows us to describe how climate impact connectivity and consequently recruitment patterns. These results constitute an important first stone of a future bridge between ecology of oyster dispersal and applications to oyster industry.

Keywords: Charentais Sound, *Crassostrea gigas*, potential larval connectivity, recruitment.

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#### ICES CM 2012/E:11

##### **Modelled larval dispersal and measured gene flow: seascape genetics of the common cockle *Cerastoderma edule***

Ilaria Coscia, Peter E. Robins, Joanne S. Porter, Shelagh K. Malham, and Joseph E. Ironside

The role of marine currents in shaping population connectivity in the common cockle *Cerastoderma edule* is investigated in the Irish Sea, a region known for complex hydrodynamic processes. *C. edule*

is one of the most valuable and exploited shellfish species in the area, yet very little is known about its population dynamics and its larval biology. In the present study, coupled hydrodynamic and particle tracking models are used in conjunction with genetic data collected at 12 microsatellite loci to estimate connectivity between populations on the coasts of Britain and Ireland. Samples were collected at 17 locations in the Irish Sea and along the northeastern European Atlantic coast and statistical analysis was carried out to assess genetic diversity, population structure, and gene flow. The results were then compared with model predictions for their validation. Genetics and modelling are in agreement and show how, away from the coastal zone, residual baroclinic currents develop along tidal mixing fronts and act as conduit systems, transporting larvae great distances. The employment of this technique to predict future changes in patterns of population connectivity due to global warming represents progress towards a sustainable future for the common cockle, and paves the way to a different approach to management of all Irish Sea shellfisheries.

Keywords: *Cerastoderma edule*, common cockle, larval dispersal, Northeast Atlantic, particle tracking model.

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## ICES CM 2012/E:12

### Putting turbot on the map: environmental determinants, philopatry, and high dispersal potential shed new light on population structure

Sara G. Vandamme, Gregory E. Maes, Els Torreele, Johan Robbens, and Filip A. M. Volckaert

Research proves that major declines in fish stock status are common, including flatfish stocks. Within the ecosystem approach to fisheries, the source of this decline cannot be understood and successfully controlled without understanding the behaviour of individuals and their interaction within this ecosystem. In the past few years, many studies suggested that several mechanisms may explain how population structure evolves in an ecosystem without obvious physical boundaries to gene flow. First, currents may be complex and oceanographic eddies and fronts may prevent mixing and diffusion of larvae. Hydrodynamic and bathymetric barriers have been shown to influence population structure of some marine organisms. Second, as a result of the historical separation of ocean basins and persistent oceanographical constraints, phylogeographical structure may persist. Finally, environmental transitions have also been associated with genetic divergence, suggesting that populations are locally adapted to their native environment. Here, we investigate the population structure of turbot (*Scophthalmus maximus*) at local and microgeographical scales in the Northeast Atlantic. Turbot has a broad geographical distribution and distinct ecological preferences. The diversity of life-history strategies across their range offers an opportunity to evaluate their effect on the genetic divergence of populations. We evaluate through spatio-temporal sampling and analysis of EST markers the subtle structure of turbot. This strategy permits us to make inferences about the evolutionary dynamics of putative adaptive population divergence. It also provides unique information about the relative importance of various evolutionary and environmental forces at fine geographical scales. Moreover, short-term temporal sampling provided insights into the stability of previously observed regional genetic breaks.

Keywords: Northeast Atlantic, population structure, seascape genetics, turbot.

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## ICES CM 2012/E:13

### Addressing the variability of drift models: the North Sea Intermodel Comparison Project

Loes Bolle, Momme Butenschön, Ute Daewel, Mark Dickey-Collas, Jason Holt, Marc Hufnagl, Martin Huret, Frank Janssen, Genevieve Lacroix, Silvia Massmann, Mark Payne, Pierre Petitgas, Thomas Pohlmann, Corinna Schrum, Morten Skogen, Meinard Tiessen, and Jan van Beek

Major questions in marine biology have always been where do species come from, where do they go to, and how are habitats of different life stages connected. The use of ocean circulation models (OCM) coupled to individual based models (IBM) have been used in recent years to investigate these questions of connectivity at passive early life stages. Indeed, these tools cannot be ignored in complex environments where observations are scarce, available samples are patchily distributed, sampling is too expensive, or other investigation tools are simply non-existent. In general, coupled models use a Lagrangian particle-tracking module linked to an OCM. The Lagrangian module also contains the IBM which can show different shades of complexity (behaviour, feeding, energetics, mortality). For the North Sea several OCMs and OCM-IBMs have been developed in the past and have been extensively used, tested, and validated in several studies individually. Here we used a variety of these independent particle-tracking models under a set of similar conditions (start date, particle release area, drift period) to estimate uncertainties and variations in the resulting drift patterns. The scenarios used were inspired by three important North Sea species—plaice, sole, and herring—with release areas covering important known spawning areas and drift duration related to larval development. The final positions of drifters, representing metamorphosis of the larvae, were described by a set of dispersal kernel parameters describing, for example, mean end position, drift direction, dispersion, and temperature experienced. These parameters were used to address intermodel, interspecies, interrelease area, and interannual differences.

Keywords: drift models, ocean circulation models, uncertainty, variability.

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#### ICES CM 2012/E:14

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### Connectivity patterns of anchovy larvae in the Bay of Biscay from a coupled transport–bioenergetic model forced by size-structured zooplankton

M. Huret, P. Vandromme, P. Petitgas, and L. Pecquerie

Connectivity during early life stages of pelagic fish, defined by survival probability between spawning and early juvenile habitats, depends on a combination of sufficient food availability and low predator encounter along drift trajectories. For anchovy in the Bay of Biscay, larval transport experiments throughout the spawning season suggest accumulation of early juveniles in the offshore area of the southern Bay, as well as retention over the mid-shelf at mid-latitude. However, late summer–early autumn surveys suggest presence of juveniles only in the former region. From this observation, we set up a bioenergetic individual-based model to test for the effect of food availability on survival patterns. The model couples a Lagrangian transport module to the hydrodynamic model MARS-3D, as well as the DEB (Dynamic Energy Budget) model for estimation of larval growth and mortality following starvation. Temperature is provided by the hydrodynamic model, whereas food is provided by observation of size-structured zooplankton biomass, from both *in situ* LOPC (laser optical plankton counter) and Zooscan processing of net haul samples. This coupled model provides the distribution patterns of larval survivors at metamorphosis for several recent years. Results suggest that drift and food availability alone remove part of the non-observed early juvenile distribution in the northern on-shelf area. We then investigated the potential role of predation in explaining the remaining discrepancies, taking data from predator presence maps available from spring acoustic surveys.

Keywords: Bay of Biscay, bioenergetics, European anchovy, larval IBM, model coupling, zooplankton.

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**ICES CM 2012/E:15**

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**Connectivity of early life stages: are the connections between spawning grounds and nurseries of sole recurrent or exceptional? A modelling study**

G. Lacroix, G. E. Maes, L. J. Bolle, and F. A. M. Volckaert

Connectivity throughout the life cycle of (flat)fish remains an open question, especially at the early life stages. The case of sole (*Solea solea*) is of particular interest because it is one of the most valuable commercial species in the North Sea. It is crucial to understand how the spawning grounds and nurseries are connected and what are the processes influencing larval retention and dispersal in order to propose appropriate management measures. The transport of sole larvae from the spawning grounds to the nurseries is driven by hydrodynamic processes but the final dispersal pattern might be affected by behavioural and environmental factors. We use a particle-tracking transport model coupled to a 3D hydrodynamic model to investigate the impact of the hydrodynamics and the environmental factors (temperature) on the dispersal of sole larvae in the southern North Sea over the period 1995–2010. The larval transport model of sole couples the 3D hydrodynamic model COHERENS with an individual-based model (IBM) of larvae. It has been implemented in the area between 48.5°N 4°W and 57°N 10°E. Connectivity between six spawning grounds of the North Sea and their associated nurseries shows a combination of retention and dispersal affecting larval stock abundance. Year-to-year variability of recruitment in the nurseries is high, both in terms of abundance (bad/good years) and larval source (self-recruitment and larval dispersal). The model results show that some connections are recurrent and others exceptional.

Keywords: larval dispersal, North Sea, particle tracking model, *Solea solea*.

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**ICES CM/E:16**

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**Autumn distribution of Western Baltic spring spawning herring (*Clupea harengus*): annual variability in southward spawning migration into the Arkona Sea (ICES Subdivision 24)**

Tanja Miethe, Tomas Gröhsler, Uwe Böttcher, and Christian von Dorrien

Western Baltic spring spawning herring perform seasonal migrations between feeding grounds in the Skagerak/Kattegat and their spawning sites in the Western Baltic Sea. The Sound (ICES Subdivision 23) is an important transition and aggregation area for herring during the spawning migration. We analysed data from German–Danish hydroacoustic surveys carried out at the beginning September/October in the years 1993–2009. These data revealed at least two different distribution patterns of migrating herring, older than 2 years of age, at the time of the survey: In some years herring aggregated in the Sound, whereas in other years the majority were detected in the Arkona Sea (ICES Subdivision 24), outside the Sound. Based on this, the Sound can be considered as an important aggregation site, yet its importance as an overwintering area varied between years. In this study, we tested whether observed annual differences in the timing of southward migration can be explained by variations in population characteristics, measured as weight and length at age and age distribution. Furthermore, we evaluated important hydrographical variables such as temperature and salinity at the surface as a proxy for climatic conditions and at the halocline in the stratified water column of the Arkona Sea as a proxy for autumn salt water inflow events. Thus, we tested whether the distribution of herring can be related to differences in environmental conditions.

Keywords: herring, hydroacoustic survey, spawning migration, Western Baltic Sea.

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**ICES CM 2012/E:17**      **Poster**

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**How is the connectivity of sole larvae affected by wind and temperature changes in the southern North Sea? A modelling approach**

G. Lacroix, G. E. Maes, L. J. Bolle, and F. A. M. Volckaert

Connectivity throughout the life cycle of flatfish is poorly understood, especially during the early life stages. In addition, little is known about the impact of anthropogenic factors, such as climate change, on larval dispersal. The case of sole (*Solea solea*) is of particular interest because it is one of the most valuable commercial species in the North Sea. It is important to understand how the retention/dispersal of larvae are affected by climate change in order to propose appropriate measures for the management of the North Sea stock. The transport of sole larvae from the spawning grounds to the nurseries is driven by hydrodynamic processes but the final dispersal pattern and larval abundance may be affected by behavioural and environmental factors. An increase of temperature could affect, for instance, the spawning period, the duration of the pelagic stage, and the mortality of eggs and larvae. Changes in the magnitude, variability, and/or direction of wind regime might affect egg and larval retention and dispersal through changes in the hydrodynamics. We compare scenarios using a particle-tracking transport model (IBM) coupled to a 3D hydrodynamic model (COHERENS) to investigate the impact of climate change, through temperature increase and wind regime change. The model was implemented in the area between 48.5°N 4°W and 57°N 10°E over the period 1995–2010. Sensitivity of connectivity between spawning grounds and nurseries to climate change is assessed by estimating the impact of hypothetical (i) temperature increases and (ii) changes in wind magnitude/direction.

Keywords: climate change scenarios, North Sea, particle tracking model, *Solea solea*.

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**ICES CM 2012/E:18**      **Poster**

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**Towards an integrated forecasting system for pelagic fisheries**

Asbjørn Christensen, Momme Butenschön, Zeren Gurkan, and Icarus Allen

First results of a coupled modelling and forecasting system for pelagic fisheries are presented. The system consists of three mathematically fundamentally different model subsystems: POLCOMS-ERSEM provides the physical–biogeochemical environment in the northwest European shelf, the Sandeel Population Analysis Model describes sandeel stocks in the North Sea, and the Sandeel Larval Analysis Model connects POLCOMS-ERSEM and SPAM by computing the physical–biological interaction. Our main findings by coupling model subsystems is that well-defined and generic model interfaces are very important for a successful and extendable coupled model framework. The integrated approach, simulating ecosystem dynamics from physics to fish, allows analysis of the pathways in the ecosystem to investigate the propagation of changes in the ocean climate and lower trophic levels to quantify the impacts on the higher trophic level, in this case the sandeel population, demonstrated here on the basis of hindcast data. The coupled forecasting system has been tested for some typical scientific questions appearing in spatial fish stock management and marine spatial planning, including determination of local- and basin-scale maximum sustainable yield, stock connectivity, and source/sink structure. Our presented simulations indicate that sandeel stocks are currently exploited close to the maximum sustainable yield, but large uncertainty is associated with determining stock maximum sustainable yield due to stock eigendynamics and climatic variability. Our statistical ensemble simulations indicate that the predictive horizon set by climate interannual variability is 2–6 years, after which only an asymptotic probability distribution of stock properties, such as biomass, is predictable.

Keywords: coupled model system, lesser sandeel, North Sea, spatial population dynamics.

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**ICES CM 2012/E :19 Poster**

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**How can genetic analysis of connectivity contribute to sustainable management?**

Ann Bucklin, Leocadio Blanco-Bercial, Nancy J. Copley, and Peter H. Wiebe

Connectivity among populations, communities, and ecosystems can be analysed and estimated using genetic data, especially DNA sequence variation for target genes. Approaches to sustainable management will require us to move beyond genetic analysis of population connectivity (i.e. exchange of individuals) to understanding and prediction of community- and ecosystem-level linkages. We report on a taxonomically comprehensive analysis of DNA sequence variation of the mitochondrial cytochrome oxidase I (COI) barcode gene for North Atlantic holozooplankton. Included are data from our earlier analysis of comparative patterns of connectivity for ecologically important North Atlantic species of copepods and euphausiids (see Bucklin *et al.*, ICES ASC 2011/J2057). Our new analysis includes DNA sequence data for representatives of 11 phyla and 26 major taxonomic groups of zooplankton. Using this comprehensive dataset, we explore novel conceptual and statistical approaches to analysis of population, community, and ecosystem connectivity. Statistical analyses are designed to address the need for community and ecosystem indicators of connectivity. Presentation and visualization of results are designed for accessibility and use by researchers and managers. In particular, we demonstrate the usefulness of COI barcode vector analysis and the resulting heat maps (similarity matrices) as genetic fingerprints of pelagic assemblages for the visualization of geographic patterns of connectivity, and suggest applications for sustainable ecosystem management.

Keywords: connectivity, DNA barcodes, zooplankton.

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**ICES 2012/E:20 Poster**

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**Effect and effectiveness of Marine Protected Areas on the spatial and temporal distribution of yellowtail flounder (*Limanda ferrugineus*) on Georges Bank**

Judith Rosellon-Druker and Saang-Yoon Hyun

Some of the most important tools for fisheries management are the Marine Protected Areas (MPAs). However, assessment of the effect and effectiveness of MPAs remains an important challenge in fisheries science. We analysed fishery-independent survey data for Georges Bank (GB) yellowtail flounder from 1984 to 2004 in three specific locations: open areas to fishing, closed area I (CAI), and closed area II (CAII). By examining time-series of catch per unit effort (cpue), we found a fourfold increase of cpue in the open areas after implementation of MPAs. In the case of CAI, the cpue was similar before and after its implementation. For CAII, the cpue increased fivefold after its implementation. Spatial analysis in open areas indicated a higher relative biomass accumulation adjacent to the reserve boundaries. We also observed a strong species preference for sandy substrate. We analysed body sizes by area as proxy for population age structure. Using a two-way ANOVA design we determined significant effects of area and time over body length. Mean body size increased by ~1.2 cm across GB after implementation of MPAs. In CAII body size increased by ~3.7 cm after its implementation. There was no apparent positive effect of CAI on body size over time, having instead a ~1.2 cm reduction after its implementation. The increase in body size inside CAII suggests lower mortality, which could potentially promote density-dependent interactions and a subsequent adult spillover effect.

Keywords: Georges Bank, MPA, relative biomass, yellowtail.

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**ICES CM 2012/E:21      Poster**

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**Variability of European eel population abundance with special reference to the Earth's rotation regime**

G. A. Chernega, Yu.A. Vyalov, and Ye. I. Kukuyev

Maintaining sustainable fisheries requires precise understanding of the mechanism of interrelations between climatic changes in the environment and stock abundance of the major fishery subjects. Based on the hypothesis that long-term fluctuations of fish stocks in large oceanic ecosystems are caused by large-scale dynamics of the water related to the Earth's rotation velocity, the investigation of long-term variability of the European eel (*Anguilla anguilla*) abundance in inland waters of Europe over the latest four decades was carried out. It has been found that under the regimes of the Earth's accelerated rotation, zonal processes over the North Atlantic are reinforced while the North Atlantic current has a negative anomaly of velocity. These conditions led to a weakened drift of European eel leptocephala to the shores of Europe. Under the regimes of the Earth's decelerated rotation, meridional processes (weakened air-mass transport from the west to the east) are reinforced, while the North Atlantic current has a positive anomaly of velocity. In such conditions leptocephala migration to European shores intensified. Acceleration in the Earth's rotation velocity was observed from the early 1970s until the mid-2000s. The trend in European eel catches during this period was falling. In the mid-1980s, when the Earth's rotation slowed down temporarily, European eel catches increased to a certain extent. According to our hypothesis, with stabilization of the Earth's decelerated rotation (regime shift occurred in the mid-2000), an increase in European eel population in the Baltic Sea basin could be expected.

Keywords: European eel (*Anguilla anguilla*), North Atlantic, regimes of zonal and meridional circulation, rotation of the Earth.

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**ICES CM 2012/E:22      Poster**

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**Elasmobranch occurrence in a coral and non-coral area in the deep waters of Ionian Sea (Eastern Mediterranean) and aspects on their life cycle related to each habitat**

Ch. Mytilineou, A. Anastasopoulou, S. Kavadas, K. Dogramatzi, and C. J. Smith

Elasmobranch species (*Squalus blainville*, *Squalus acanthias*, *Galeus melastomus*, *Etmopterus spinax*, *Scyliorhinus canicula*, *Raja oxyrinchus*, *Raja clavata*, and *Dasyatis violacea*) were collected by experimental longline fishing in a coral (CA) and a non-coral (NCA) area in the eastern Ionian Sea off Cephalonia Island. Sampling was carried out in deep waters ranging between 350 and 850 m depth during summer and autumn 2010 in the framework of the CoralFISH project. Some of the species were present only in one of the areas (CA: *R. clavata*, *S. canicula*; NCA: *S. acanthias*), whereas the remaining seemed to prefer CA. *S. blainville* showed higher catches in terms of numbers and weight in CA in summer, but values increased in NCA in autumn. Statistical analysis (whenever possible because of the low number of specimens for some species) showed that mean TL was higher in NCA for *S. blainville* and *E. spinax*, although both species were more abundant in CA. *G. melastomus* sizes did not differ between the study areas. Male *S. blainville* are gathered mainly in CA, while NCA was mainly inhabited by females in both sampling seasons. Females dominated *E. spinax*, *S. canicula*, and *D. violacea* catches. Only male *R. oxyrinchus* were found in NCA. The sex ratio was around 1 for the remaining elasmobranch species. More mature *G. melastomus* were found in CA. The results are discussed in the context of the relation of habitat characteristics with various aspects of the life cycle of the studied elasmobranchs.



Keywords: coral habitat, deep waters, elasmobranchs, *Etmopterus spinax*, *Galeus melastomus*, *Raja clavata*, *Raja oxyrinchus*, *Squalus acanthias*, *Squalus blainville*.

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**ICES CM 2012/E:23****Occurrence of European anchovy and European sardine in the Strait of Sicily (central Mediterranean Sea) for the identification of essential fish habitat**

Bernardo Patti, Marta D'Elia, Enza Quinci, Angelo Bonanno, Gualtiero Basilone, and Salvatore Mazzola

Sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) are two of the most economically important species in the Strait of Sicily. The study of relationships between fish species and environmental factors is important in order to identify favourable spawning and feeding areas and to predict habitat suitability. The large spatial–temporal variability that characterizes the dynamics of a pelagic ecosystem makes it difficult to develop species-habitat models, but the identification of these areas can contribute to the sustainable management of fish resources. Generalized additive models were applied to presence/absence data in order to identify how the occurrence of anchovy and sardine populations is connected with environmental variables. Biological and depth information were obtained from pelagic hauls carried out in the Sicilian Channel during the summers of 2009, 2010, and 2011. Environmental data (SST, Chl *a*, and current speed) were derived from satellite imagery (MODIS-Aqua) and altimetry (AVISO). Depth and Chl *a* were found to be the most significant variables in estimated models. Results show a higher probability of finding anchovy at <90 m depth and sardine at <70 m depth, indicating a preference for shallower water for both species but a wider bathymetric distribution for anchovy. A negative effect on sardine presence appears to be induced for SST >24°C. The influence of Chl *a* on occurrence is positive for both species with a linear relationship for sardine and non-linear for anchovy. Higher concentrations of phytoplankton in surface waters may be associated with more favourable feeding areas for small planktivorous pelagic fish, such as anchovy and sardine.

Keywords: environmental factors, generalized additive models, small pelagic fish, Strait of Sicily.

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**ICES CM 2012/E:24      Withdrawn**

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## Theme Session F

### Consequences of improved survey performance on assessments and management advice? Do innovations in survey and sampling design and technology make any difference?

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#### ICES CM 2012/F:01

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##### Impact of survey design changes on stock assessment advice: sea scallops

Stephen J. Smith and P. Brad Hubley

Annual surveys of marine resources are often used to monitor changes in population composition and abundance. For those surveys based on a probability design, improvements to the probability design are evaluated with respect to the resultant increase in precision of the survey estimates. While these precision estimates will reflect the current efficiency of the survey design, improvements to the survey design will only carry over to stock assessment advice if the survey precision estimates are included in the process to generate this advice. Advice on catch levels for sea scallop populations (*Placopecten magellanicus*) around Nova Scotia is developed using a delay-difference state space population model and data collected annually using probability survey designs. Survey estimates of precision can be directly included into the observation model component of the population model and will affect the provision of advice in terms of probabilities of exceeding reference points and predictions of future biomass. In this paper we present results on the sensitivity of stock assessment advice to changes in the level of precision of survey estimates.

Keywords: Bayesian models, benthic surveys, design-base surveys, design efficiency.

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#### ICES CM 2012/F:02

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##### A parsimonious estimator of abundance based on scientific surveys

Michael Pennington

Virtual population analysis (VPA) estimates of current stock size often differ significantly from the ultimate converged estimates. One reason for these revisions is that the relation between the commercial catch of cohorts still in the fishery and the actual population is usually unknown and probably changes from year to year. An alternative to a VPA-type assessment of the current condition of a stock would be to base the assessment on, at least in theory, known relations. A survey ideally samples a stock in a consistent, standardized way, while converged VPA-type estimates based on accurate commercial catch data should provide a fairly precise historical estimate of a cohort's size. Therefore it may be sensible to reverse the roles presently played by surveys and commercial catch data for some fish stocks. That is, instead of using survey data to tune a model based on commercial catch data, we could use historical catch data to calibrate the survey. As an illustration, converged ICES estimates of stock size (1981–1992) were used to calibrate the Norwegian–Russian winter trawl survey for Northeast Arctic cod. In particular, the subsequent survey-based abundance estimates of ages 7+ cod, which are independent of any commercial catch at age data after the calibration period, were in 11 out of 15 years more accurate than the annual ICES estimates. Currently, based on the 2011 survey-based estimate and other information, it appears likely that the 2011 VPA significantly underestimated the abundance of 7+ cod.

Keywords: Barents Sea, Northeast Arctic cod, scientific surveys, survey calibration.

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**ICES CM 2012/F:03**

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**Forming collaborative partnerships to improve fisheries research surveys**

Greg DeCelles, Sally Roman, Adam Barkley, and Steve Cadrin

Our experience with industry-based surveys demonstrates that forming collaborative partnerships between scientists and fishers can greatly improve the results of surveys and stock assessments. In our research, involving members of the fishing industry during each stage of the survey design and planning process was critical for improving survey results. While planning surveys, we solicited information from fishers' experience to define our study areas, and to choose the most appropriate times of year to sample the resource. We collaborated with fishers to define the survey objectives, design survey trawls, develop practical protocols, and interpret results. The greatest benefits from collaborating with the fishing industry have been realized during fieldwork. Fishing vessels provide a cost-effective platform for fisheries-independent surveys. The local ecological knowledge of our industry partners allowed us to extend the sampling area to habitats that are difficult to trawl and are typically undersampled by research vessels. Fishers' practical experience was also valuable for minimizing lost sampling time when problems arose, such as trawl damage. After fieldwork and data analysis were completed, we found that it is important to share the results of the surveys with our industry collaborators, because their unique perspectives offered important insights into the results. By combining the skill sets of fishers and fisheries scientists, collaborative industry-based surveys provide an important platform for collecting the information that is needed for accurate stock assessments.

Keywords: assessment, collaboration, sampling design, surveys.

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**ICES CM 2012/F:04**

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**Improving survey-derived indices of abundance by combining bottom-trawl and acoustic data**

Stan Kotwicki, Patrick Ressler, James N. Ianelli, André E. Punt, and John K. Horne

The abundance of semi-pelagic species is commonly estimated using acoustic-trawl and bottom-trawl surveys, both of which sample a restricted vertical zone. Acoustic instruments are effective in the water column, but have a near-bottom acoustic dead zone, in which fish near the seafloor cannot be detected. Bottom-trawl surveys cannot account for fish that are located above the so-called effective fishing height in the bottom-trawl blind zone. These blind zones create negative biases in abundance estimates derived from either method. Here, we present a method for deriving less biased, improved indices of abundance by incorporating estimates of bottom-trawl efficiency parameters derived from combining acoustic and bottom-trawl data. Bottom-trawl efficiency parameters used are: effective fishing height, density-dependent efficiency, and catchability ratio between acoustic and bottom trawl abundance data. This method was applied to the time-series of abundance indices derived from bottom-trawl and acoustic-trawl surveys of walleye pollock in the eastern Bering Sea. Two new time-series of indices of abundance were estimated. First, the bottom-trawl survey time-series was corrected to account for the density dependence of the bottom-trawl efficiency. Second, a new time-series of combined acoustic-trawl and bottom-trawl survey data was estimated. Both new time-series were compared with old bottom-trawl and acoustic-trawl survey-specific indices with respect to relative trends, uncertainty, and expected biases.

Keywords: acoustic-trawl survey, bottom-trawl survey, abundance indices, combining bottom trawl and acoustics.

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**ICES CM 2012/F:05**

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**Evaluating how precision in estimates of abundance indices by age from a fisheries-independent trawl survey affects the assessment of Northeast Arctic cod**

Sam Subbey, Aanes Sondre Aanes, and Jon Helge Vølstad

The rules for setting quotas for Northeast Arctic cod (NEAc) are based on how estimates of stock parameters relate to defined biological reference points obtained from the Extended Survivors Analysis (XSA) model, calibrated using bottom-trawl survey data from the Barents Sea. In this paper we use simulations to investigate how the precision in estimates of relevant stock parameters for NEAc relates to different levels of sampling effort in the trawl survey. We also evaluate the importance of estimates of abundance indices by age as compared to estimates of catch-at-age for assessments and management advice. It is generally assumed that catch-at-age is known exactly and that uncertainty in estimates of abundance is chiefly caused by errors in the survey indices. However, catch-at-age is estimated, and subject to sampling errors that depend on the design and sampling effort in fisheries-dependent surveys. This must be taken into account when evaluating the performance of fisheries-independent surveys. The yearly winter survey used for tuning is expensive, has large area coverage, and samples from 176 to 394 trawl stations. It is therefore important to establish the required survey effort to achieve adequate precision in estimates of stock parameters. We explore whether the effective sample size for estimating simple statistics, such as the proportion of ages 7+, or mean age, can serve as a proxy. We adopt a statistical catch-at-age model in AD Model Builder, which also allows errors in catch-at-age when evaluating effects on sampling strategies in the trawl survey on assessment and management advice.

Keywords: catch-at-age, catch errors, effective sample size, effort, reference points, survey.

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**ICES CM 2012/F:06**

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**Long-term survey strategy for deep-sea fish species in Norwegian waters – evaluation criteria and implications for survey outputs to advisory work**

A. Harbitz, E. Hallfredsson, B. Planque, and O. T. Albert

Deep-sea fish species are widely distributed within the Norwegian EEZ from the Barents Sea in the north, along the continental slope to the North Sea and the Norwegian trench in the south, as well as in the deep coastal fjords. To monitor these species, extensive survey coverage is thus required, and this has been achieved partly through dedicated surveys and partly by inclusion of deep sampling stations in multipurpose surveys. In this work an overarching long-term survey strategy was devised by evaluation of outputs to assessment, management, and research, and adapting an intuitive traffic-light approach in a systematic manner. We present how the multiannual survey strategy can be developed and analyse the implication of such strategy on survey cost, precision of survey indices, and potential for innovative research. The strategy involves three cruises dedicated to deep-sea research in addition to other surveys with deep stations. The approach for evaluating different scenarios is described here, along with results from the 2011 November/December survey with Greenland halibut as a target species where an abundance precision of about 20% was obtained despite a more than 50% reduction in sample size. We show that the multiannual planning now implemented by the Institute of Marine Research results in time gain that gives opportunity for experimental sampling research, for example, to be done during the survey without increased effort in ship time and staffing. This planning can serve as a prototype for multiannual, multiregion, and multination survey strategies, consistent with the ecosystem approach to fisheries management currently developed within ICES.

Keywords: deep-sea fish, multispecies approach, survey design.

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**ICES CM 2012/F:07**

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**The application of new acoustic observations and techniques to stock assessment of walleye pollock in the eastern Bering Sea**

P. H. Ressler, J. N. Ianelli, T. Honkalehto, C. D. Wilson, A. De Robertis, and Stan Kotwicki

Better information on the abundance and distribution of fish stocks and their prey can improve stock assessment. Acoustic-trawl survey techniques are a proven means of providing this information. However, such observations are costly and benefits to stock assessment and fisheries management decisions are sometimes unclear. We outline two examples of how new cost-effective sources of information on the semi-pelagic gadid walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea are being used in stock and ecosystem assessments. In the first case, opportunistically collected acoustic backscatter data from bottom-trawl survey vessels were processed to provide an additional assessment index of the pelagic portion of walleye pollock biomass, which can be used to “fill in” years when funds are unavailable to conduct a full acoustic-trawl survey. A five-year time-series of this index affected recent stock assessment model results and quota recommendations for 2012. In the second case, multifrequency classification of acoustic backscatter data collected during acoustic-trawl surveys of pollock and additional net sampling were used to develop an index of euphausiid (“krill”, *Thysanoessa* spp.) biomass and distribution. Since euphausiids are important prey for pollock and many other species in the Bering Sea, this new time-series has been used as one measure of food availability to inform stock assessment of walleye pollock, to inform a broader assessment of ecosystem status, and for comparison to end-to-end models that support an ecosystem approach to fisheries management.

Keywords: acoustic survey, Bering Sea, euphausiids, ecosystem approach to fisheries management, stock assessment, walleye pollock.

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**ICES/CM/2012/F:08**

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**Influence of survey improvements on assessments of fish stocks in the US**

Richard D. Methot Jr.

Fish abundance surveys in the US are principally conducted from NOAA research vessels and chartered fishing vessels and utilize a wide range of sampling gears depending on the habitat and life history of the stocks being surveyed. Bottom-trawl, longline, and pot surveys in several regions each provide the basis for assessment of tens of stocks. Acoustic surveys are used for some pelagic stocks, and optical methods deployed from towed and autonomous vehicles are beginning to reach into previously unsurveyed habitats. Standardization of the protocols for each survey provides a relative index of fish abundance over time. Assessments based on relative abundance surveys derive most of the information on absolute stock abundance from the fishery catch, which is more routinely measured on an absolute scale. Various technologies such as codend cameras, net mensuration, and net-mounted sonars are improving the calibration of survey measurements with the goal of attaining direct estimates of fish abundance, not just a relative index of abundance. Simulation studies are used here to illustrate the expected improvements to be obtained in assessment precision and accuracy when surveys are calibrated directly to stock abundance. Preliminary analysis suggests that assessments that are based on both absolute levels of catch and absolute levels of surveyed fish abundance may be better able to infer the level of natural mortality, which is even more challenging to measure empirically than the catchability of the survey gear.

Keywords: calibration, fish surveys, stock assessment, technology.

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**ICES CM 2012/F:09**

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**DeepVision: Improving surveys through identification and measurement of fish inside a trawl**

Shale Rosen and Darren Hammersland-White

Scantrol AS and the Institute of Marine Research, Bergen, Norway are cooperating to develop camera-based technology to identify and measure fish as they pass through the extension of a survey trawl. Data, including full colour images, are streamed live to the vessel and stored for later analysis of species and sizes encountered. The three-dimensional location of capture for each fish is recorded, allowing investigations of distribution with respect to depth and geographic location as well as species overlap. When surveying species or areas where mortality during surveys is a concern, the system can be used with an open codend, releasing individuals after they are imaged. The fish are never physically handled and release occurs at the same depth as capture, consequently impairment and mortality are expected to be very low. By eliminating the need to retrieve and empty the codend, a single trawl haul can be of long duration, with a large sampling area/volume. Field trials of the system have verified that lengths calculated from the images using photogrammetric techniques match manual measurements of the catch, and that the system can be easily integrated into existing survey trawls and protocols. Analysis of the images is time intensive, but techniques are being developed and refined to automate many of the tasks.

Keywords: stereo camera, image analysis, trawl surveys.

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**ICES CM 2012/F:10**

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**Improved methods for mapping distribution and abundance of pelagic fish schools with omnidirectional fisheries sonar**

Héctor Peña and Egil Ona

When pelagic fish are organized in schools distributed close to the sea surface, avoidance of the survey vessel and the echosounder blind zone are potential problems for the standard echosounder method for abundance estimation. Modern omnidirectional fisheries sonars are able to detect fish schools very close to the sea surface in an effective volume which is orders of magnitude larger than the echosounder. Some sonars can also deliver digital data adequate for post-processing. A new tool for displaying and processing sonar data was used for mapping and extracting school characteristics (relative density, morphology, swimming direction, and speed) for herring and mackerel in the Norwegian Sea. A combined analysis with the echosounder data shows the clear advantages of the sonar data and the weakness of the echosounder sampling, especially in areas with specific fish distributions. School migration direction and speed obtained from the sonar analysis also provide new information for better understanding fish migration and their interactions with oceanographic conditions (i.e. food availability, currents) that can be used in the present end-to-end ecosystem models for the Norwegian Sea. The ongoing efforts in developing calibration methods for these particular sonars will allow more quantitative estimation of school biomasses, improving survey performance and eventually giving better stock assessments.

Keywords: echosounder, pelagic fish and fish migration, schools, sonar.

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**ICES CM 2012/F:11**

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**Enhancing survey coverage with no net increase in survey effort**

Matthias Kloppmann, Finlay Burns, Cindy van Damme, and Jens Ulleweit

The mackerel egg survey (MEGS) delivers the only fishery-independent data for the assessment of Northeast Atlantic mackerel. Changes in the temporal and geographical distribution of mackerel spawning coupled with renewed discussion surrounding the spawning biology in mackerel necessitated an examination of the traditional MEGS design. Replicate sampling during the 2007 MEGS provided information on intraperiod egg production variability as well as the potential impact to the total annual egg production (TAEP) of only surveying alternate transects. The recalculation showed that adopting an alternate transect approach would have resulted in either 16.7% under- or 14.7% overestimation of the TAEP depending on whether interpolation was completed on even or odd transects. High variability in egg production early in the spawning season (period 2 and pre 2) was mainly responsible for these differences, with the highest variability in both abundance and stage composition existing between replicates with the longest time interval between samplings. Short time intervals revealed a large variability when mean abundance was high as well. This station-by-station variability was to a large degree negated, however, when calculating the daily egg production by transect. The results show that the alternate transect design is optimized for the AEPM design. Given the current expansion of the mackerel spawning area with every subsequent MEGS survey the alternate transect option provides enhanced survey coverage capability where there is no net increase in survey effort.

Keywords: AEPM, mackerel egg survey, survey design.

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**ICES CM 2012/F:12**

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**Innovations in survey and sampling design in the Chilean crustacean swept area assessments**

E. Acuña, R. Alarcón, L. Cid, and A. Cortés

Three crustacean species are subject to yearly swept area assessments off northern Central Chile: a pandalid shrimp (*Heterocarpus reedi*) and two munidid squat lobsters (*Cervimunida johni* and *Pleuroncodes monodon*). One of the first improvements of these studies was establishing the spatial distribution of their fishing grounds, using historical positive surveys and commercial tows irrespective of their catch, to determine optimal sampling strategy. Innovations in swept area assessment surveys included changing the original systematic sampling by longitudinal transect design and then, because of a requirement to intensify sampling effort in areas of higher abundance of species, using an adaptive strategy, and finally, adopting a stratified random sampling strategy for these resources. The assumption of uniform distribution within sampling units was tested through evaluation of sampling support using variance component models. Different estimators of mean density have been used to quantify the biomass of these species: arithmetical mean estimator, ratio estimator, bootstrap, Delta-lognormal, and geostatistical estimators. Performance of these estimators was tested using number of zero values in a simulated survey. Methodological approaches, including tow duration and determination of tow beginning and end, are also addressed. Different area estimation methods of the standing stocks of these crustacean species were also reviewed.

Keywords: Chile, deep-sea shrimp, squat lobsters, trawl research surveys.

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**ICES CM 2012/F:13**

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**A comparison of scallop length distributions obtained from AUV and dredge surveys**

Warsha Singh, Erla B. Ornlófsdóttir, and Gunnar Stefánsson

A small-scale camera-based autonomous underwater vehicle (AUV) survey of Iceland scallops was conducted at a defined site off western Iceland. Prior to length estimation of the identified shells, the distortions introduced by the vehicle orientation and the camera lens were corrected. The average AUV pitch and roll was 1.3° and 2.3°, which resulted in <0.1% error in ground distance, rendering these effects negligible. A quadratic polynomial model was identified for lens distortion correction. This model successfully predicted a theoretical grid from a frame photographed underwater, representing the inherent lens distortion. The predicted shell lengths were scaled for the distance from the bottom at which the photos were taken. This approach was validated by length estimation of scallops of known sizes. An underestimation of approximately 0.5 cm was seen, which could be attributed to pixel error, where each pixel represented 0.24 × 0.27 cm. After correcting for this difference the estimated lengths ranged from 3.8 to 9.3 cm. A comparison of the length distribution from a small-scale dredge survey carried out in the vicinity showed non-overlapping peaks in size distribution, with scallops of a broader size range visible in the AUV survey. Further investigations are necessary to evaluate any underlying bias and to validate how representative these surveys are of the true population. The low-resolution images made identification of smaller scallops difficult. Overall, the observations of very few small scallops in both surveys could be attributed to low recruitment levels in recent years because of the known scallop parasite outbreak in the region.

Keywords: AUV, dredge, Iceland scallops, length distribution.

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**ICES CM 2012/F:14      Withdrawn**

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**ICES/ASC 2012/F:15**

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**Generating a biologically adequate single-species hake assessment in Namibia from survey data information**

Espen Johnsen and Johannes Kathena

*Merluccius capensis* and *M. paradoxus* are morphologically very similar and cannot be registered separately by species in the Namibian commercial hake catches. This prevents the conduction of a biologically plausible single-species stock assessment. Here, species-separated data from scientific surveys are used to model the spatio-temporal overlap of the two species which are then used to predict the catch by species in each commercial trawl. The study presents a method which compensates for both the escape and codend retention differences in the survey and commercial trawls. The accuracy with which species were identified was found to be considerably higher during scientific surveys compared to that obtained from trained observers on board commercial vessels. In support of previous findings, *M. capensis* had a shallower and more northerly distribution than *M. paradoxus* with depth and latitude together explaining 85% of the residuals in the models produced from survey data, respectively. Model outputs suggest that during the period 1998–2007, *M. paradoxus* has dominated the annual hake catches. Even though our method is unable to account for abrupt and unexpected changes in the species' geographical distribution, it does open the way for the establishment of a single-species hake assessment in Namibia.

Keywords: assessment, hakes, Namibia, species separation.

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**ICES CM 2012/F:16**


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**Investigation of uncertainty in Baltic Sea acoustic survey results for management application**

S. Kasatkina and P. Gasyukov

The authors estimated the overall uncertainty in abundance indices of herring and sprat based on the Baltic International Acoustic Surveys (BIAS), and demonstrated that uncertainty in survey results varies considerably by years, species, and age groups. Using the XSA method it was shown that introducing abundance indices variance into the stock assessment model resulted in new stock estimates and parameters of herring and sprat populations (recruitment, total and spawning biomass, mean fishing mortality), as well as in changes in the temporal trends of fish stock dynamics. The authors analysed the contribution of the major influencing factors in survey variance and showed the high error in recruitment indices. Approaches to reducing uncertainty in the acoustically derived abundance indices and biomass were discussed. The highest contribution to survey-related errors came from the TS–length function. It was shown that parameters of the TS function and their statistical characteristics resulted in absolute values and uncertainties of the abundance indices by years for each age group. The differential catchability of survey trawls is also a significant source of uncertainty in the acoustic surveys. The authors traced the effect of trawl differential catchability from the length–species composition of catches to estimates of acoustically derived abundance indices by age groups. In conclusion, the authors demonstrated that introducing the new proposed TS function and trawl differential catchability into the BIAS analysis should allow more realistic assessment of herring and sprat abundance for each age group, by year, so providing vital information for tuning stock assessment methods.

Keywords: acoustic surveys, Baltic Sea, overall uncertainty of abundance indices, sprat and herring, target strength, trawl catchability.

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**ICES CM 2012/F:18      Poster**


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**Can we improve stock assessments by using dynamic habitat models and fishery-dependent surveys as a supplement to current fishery-independent surveys?**

J. Kohut, J. Manderson, J. Hoey, C. Roebuck, L. Palamara, M.J. Oliver, S. Gray, G. DiDomenico, O. Jensen, and E. Bohchenek

Fisheries-independent bottom-trawl surveys used for stock assessments in the Mid-Atlantic Bight, USA (MAB) are confined to continental shelf waters and scheduled during the spring and fall of the calendar year. Habitats in the MAB, however, are strongly seasonal and highly dynamic over short time-scales. These dynamics are impacted by a rapidly changing climate. Fish distributions, particularly of small, highly migratory pelagics, vary based on these dynamics rather than on changes in our calendar year. In collaboration with the industry we developed a butterflyfish (*Peprilus triacanthus*) habitat model that captures these dynamics at a coarse scale. Further we evaluated this model adaptively in real-time during an 8-day trial aboard a fishing vessel. We discuss the implications of the at-sea trial on science and ecosystem management in the region. Based on our observations, we believe a coarse-scale dynamic habitat model can be useful for identifying large regions where the risk of a large catch may be high. Finer scale observations are needed to downscale the model to a resolution used by fishers. We suggest that habitat models could be used to supplement existing surveys by weighting stock assessment indices by the amount of habitat that is actually sampled by assessment surveys. We also propose that existing surveys can be expanded to include the commercial fleet sampling over the modelled habitat with trawls and

acoustics. Both will help address large changes in abundance over fine space- and time-scales and extend the coverage into habitat regions not included in fishery-independent surveys.

Keywords: butterfish, habitat, industry collaboration, Mid-Atlantic Bight.

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### ICES CM 2012/F:19

#### **Improving assessment methods: developing and evaluating alternative estimators of survey uncertainty**

Mathieu Woillez, Paul Walline, Christopher D. Wilson, Martin W. Dorn, James N. Ianelli, and André E. Punt

A critical feature in all modern stock assessment approaches is the characterization of uncertainty. Fundamental to this characterization is the need to have reliable estimates of survey uncertainty. In this study, our objective was to evaluate and improve stock assessment methods by more fully quantifying sources of survey uncertainty by age class. In the case of the walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea (EBS), a comprehensive evaluation of the uncertainty of acoustic-trawl survey data was performed to appropriately include these data in the stock assessment model. Uncertainties associated with each variable (i.e. acoustic backscatter, length and age composition) and those from functional relationships among variables were evaluated and combined to produce estimates of abundance-at-age and associated uncertainty. Uncertainty due to sampling in space was evaluated using geostatistical conditional (co)simulations for the acoustic backscatter and length frequencies. Uncertainty due to errors in functional relationships was evaluated using bootstrapping for the target strength-to-length relationship and for the age-length key. This simulation framework was used to assess the contribution of each of these major sources of uncertainty for acoustic-trawl surveys of walleye pollock in the EBS from 2006 to 2010. The framework allowed computation of abundance-at-age variance-covariance matrices. These estimates were compared by applying them directly within the stock assessment model currently used to provide management advice. This required an alternative likelihood specification and showed that typical multinomial likelihood methods commonly assumed within stock assessments results in different estimates of key aspects of assessment uncertainty.

Keywords: acoustic-trawl survey, bootstrap, eastern Bering Sea, geostatistical (co)simulations, stock assessment, total uncertainty, walleye pollock.

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### ICES CM 2012/F:20

#### **Measuring pelagic fish over its full vertical distribution, a combined echosounder and sonar estimate.**

Rolf J. Korneliussen, Egil Ona, and Hector Pena

The acoustic blind zone is the zone from the surface to the transducer mounting depth added to the transducer near field; it is often 10–15 m in large research vessels with a drop keel. In addition, the effective observation volume in the fairly narrow echosounder beams close to the vessel is small when surveying small pelagic schools close to the sea surface. The Simrad MS 70 scientific multibeam sonar has been used to map the horizontal and vertical distribution of herring in the Norwegian Sea. The measurement method for combining sonar and echosounder estimate is suggested, and particular examples are shown where both instruments show strengths and weakness. The potential bias in the standard echosounder estimate when used alone is discussed.

Keywords: avoidance indicator, bias, blind zone, sonar.

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**ICES CM 2012/F:21**

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**Possible reductions in Barents Sea surveys—a test of its influence on Northeast Arctic cod assessment quality**

Yury Kovalev and Anatoly Chetyrkin

The problem of funding could lead to fewer and less frequent surveys. This study evaluated how such a reduction may affect the quality of Northeast Arctic (NEA) cod stock assessment, which relies on the results of survey data. Based on data from the ICES Arctic Fisheries Working Group collected for the period from 1946 to 2010, VPA/XSA stock assessments were performed in FLR with different assumptions on possible reduction in surveys. For all explored cases of reduced frequency of surveys a serious deterioration of the NEA cod assessment quality was observed. Retrospective patterns of SSB estimates demonstrate possible deviation of up to 55% and the same effect is observed for total stock estimates. If such a situation becomes real, it may lead to serious under/overestimation of the stock and TAC. In addition, in current ICES practice the results of NEA cod assessment are used for NEA haddock assessment and capelin TAC prediction, for which cod consumption is taken into account. Thus a decrease in cod assessment quality will influence the quality of NEA haddock and capelin assessments and advice. It was also concluded that reductions in survey frequency may reduce the quality of assessments for other species as these surveys are multispecies.

Keywords: assessment quality, frequency of surveys, NEA cod.

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**ICES CM 2012/F:23**

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**Impact of the methodological improvement of the surveys of cephalopods in Morocco**

Abdelmalek Faraj and Nicolas Bez

The octopus stock (*Octopus vulgaris*) off the south of Morocco has been exploited as a fishery resource in the national fishery for many decades. The National Institute of Fisheries Research (INRH) has carried out a monitoring programme of demersal stocks of this area for more than 30 years with the research vessel “Charif Al Idrissi”. The objective of this monitoring programme is to quantitatively evaluate the stock status and the impact of fishing. Since the end of the 1990s, a scientific survey has been evolved through (i) improving the survey design, (ii) using new equipment, and (iii) introducing geostatistic techniques. Through these improvements, instead of calculating abundance indices based on cpue (kg/h), spatial distribution and relative biomass with precision are estimated. Moreover, these developments have also improved the capacity of the INRH scientists to formulate scientific advice with significant information in fisheries management, including seasonal total allowable catch (TAC) of octopus stocks. We present the series of innovations and developments that have been conducted on cephalopod assessment survey methodology, developing the capacity of INRH scientists to practically advise managers.

Keywords: none

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**ICES CM 2012/F:24      Poster**


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**Using underwater TV images to count *Nephrops* burrows in Portuguese waters**

Ana Moreira, Paulo Fonseca, and Cristina Silva

The Portuguese crustacean fishery is a highly valuable component of the Portuguese continental bottom trawl. There are about 30 vessels directed to this fishery, operating mainly off the south coast and to a lesser extent off the southwestern one. The depth range of this fishery goes from 150 m to more than 600 m. The Crustacean TV Survey is a part of the European Union's Data Collection Framework (DCF/PNAB), which aims at collecting catch and biological information for commercial stock management. The main objectives of this survey are thus: estimating abundance indices and determining the length structure and maturation of the main target species: rose shrimp, *Parapenaeus longirostris* and Norway lobster, *Nephrops norvegicus*, as well as deep-water shrimps: red shrimp, *Aristeus antennatus*, giant red shrimp, *Aristaeomorpha foliacea* and scarlet shrimp, *Aristaeopsis edwardsiana*. Numerous bycatch fish species, including European hake, anglerfish, and blue whiting, are often retained. During the 2009 survey, a further objective was introduced. A video camera was mounted on the trawl headline pointing forward, with the purpose of obtaining bottom footages for the estimation of Norway lobster density based on their burrowing systems counts. Concurrently, survey density was also estimated from cpue for a total of 64 stations. Both trawled and filmed areas were calculated from data obtained with a Scanmar sensor and laser systems, respectively. Given that Norway lobster display a diel emergence pattern which may vary according to the depth, cpue values were modelled using a generalized linear model with a log link function. Finally, a linear regression was established between the adjusted catch survey densities and the density based on burrow counts. This relationship was based on only 27 stations, deeper than 300 m, resulting in a regression coefficient of 0.52.

Keywords: burrows, *Nephrops*, Portuguese.

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**ICES CM 2012/F:25      Poster**


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**T-NASS: Counting whales in the North Atlantic: big is useful**

M. Acquarone, G. Desportes, J.-F. Gosselin, T. Gunnlaugsson, M. P. Heide-Jørgensen, J. Lawson, B. Mikkelsen, N. Øien, D. Ólafsdóttir, D. G. Pike, G. A. Víkingsson, L. Witting, and V. Zabavnikov

NAMMCO coordinated a basin-wide estimation of abundance of cetacean populations in the Northern North Atlantic from surveys in summer 2007. The surveys, called T-NASS (Trans-North Atlantic Sightings Survey) were a component project of the IPY - ESSAR, adding to the series of North Atlantic Sightings Surveys (NASS) conducted in 1987, 1989, 1995 and 2001: a 20-year time series, a realistic opportunity for detecting changes in abundance over time for cetacean species with long life spans and slow reproductive rates. T-NASS involved 7 vessels, 5 aircraft and 79 observer positions for the core survey provided by the Faroe Islands, Iceland, Greenland, Norway and Canada (over 54,000 nm on effort and about  $1.8 \times 10^6$  nm<sup>2</sup>). Additional 10 observers on 5 fishery surveys vessels (Russia, Germany, Norway and UK) covered adjacent areas in the same season: ICES Redfish in the Irminger Sea, ECOMAR to the Mid Atlantic Ridge and Norwegian Pelagic in the Norwegian Sea. For the first time, a Trans-North Atlantic survey was achieved: the largest coordinated whale survey to date in the Atlantic. All requested stock assessments for large whale species in the North Atlantic based on sightings data from the T-NASS 2007 survey, and additional surveys in 2009, have now been finalized. These stock assessments by the Scientific Committee of NAMMCO constitute the main basis for catch limits set for some baleen whale stocks (fin and minke whales) in the North Atlantic. The next Trans-North Atlantic Sighting Survey is scheduled to take place around 2015, and planning is already under way.

Keywords: marine mammals, cetaceans, whales, abundance, line transect, survey, management, NAMMCO, T-NASS, TNASS.

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**ICES CM 2012/F:26      Poster**

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**Opportunistic analysis of echosounder data to locate buried sand lance using QTC IMPACT**

Theresa Kirchner, Ari S. Friedlaender, J. Christopher Taylor, Elliott L. Hazen, Michael Thompson, and David Wiley

Opportunistic analyses can be a time- and cost-effective tool for fish abundance and distribution estimation by maximizing the use of the vast amounts of existing datasets from underwater acoustic surveys. In the current study, existing echosounder data were used opportunistically to detect and locate buried sand lance on Stellwagen Bank, USA. The acoustic ground discrimination system QTC IMPACT was used to extract acoustic information on the seabed from echosounder data, and to divide the substrate into acoustically distinct sediment classes. The QTC sediment class distribution was compared to existing bottom typing data from the US Geological Survey. It was assumed that a given QTC class could be associated with a given bottom type, and that therefore, discrepancies between QTC class and bottom type distribution probably resulted from sand lance burial. For none of the frequencies (38 and 120 kHz), spatial scales, or echosounder mounting systems (hull- vs. towfish-mounted) analyzed could the distribution of QTC classes be explained by underlying bottom type alone. A strong correlation between water depth and the QTC classification's principal components indicated the existence of a depth trend in the data, which—at least on a small spatial scale—probably resulted from an apparent QTC-inherent depth trend. The unexplained variability in the QTC class distribution inhibited the use of QTC data for the location of buried sand lance. Sediment samples from dedicated surveys could facilitate the interpretation of QTC class variability. We conclude that currently, opportunistic acoustic data analyses cannot replace physical samples for buried sand lance detection.

Keywords: opportunistic data analysis, QTC IMPACT, sand lance, Stellwagen Bank.

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**F:27      Withdrawn**

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## Theme Session G

### Implementation of the European Union Marine Strategy Framework Directive (EU MSFD): implications for science and policy

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#### ICES CM 2012/G:01

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##### Combining multiple surveys to derive regional-scale assessments of the status of fish communities from subregional-scale datasets

Samuel Shephard, Leonie Dransfeld, Simon P. R. Greenstreet, Elena Guijarro-Garcia, Daniel Oesterwind, Rick Officer, and David G. Reid

The Marine Strategy Framework establishes four European Marine Regions, based on geographical and environmental criteria. Each Member State is required to develop a marine strategy for their own waters (EEZs or extended Continental Shelf areas), but Good Environmental Status will be considered at region or subregion scale. The Northeast Atlantic Marine Region is divided into four subregions (Atlantic Ocean; Bay of Biscay and the Iberian coast; Celtic Seas; and Greater North Sea). The spatial extent and ecological diversity of the subregions presents a challenge for data collection and monitoring programmes, especially for widespread and diverse ecosystem components such as fish communities. In the North Sea, fish community monitoring is strongly facilitated by a well-integrated international bottom-trawl survey that covers much of the Greater North Sea subregion. However, in other subregions, fisheries surveys are typically conducted by individual nations, with spatial coverage referring to national waters or traditional fishing grounds. The Celtic Seas subregion is covered by at least three separate surveys, which occur in different (but sometimes overlapping) areas and seasons and follow somewhat differing protocol. In this paper, we disaggregate the North Sea Q1 survey to develop a protocol for developing abundance indicator series for subregions covered by several surveys. We then apply the protocol to the Celtic Seas subregion and present an ensemble abundance indicator for this area.

Keywords: Celtic Sea, fish community, large fish indicator, MSFD, size structure.

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#### ICES CM 2012/G:02

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##### Setting the stage for improved Marine Strategy Framework Directive foodweb indicators

Axel G. Rossberg, Maria Fatima Borges, Tak Fung, Simon P. R. Greenstreet, Paula Haynes, Ellen L. R. Kenchington, Han Lindeboom, Isabelle Rombouts, Samuel Shephard, Gro I. van der Meeren, and David G. Reid

As noted in the EC (2010) Decision Document on Marine Strategy Framework Directive (MSFD) attributes, there are a number of perceived shortcomings in the list of indicators proposed to support MSFD Descriptor 4. Among the principal shortcomings was that the indicators primarily focus on measures of the “structure” of foodwebs, and only one indicator (on productivity) is proposed for the “functioning” or the dynamics of the processes operating within foodwebs; despite a strong emphasis on function in the report by the group tasked with developing criteria and methodological standards for this Descriptor. Here we show that these two characteristics of foodwebs can be seen as intertwined—variation in the structure of foodwebs invariably alters the dynamics of processes and therefore the functioning of foodwebs. So, where should the primary attention of conservation be? Logically, the functioning of an ecosystem cannot be conserved directly, only the structures providing the functions can. However, most structures will be supported by specific foodweb functions. Two lines of thought are contrasted and synthesized: that Good Environmental Status (GES) of foodwebs is, to a large extent, dependent on foodweb function, and that GES of foodwebs is largely reducible to questions of structure. We set the scene and

provide guidance for further research on the identification of operational foodweb indicators to achieve a more comprehensive implementation of Descriptor 4. This work was carried out by a subgroup of the ICES Working Group on Ecosystem Effects of Fishing Activities (WGECO) examining approaches to foodweb GES indicators.

Keywords: foodwebs, function, MSFD, structure.

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## ICES CM 2012/G:03 Poster

### Measuring Marine Strategy Framework Directive Descriptor 10 microparticle indicator in the marine environment—how hard can it be?

Heather A. Leslie and A. Dick Vethaak

Initial pioneering studies have detected microplastics in the marine environment—in surface waters, continuous plankton recorder samples (10 m depth), in marine sediments, and in field-collected marine organisms. Microparticles, especially microplastics, are one of the four indicators to be assessed and potentially monitored within Marine Strategy Framework Directive (MSFD) Descriptor 10 Marine Litter, but as indicators, microplastics require further development. Microplastics are commonly defined as synthetic polymer particles “less than 5 mm” but can often be much smaller than 5 mm. Evidence exists that the hazards posed by plastic particles in the ultrafine range (low micrometre to nanometre particles) may also be significant. Seafood safety is therefore also dependent on ensuring that ultrafine synthetic polymer particles are not present in edible seafood tissues. Most detection of microplastics has been on a visual basis under the microscope, with staff manually separating the microplastics from non-plastic microdebris collected in nets, sieves, or in gut contents of biota. We will briefly compare analytical methods for the analysis of microplastics in environmental samples, including biota. What are the real size limits of the plastic particles we are measuring with the current approaches to sampling and analysis? Which size categories are potential threats to marine organisms and are we measuring or missing these size categories with current approaches? What are the quality control issues that should be addressed for microplastics sampling and analysis? These questions will be addressed and recommendations given for future research and development in this emerging field of study.

Keywords: analytical methods, indicator, microplastics, monitoring.

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## ICES CM 2012/G:04

### Contaminants status assessment in the Polish sector of the Baltic Sea within the Marine Strategy Framework Directive

Tamara Zalewska, Beata Danowska, Jerzy Woron, Anna Olszewska, and Joanna Szlinder-Richert

In response to Article 8 of the Marine Strategy Framework Directive 2008/56/EC (MSFD), an initial assessment (IA) of the Polish marine areas was carried out in Poland in 2011 and 2012. An important element of this assessment was the determination of the contaminants status and a quantitative evaluation of contaminant effects on biota. Contamination of the marine environment by hazardous substances is regarded as an anthropogenic pressure factor, significantly affecting the health of ecosystems. The assessment of hazardous substances was carried out within Descriptor 8: “Contaminants and pollution effects” and Descriptor 9: “Contaminants in fish and other seafood”. Core indicators for the assessment were selected taking into account the recommendations of the HELCOM CORESET project, within which the indicators specific for the Baltic Sea area were designated. The applicability of the selected indicators was tested considering their representativeness in the assessed regions of the Polish sector of the Baltic Sea as well as taking into account data availability. Finally, 26 substances were selected representing three groups

of chemicals: persistent organic pollutants, heavy metals, and radionuclides. Their concentrations determined in marine organisms (mussels and fish), marine sediments, and water were compared with the reference values to calculate contamination ratios. These ratios were then translated into a five-class classification scheme following the Water Framework Directive system of high, good, moderate, poor, and bad status. The MSFD-defined border between Good Environmental Status (GES) and sub-GES was assumed to be between the good and moderate status. The assessed subregions within the Polish sector of the Baltic Sea comprised transitional waters as well as offshore areas.

**Keywords:** Baltic Sea, contamination, hazardous substances, MSFD.

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## ICES CM 2011/G:05

### **Challenges and merits of Marine Strategy Framework Directive implementation in the Polish sector of the Baltic Sea: environmental status assessment linking multiple indicators and pressures**

Elżbieta Łysiak-Pastuszek, Magdalena Błęńska, Paulina Brzeska, Iwona Bubak, Barbara Burakowska, Andrzej Osowiecki, Monika Michałek, Anna Śliwińska, and Tamara Zalewska

Within the context of the Marine Strategy Framework Directive (MSFD) implementation Member States are required to report to the EC on the current state of their marine areas, define the desired state of the marine environment by the determination of Good Environmental Status (GES) characteristics and associated environmental targets as well as establish and implement measures in case the current status of the environment deviates from the desired one. In the implementation process in Poland, multiple indicators characterizing each of 11 descriptors required by the Commission Decision were selected based on the availability of the most recent data, both from national monitoring and various scientific projects. Relying on WFD principles it was decided to apply five class system at individual indicator level, assuming GES as the border between good (class 4) and moderate (class 3) status. The methods of indicator aggregation within a descriptor and especially linkages between the descriptors presented the key challenges in the assessment procedure. For this purpose an interactive tool was developed combining the response/status indicators with pressure indicators. The assessment procedure comprised the core indicator level throughout the descriptor to assessment units/areas which, within the Polish sector of the Baltic Sea, were developed in cooperation with the HELCOM CORESET group of experts.

**Keywords:** Baltic Sea, biodiversity, environmental status assessment, eutrophication, MSFD.

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## ICES CM 2012/G:06

### **Should we protect/restore the age structure of exploited fish stocks?**

Thomas Brunel and GerJan Piet

Independent of the level of abundance, an unbalanced age structure is often perceived as a sign of increased risk in exploited fish stocks. Therefore, metrics describing age structure are now being proposed as new indicators of stock status. Two underlying assumptions to this new management criteria remain to be tested: first, that managers can exert control over age structure, independent of the regulation of stock abundance, and second, that a balanced age structure is indeed indicative of a “healthier” stock. The present work investigates these questions using simulations from a generic model parameterized to represent the dynamic of North Sea cod, plaice, and herring. Recruitment in the model is based on egg production, which is more sensitive to age-structure variations than the traditionally used spawning stock biomass (SSB). By applying different selection patterns



(fishing mortality at age profile), it was possible to obtain different age structures, but age structure was also influenced by the absolute level of fishing pressure, and by the natural variability in recruitment. A depleted age structure resulted in a more variable stock, but again this effect was modulated by the level of fishing mortality. The speed with which the stocks reacted to changes in fishing mortality was correlated to age structure, a well-balanced age structure resulting in a slower depletion when fishing mortality increased, but also to a slower rebuilding when fishing mortality was reduced. Finally, the stocks were more deeply impacted by a prolonged period of detrimental environment when their age structure was not well-balanced. We conclude that different aspects of fish stock dynamics are linked to their age structure, and discuss whether this reflects a real intrinsic influence of the age structure or only the direct consequence of harvesting the stocks with different selection patterns.

Keywords: demographic structure, fish stock management, GES descriptor, North Sea, resilience, TEP.

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## ICES CM 2012/G:07

### Testing of future contaminant monitoring programmes capable of addressing Descriptor 8 as defined by the Marine Strategy Framework Directive

T. Maes, B. P. Lyons, and J. Thain

The UK Clean Seas Environmental Monitoring Programme (CSEMP) was designed to monitor concentrations and effects of selected contaminants in fulfilment of the OSPAR JAMP status and trends programme. The data have been assessed and reported in the past through UK Charting Progress and QSR reports. The Marine Strategy Framework Directive (MSFD) aims to achieve Good Environmental Status in Europe's seas by 2020. In order to fulfil this requirement a set of 11 descriptors have been defined of which Descriptor 8: "Concentrations of contaminants are at levels not giving rise to pollution effects" is of particular importance in terms of future contaminant offshore monitoring programmes. In order to address this descriptor a more integrated approach of monitoring chemical contaminant levels alongside biological effect measurements relating to the effect of pollutants is desirable, but needs to be tested to address its practicability. This will be addressed through a trial programme based on the ICES Study Group for the Integrated Monitoring of Contaminants and Biological Effects (SGIMC) integrated scheme, and in addition be driven by a risk-based, cost-effective, fit-for-purpose approach. A main objective will be to align existing monitoring programmes (CSEMP, Water Framework Directive, and Environmental Quality Standards Directive) to make best use of the UK's marine monitoring resources and datasets, and to provide environmental managers with comprehensive information and a sound scientific basis for decision-making.

Keywords: biomarkers and chemical monitoring, integrated assessment, Marine Strategy Framework Directive (MSFD), SGIMC.

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## ICES CM 2012/G:08

### Case study: potential to use an integrated assessment framework for contaminants and biological effects to determine Good Environmental Status for Descriptor 8 under the Marine Strategy Framework Directive

B. P. Lyons, T. Maes, J. E. Thain, C. D. Robinson, and M. J. Gubbins

The use of biological effects tools can assist Member States to meet the challenges outlined by the European Union Marine Strategy Framework Directive (MSFD) which requires them to develop a robust set of tools for defining 11 qualitative descriptors of Good Environmental Status (GES), such as demonstrating that "Concentrations of contaminants are at levels not giving rise to pollution

effects” (GES Descriptor 8). Here we discuss the combined approach of monitoring chemical contaminant levels, alongside biological effect measurements relating to the effect of pollutants, for undertaking assessments of GES across European marine regions. Using data collected as part of the UK’s Clean Seas Environmental Monitoring Programme (CSEMP), we outline the minimum standards that biological effects tools should meet if they are to be used for defining GES in relation to Descriptor 8. Adopting the recommendations of the ICES Study Group for the Integrated Monitoring of Contaminants and Biological Effects (SGIMC) we present a series of case studies demonstrating how such an approach, using contaminant (e.g. metals, polycyclic aromatic hydrocarbons, polychlorobiphenyls) and biological effects (e.g. EROD, bile, and pathology) data, in sediment, water, and biota could be used to contribute to the determination of GES in the marine environment.

Keywords: biological effects techniques, biomarkers and biomonitoring, Marine Strategy Framework Directive (MSFD).

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## ICES CM 2012/G:09

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### Fisheries cruises for marine litter monitoring

T. Maes, M. Nicolaus, and J. Thain

The European Union Marine Strategy Framework Directive (MSFD) requires Member States to put in place measures to achieve Good Environmental Status (GES) in Europe’s seas by 2020. The MSFD lists 11 GES Descriptors for the specific areas under which GES must be achieved. MSFD Descriptor 10 on marine litter requires that “Properties and quantities of marine litter do not cause harm to the coastal and marine environment”. The challenges in developing a future monitoring programme for the assessment of marine litter capable of answering questions such as posed by the MSFD are to identify the quantities of litter in the marine environment, the major processes that control the entry and/or removal of litter from the oceans and the transformations that occur during the lifecycle of any given litter item. Monitoring is crucial to assess the efficacy of measures implemented to reduce the abundance of marine litter, but it is complicated by large spatial and temporal heterogeneity in the amounts of litter and by our limited understanding of the pathways followed and its long-term fate. However, the most efficient and cost-effective solution is to gather as much data as possible on the back of existing fisheries cruises in order to get the necessary evidence to implement a robust monitoring programme and determine measures. We present a series of surveys demonstrating how such an approach, using fisheries and other scientific cruises, was used to determine marine litter distributions and types in the marine environment.

Keywords: Marine Strategy Framework Directive (MSFD), Descriptor 10, marine litter monitoring, distribution and types.

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## ICES CM 2012/G:10

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### The use of biological effect measurements to assist the determination of Good Environmental Status for EU Marine Strategy Framework Directive Descriptor 8

John Thain, Matthew J. Gubbins, Craig Robinson, Ian Davies, and Dick Vethaak

Many maritime countries in Europe have marine environmental monitoring programmes which include the measurement of chemical contaminants and related biological effects. How best to integrate these two types of monitoring data into meaningful assessments has been the subject of much recent effort by a number of ICES Working and Study Groups, including the Study Group for the Integrated Monitoring of Contaminants and Biological Effects (SGIMC) and the Working Group on the Biological Effect of Contaminants (WGBEC). The output from this process has culminated in draft OSPAR guidelines and an ICES CRR (in press). The OSPAR guidelines have

been adopted on a trial basis for the period of three years to establish their practical applicability. The work has concentrated on defining a core set of techniques that can be used across maritime areas, defining confounding factors, supporting parameters, and standards for measurement. Most importantly, the output of the work has defined assessment criteria for biological effect measurements and suggests how these measurements can be used in an integrated manner together with chemical contaminant measurements in biota, sediments, and water. The scientific basis for this approach is presented. The approach is also considered to provide a potential tool for EU Member States to determine whether Good Environmental Status (GES) for Descriptor 8 is being achieved (i.e. concentrations of contaminants are at levels not giving rise to pollution). National and international case studies to demonstrate the approach have been recently trialled and suggest that adoption of the approach adds value to environmental assessments.

Keywords: biological effects, integrated monitoring, Marine Strategy Framework Directive, Descriptor 8.

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## ICES CM 2012/G:11

### A Good Environmental Status assessment procedure for benthic habitats: weighing and integrating alternative approaches

Gert Van Hoey, Jozefien Derweduwens, Sofie Vandendriessche, and Kris Hostens

Criteria and indicators related to the assessment of benthic habitats are included in Descriptors 1, 4, and 6 of the Marine Strategy Framework Directive (MSFD). Therefore, an appropriate, integrative assessment procedure for this habitat type should contribute to an integrated assessment of the marine status. An assessment procedure for determining the Good Environmental Status (GES) of benthic habitats requires attention to the following topics: (i) the selection and integration of complementary indicator tools to assess the structure and function of the benthic ecosystem (indicator approach), (ii) a habitat assignment of the area (habitat approach), (iii) reference or target conditions for the different benthic parameters (reference approach). For all these aspects, different approaches exist, of which the reference and indicator selection approaches have been largely discussed in the literature. The aspect of the habitat approach is sometimes neglected, but is essential in determining the GES conditions per habitat type, due to the difference in structure and function per habitat type. An objective assessment of target conditions is a challenge in areas lacking pristine sites, and areas for which historic data are not available. The integration of the outcomes out of the diverse set of benthic indicators could be tackled using a confidence decision diagram. In this study, the relation between different habitats, reference settings, and indicator approaches on the GES assessment of benthic habitats was investigated and illustrated with analyses based on a large benthic dataset from the Belgian Part of the North Sea (1977–2009).

Keywords: benthic habitats, indicators, integrative assessment procedure, targets.

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## ICES CM 2012 /G:12

### Setting ecological benchmarks and combining status across indicators and descriptors: lessons learned from integrated advice and assessments

Jake Rice

The ICES Joint Research Centre (JRC) Task Groups conducting the background work for implementing the Marine Strategy Framework Directive (MSFD) provisions on Descriptors took a variety of approaches to the tasks of setting benchmarks for Good Environmental Status (GES) on various indicators, and for combining the indicator-specific results into Descriptor-specific conclusions about GES. The Coordinating Committee for the Task Groups grappled more with the

challenges of producing coherent evaluations of GES from the diverse inputs across Descriptors, in the end failing to converge on a single recommended way forward. This talk will review experience gained in other Science Advisory fora, including fisheries harvest advice using indicators for both biomass and fishing mortality, species at risk assessments using multiple quantitative criteria for assessing risk of extinction, and habitat quality advice where there could be large numbers of environmental quality indicators whose results had to be combined into single evaluations of habitat quality. Among the important lessons learned from these experiences are that:

- there are sound policy foundations for setting ecologically coherent reference points across diversity ecological properties;
- formal algorithmic methods for assessing status on single indicators and combining status assessments across multiple indicators have been developed multiple times, and always abandoned for good practical reasons;
- integrated assessments, combining simple algorithmic approaches with informed narrative, are possible to conduct objectively, and can be greatest value to policy and management. but require well-designed and managed science advisory processes.

The talk will summarize the rationales for and implications of these lessons.

Keywords: Descriptors, indicators, integrated assessments, management benchmarks, MSFD.

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## ICES CM 2012/G:13

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### **A process for evaluating management measures to achieve Good Environmental Status**

H. J. Bloomfield, A. M. Knights, and L. A. Robinson *et al.*

The Marine Strategy Framework Directive (MSFD) defines environmental objectives (descriptors) for European seas and strives to achieve Good Environmental Status (GES), based on sustainable utilization of healthy marine ecosystems in support of sustainable development. Achieving GES is complicated by the complex relationship among multiple human activities, and their associated pressures and impacts on the marine environment. Change in environmental status of a descriptor has the potential to be effected through a number of pathways. In addition there are links between descriptors and the choice of management measures may have implications that resonate across more than one descriptor. While more than one management strategy might be able to deliver GES, the economic and social costs and benefits of implementation may vary due to differences in environmental status, type and scale of human activities, the sectors which are affected, and the magnitude to which those sectors are restricted. Decisions on which management measures should be implemented will depend on social and economic objectives for resource use, and the governance structure. Here we describe a process for exploring the complexity of these issues to inform decision-making in pursuit of GES illustrated by case studies from the MSFD's four regional seas.

Keywords: costs and benefits, European regional seas, Good Environmental Status, management strategy evaluation.

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**ICES CM 2012/G:14**


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**Descriptor 2 of the Marine Strategy Framework Directive: ten suggestions to move forward**

Henn Ojaveer, Sergej Olenin, Dan Minchin, Ana Amorim, Joao Canning-Clode, Paula Chainho, Gordon Copp, Bella Galil, Stephan Gollasch, Anders Jelmert, Stefan Kacan, Francis Kerckhof, Ian Laing, Maiju Lehtiniemi, Tracy McCollin, Cynthia McKenzie, Josip Mikus, Laurence Miossec, Anna Occhipinti, Marijana Pecarevic, Judith Pederson, Gemma Quilez-Badia, Andrea Sneekes, Lauri Urho, Jeroen Wijsman, and Argyro Zenetos

EC Decision 2010/477/EU defines the two criteria for assessing progress towards Good Environmental Status relevant to Descriptor 2 “Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem“:

1. abundance and state characterization of non-indigenous species (NIS), in particular invasive species
2. environmental impact of invasive non-indigenous species.

The following ten points should be considered when addressing this descriptor:

1. Availability of taxonomic expertise is critical to address Marine Strategy Framework Directive (MSFD) Descriptor 2 criteria and indicators.
2. Evaluation of the numbers of NIS, their spread and impact need to be standardized.
3. Evaluation of the newly arrived NIS may start with selected well-studied taxonomic groups.
4. Ratio of NIS/NS (native species) in a region or habitat is to be calculated and evaluated based on contemporary reliable data.
5. Ratios (NIS/NS) and NIS impacts may vary with habitat, region, and presence of other drivers, and so could be independent of NIS management actions.
6. NIS with lesser recognized impact may be evaluated separately.
7. NIS inventories should be accompanied by pathways and vector analyses.
8. Selected areas (hot-spots) could be used in monitoring to improve cost-effectiveness.
9. Management options should be agreed by neighbouring countries because of the risk of secondary spread of NIS, as appropriate.
10. NIS with known impact(s) are to be managed as is practicable and on the basis of this the success of managements effort should be evaluated.

Keywords: generic suggestions, Good Environmental Status, non-indigenous species.

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**ICES CM 2012/G:15**


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**Proxies for estimation of relative fishing mortality when biomass is unknown**

Rainer Froese and Arlene Sampang

The Marine Strategy Framework Directive proposes two indicators for assessing the level of pressure of fishing activities on the target species. The primary indicator is the fishing mortality ( $F$ ) relative to the one ( $F_{msy}$ ) that will eventually lead to the maximum sustainable yield. The secondary indicator is the catch/biomass ratio relative to a catch/biomass proxy for  $F_{msy}$ . Both indicators and their reference points need biomass of the target stock to be known. Biomass is, however, unknown for the majority of fish stocks in European waters. Fish grow throughout their lives, and the mean size they reach is a function of their average rate of total mortality over the past years, roughly equal to generation time. This presentation proposes mean length in the commercial catch and the von Bertalanffy growth parameter  $K$  or the rate of natural mortality as reasonable proxies for  $F$  and  $F_{msy}$ , respectively. These proxies will be evaluated against respective estimates derived from full stock assessments.

Keywords: Marine Strategy Framework Directive, proxies for fishing pressure.

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**ICES CM 2012/G:16**

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**Assessing Good Environmental Status for Descriptor 8—an integrated assessment of contaminants and their biological effects across multiple matrices in the Firth of Forth, Scotland**

C. D. Robinson, M. J. Gubbins, B. P. Lyons, J. Bignell, T. Bean, K. MacNeish, P. Dymond, J. Dobson, L. Webster, and J. E. Thain

Descriptor 8 of the Marine Strategy Framework Directive (MSFD) requires that “Concentrations of contaminants are at levels not giving rise to pollution effects” in order for Good Environmental Status (GES) to be achieved. Prior to publication of the MSFD, OSPAR/ICES Working and Study Groups identified a coherent set of biological effects measurements spanning various trophic levels and levels of biological organization, and developed a scheme to produce a holistic assessment of environmental status with respect to contaminants through integration of the biological effects measurements with chemical concentration data. To trial the integrated approach, we established a demonstration programme that included the determination of biological effects responses in mussels and flounder in addition to existing monitoring for the OSPAR CEMP that included chemical analyses of biota and sediment, and biological effects responses such as imposex in dogwhelks and EROD activity in flatfish. We demonstrated the utility of the OSPAR/ICES scheme by conducting an integrated assessment of the environmental status of the Firth of Forth, including measurements in dogwhelks, mussels, fish, water (passive sampling), and sediment. Contaminant concentrations and effects showed an inshore–offshore gradient within the Firth of Forth area and while most were below levels of concern, there were individual cases that exceeded the environmental assessment criteria. An assessment of these data is presented which integrates across determinants, matrices and sites and is used to propose status for the area with respect to Descriptor 8.

Keywords: Firth of Forth, integrated monitoring, Marine Strategy Framework Directive, Descriptor 8.

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**ICES CM 2012/G:17**

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**Temporal trends in the trophic guild composition in fish communities: development of indicators to support the Marine Strategy Framework Directive**

Paula S. Haynes, Simon P. R. Greenstreet, Deirdre Brophy, David G. Reid, and Samuel Shephard

Fishing pressure can change the structure of marine foodwebs, which may impair the functioning of these systems. Under the Marine Strategy Framework Directive (MSFD), indicators of the “abundance trends of functionally important selected groups/species” are required in order to track fishing-induced change in fish community structure. While recent studies have examined the effects of fishing on size structure of demersal fish communities, few have investigated how trophic structure may be altered. Based on published diet data, we allocated Northeast Atlantic fish species to one of four broad trophic guilds: demersal piscivores, demersal benthivores, pelagic piscivores, and pelagic planktivores. Ontogenetic shifts in diet were accounted for, by allowing allocation to guild to change with increasing size (length). Time-series of the proportion (by biomass) of the sampled community representing each guild were calculated for each of five fisheries surveys in the Celtic Sea, North Sea, and Baltic. Biomass of trophic guilds typically fluctuated annually without a clear trend. This pattern contrasts with previously observed declines in fish community size, as identified using the Large Fish Indicator for the same data. This suggests some resilience in the trophic structure of the system and demonstrates the utility of a Trophic Guilds Indicator for examining long-term variation of the trophic composition of fish communities.

Keywords: fish community, Northeast Atlantic, resilience, Trophic Guilds Indicator.

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**ICES CM 2012/G:18      Withdrawn**

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**ICES CM 2012/G:19      Poster**

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**The usefulness of secondary fish stock indicators regarding the Marine Strategy Framework Directive Descriptor 3**

W. N. Probst and D. Oesterwind

In 2010 the European Commission published a suite of criteria, indicators, and methodological standards on how to assess the environmental status within the 11 descriptors of the Marine Strategy Framework Directive (MSFD) (EU-COM Decision 477/2010). For Descriptor 3 dealing with the status of exploited fish and shellfish stocks, the EU guideline distinguishes between primary and secondary indicators, depending whether data from analytical stock assessments are available or not. Whereas the primary indicators are based on fishing mortality and spawning stock biomass from analytical stock assessments, the secondary indicators are based on catch abundance in scientific surveys and commercial landings data. Here we present a comparison between the primary and secondary indicators of fish stocks from the Baltic and North Sea testing their congruence in the time-series and the resulting implications for the assessment of stock status when using different indicator suites.

Keywords: assessment, Descriptor 3, Marine Strategy Framework Directive, primary indicator, secondary indicator, stock status.

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**ICES 2012/G:20      Poster**

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**New indicators for assessing coastal benthic biodiversity**

Kaire Torn, Kristjan Herkül, and Georg Martin

The EU Marine Strategy Framework Directive (MSFD) requires Member States to develop by 2012 marine strategies for their sea areas, including an initial assessment of the state of the environment, a definition of Good Environmental Status, and establishment of environmental indicators, targets, and monitoring programmes. Biological diversity is one of the descriptors of status of marine environment. In the framework of the EU LIFE+ project MARMONI we developed two innovative indicators and methods for assessing coastal benthic biodiversity: (i) indicator based on the structure of macrovegetation of stormcast (stormcast macrovegetation index, SMI), (ii) indicator based on the spectral variability of a remotely sensed imagery (spectral variability index, SVI). Compared to commonly used monitoring methods, SMI is easy to use and cost-effective. SMI was developed during a case study on data collected from northern Gulf of Riga (Baltic Sea) and based on relationship between eutrophication and species diversity in benthic vegetation. Abundance of the key species and the species richness of the area are the components of index. SVI is based on the spectral variation hypothesis that predicts a positive correlation between spectral variability of a remotely sensed image and biodiversity. Our study is the first attempt to apply the spectral variation hypothesis in the marine environment using air-borne hyperspectral imagery. All coverage-based benthic diversity measures showed low but statistically significant positive correlations with spectral variability indicating the relevance of the method in assessing marine environmental status.

Keywords: Baltic Sea, biodiversity indicator, macrovegetations, remote sensing, stormcast.

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**ICES CM 2012/G:21    Poster**

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**Assessment and monitoring of ocean noise in Irish waters**

Suzanne Beck, Joanne O'Brien, Michel Andre, Simon Berrow, and Ian O'Connor

Anthropogenic noise is now recognized as a significant pollutant in the marine environment, and the EU Marine Strategy Framework Directive (MSFD) aims to address this. At present two indicators are set out under MSFD to assess ocean noise: "11.1.1: low and mid frequency impulsive sound" and "11.2.1: low frequency continuous sound". Under assessment of Indicator 11.1.1 this study aims to create a register of licensed low- and mid-frequency impulsive sound activities carried out within the Irish EEZ. We aim to generate noise maps of the Irish EEZ illustrating areas of high low- and mid-frequency impulsive anthropogenic noise levels. To assess Indicator 11.2.1 we aim to conduct an audit of acoustic datasets collected to date within the Irish EEZ and use recordings when possible to identify shipping and other target sounds. There is particular concern of the effects of anthropogenic noise on marine mammals because they have a highly developed auditory system and use sound actively for orientation, feeding, and communication. This project aims to estimate an approximate disturbance area for baleen whales through sound propagation modelling and data gathered from ship vessel monitoring systems (VMS) and automatic identification systems (AIS). This study will deploy a noise monitoring device from which average ambient noise levels can be measured for deployment durations and extrapolated over a calendar year using specialized acoustic models. This work, funded by the Environmental Protection Agency, serves to inform management on how to meet requirements under MSFD and provide recommendations on cost-effective monitoring schemes.

Keywords: anthropogenic noise, Indicator 11.1.1, Indicator 11.2.1, MSFD.

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**ICES CM 2012/G:22    Poster**

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**<sup>137</sup>Cs as core indicator of the Baltic Sea marine ecosystem health**

Tamara Zalewska and Maria Suplińska

The levels of various hazardous substances in fish, including radionuclides of anthropogenic origin, have become the focus of recent marine assessment activities and legal regulations. One example of these acts is the EU Marine Strategy Framework Directive (MSFD), which states that Good Environmental Status (in European seas) can only be achieved when concentrations of contaminants, including radionuclides, in the marine environment are at levels not giving rise to pollution effects. In the case of the Baltic Sea, the level of pollution with radioactive caesium (<sup>137</sup>Cs) is higher than in other regions of the world oceans. Thus the importance of radionuclide status monitoring was included in the Baltic Sea Action Plan of HELCOM (BSAP), in which restoring GES and achievement of pre-Chernobyl levels of radioactivity are the main targets. For these reasons, <sup>137</sup>Cs was selected as the core indicator for the Descriptor 8: "Contaminants and pollution effects" both within the HELCOM CORESET project and in the Polish Initial Assessment (IA) carried out according to Article 8 of the MSFD. In this paper results are presented of a study on changes in <sup>137</sup>Cs radioactivity concentration in three fish species from the southern Baltic Sea: cod (*Gadus morhua*), herring (*Clupea harengus*), and flounder (*Platichthys flesus*) in the period 2002–2010. A marked decline in caesium activity in fish muscle tissue was observed, which reflected changes in radionuclide concentration in seawater. However, no statistically significant temporal trends were determined in the changes of concentration coefficients ( $CF_{\text{fish/seawater}}$ ).

Keywords: caesium 137, core indicator, fish, Baltic Sea.

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**ICES 2012/G:23****Poster**

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**Interactions between reflectance spectra and primary production of different algal communities (*Fucus vesiculosus* and *Cladophora glomerata*)**

Teemar Püss, Tiina Paalme, and Tiit Kutser

Determination of Good Environmental Status for coastal waters includes assessing the state of benthic macroalgal communities. Alterations in the structure of benthic algal communities are used as indicators of the overall disturbance of coastal ecosystem in different assessment systems (EU WFD, EU Marine Strategy Framework Directive). The mass development of ephemeral (like green algae *Cladophora glomerata* and brown algae *Pilayella littoralis*) algae has become a widespread phenomenon in shallow coastal waters worldwide, related mostly to continuous eutrophication of coastal waters. Such algae are seasonal, decay quickly once detached from their substrate and therefore are not expected to form extensive and long-lasting drifting mats. However, the drifting algae may severely disturb attached macrophyte communities growing underneath. There is a need for development of effective, low-cost tools for measuring the effects of the eutrophication and other disturbances in coastal ecosystem covering different geographical scales. Here, the use of remote-sensing tools seems to be promising in addition to traditional monitoring methods. In a field experiment we estimated how the short-term presence of drifting algae affected photosynthetic production and reflectance spectra of *Fucus vesiculosus* and *Cladophora glomerata* communities—key habitat-forming species in coastal waters of northeast Baltic Sea. The results of our experiments showed important relations between primary production and reflectance spectra among shallow-water macroalgal communities (*Fucus vesiculosus* and *Cladophora glomerata*). Reflectance spectra varied seasonally and depended on physiological conditions of macroalgae. This tool could be developed for use in assessment of the state and disturbance level of coastal benthic communities.

Keywords: *Cladophora glomerata*, *Fucus vesiculosus*, primary production, reflectance spectra.

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## Theme Session H

### Advances in the traceability of fish and fish products: from species to populations

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#### ICES CM 2010/H:01

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##### **SNP discovery in *Thunnus alalunga* and *T. thynnus* provide insights into worldwide population structure and a traceability tool for *T. alalunga***

Aitor Albaina, Mikel Iriondo, Igor Velado, Urtzi Laconcha, Iratxe Zarraindia, Carmen Manzano, Haritz Arrizabalaga, Miguel Ángel Pardo, Nicolas Goñi, Ibon Cancio, Gilad Heinisch, Molly Lutcavage, W. Stewart Grant, and Andone Estonba.

The optimal management of the commercially important, but overexploited pelagic tunas, albacore (*Thunnus alalunga*) and Atlantic bluefin tuna (*T. thynnus*), requires a better assessment of population structure than has been provided by previous molecular methods. Despite numerous studies of both species, their population structures remain controversial. This study reports the development of single nucleotide polymorphisms (SNPs) in albacore and Atlantic bluefin tuna and the application of these SNPs to survey genetic variability across the entire geographic ranges of these tunas. Briefly, a total of 616 SNPs were discovered via comparative sequencing of 54 nuclear DNA fragments in 35 albacore tuna with distinct geographical origin. A subset of 53 SNPs were genotyped in 460 albacore collected along the whole distribution range of this species. These SNPs yielded values of  $F_{ST}$  between samples ranging from 0.0 to 0.052. No significant heterogeneity was detected within oceans, but between-ocean comparisons were significant. In addition, 17 SNPs were developed in Atlantic bluefin tuna by cross-species amplifications of assays designed for albacore. Variability for these SNPs was surveyed in 107 fish, yielding an  $F_{ST}$  of 0.114 between Northeast Atlantic and Mediterranean populations. These SNP markers for albacore and bluefin tuna can be used to genotype large numbers of fish without the need for standardizing alleles among laboratories. Moreover, an origin assignment tool consisting of 18 SNPs and capable of distinguishing among albacore from the Mediterranean Sea, Atlantic Ocean, and Indian-Pacific Oceans was patented. This molecular tool will be valuable for identifying potential commercial frauds.

Keywords: tuna, SNP discovery, population genetics and traceability, whole distribution range.

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#### ICES CM 2012/H:02

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##### **Population genetic structure and traceability of the European anchovy (*Engraulis encrasicolus*) using SNP-type markers**

Iratxe Zarraindia, Aitor Albaina, Mikel Iriondo, Miguel Angel Pardo, Carmen Manzano, W. Stewart Grant, Xabier Irigoien, and Andone Estonba

An important application of genetic tools is the use of molecular markers to assess the stock structure and traceability (origin assignment of individuals to populations) of a harvested species. This study applied 47 nDNA and 15 mtDNA single nucleotide polymorphisms (SNPs) to analyze 626 European anchovies from the whole range of distribution of the species in order to resolve shallow and deep levels of population genetic structure. These SNPs defined 10 genetic entities within two larger genetically distinctive groups associated with oceanic variables and different life-history traits: one major group of Iberian-Atlantic populations was associated with upwelling areas on narrow continental shelves and included populations spawning and overwintering in coastal areas and, a second group included northern populations in the NE Atlantic (including the Bay of Biscay) along with the Mediterranean ones and was associated with wide continental shelves with local larval retention currents. This second group tends to spawn and overwinter in oceanic areas. These two groups encompass ten populations that differ from previously defined management

stocks in the Alboran Sea, Iberian-Atlantic, and Bay of Biscay regions. In addition, 16 SNPs have been selected to assign European anchovies from the Iberian-Atlantic, Mediterranean region, and Bay of Biscay area to their population of origin to identify potential commercial frauds. This genetic tool is currently being used to protect the consumer and the standard of quality of the Bay of Biscay anchovy, which is highly appreciated by the consumer and the canning industry.

Keywords: *Engraulis encrasicolus*, genetic population structure, traceability tool, whole distribution range.

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## ICES CM 2012/H:03

### Aquaculture forensics: tracing the source of farmed escapees with DNA

Kevin A. Glover and Øystein Skaala

Each year, hundreds of thousands of Atlantic salmon, rainbow trout, and Atlantic cod escape from Norwegian aquaculture facilities into the wild. These escapees represent a significant threat to the genetic integrity of native populations. According to Norwegian aquaculture regulations, fish farmers are legally obliged to report escapes of fish from their facilities to the regulatory body, the Norwegian Directorate of Fisheries (NDF). However, underreporting remains a major issue. In response to the needs of the NDF, we developed an effective “stand-by” method, based upon DNA analysis, to identify the farm of origin for escaped farmed salmon (ICES *J. Mar. Sci.* 2008, 65: 921–920 and *Aq. Environ. Interactions* 2010, 1: 1–10). The method is used where large numbers of escapees are observed in the wild but no farm has reported losses. It has been successfully implemented in more than ten “cases”, and has resulted in substantial fines for three companies. The method has also been successfully adapted to trace the source of both rainbow trout and cod escapees. We have clearly demonstrated that an ad-hoc approach, using DNA methods has been highly successfully in increasing traceability in aquaculture. Furthermore, the method that we describe will be possible to implement in other countries and for other species where similar management challenges exist.

Keywords: aquaculture, escapees, fisheries forensics, Norway, traceability.

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## ICES CM 2012/H:04

### Fisheries forensics: the Norwegian Minke whale DNA register (NMDR)

Kevin A. Glover, Tore Haug, Nils Øien, Lars Walløe, Lotta Lindblom, Bjørghild B. Seliussen, and Hans J. Skaug

The commercial exploitation of minke whales in Norway was re-established in the early 1990s. This is strictly regulated by a number of methods, and possibly represents one of the most controlled “fisheries” in the world. Control measures include, among other components, permit regulation and control, extensive remote sensor data, and not least, an individual-based DNA register built upon similar principles to human DNA registers (NMDR). The NMDR contains DNA profiles for 98.6% of all whales (7751) commercially harvested by Norway in the period 1996–2010. The genetic profile is established by the analysis of a sex marker, sequencing a fragment of the mtDNA d-loop, and the analysis of 10 polymorphic short tandem repeats (STRs). All samples are analysed twice, using separate DNA isolations, and contains extensive quality checks. Samples from each year’s catch are analysed at the end of the season then entered into the register. The legal status of “suspect” meat or other products derived from minke whales can be verified by their genetic analysis and match/mismatch to an individual genetic profile in the DNA register. However, the register does not only serve as a functional control organ, it also provides a clear deterrent against any attempts at illegal trade of whale products under the cover of the legal harvest conducted in Norway. While the individual sample approach is rather costly on a per-unit basis, similar registers

for other high-value marine products, such as other whale species, tuna, sharks, and similar could be established.

Keywords: commercial whaling, DNA register, individual identification, Norway.

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## ICES CM 2012/H:05

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### **From research to reality: transferring state-of-the-art population genetics into forensic traceability tools for fisheries monitoring and enforcement**

Rob Ogden and Ross McEwing

The transfer of novel technologies from research to applied science is key to the successful completion of any policy cycle that advocates the development of technological solutions to address issues within society. To support moves towards sustainable fisheries management, the potential usefulness of novel technologies, in particular DNA analysis, for addressing issues associated with the identification and authentication of traded fish and fish products is now widely recognized. In response to increasing concern over global levels of illegal, unreported, and unregulated (IUU) fishing, a number of research projects have been undertaken in the past five years to enable and demonstrate the use of DNA analysis in fisheries control and enforcement. However, until very recently, the transfer of research outputs into applied testing systems has been limited. The EU FP7 project, FishPopTrace, set out to assess and develop a range of novel tools for population assignment of fish belonging to four commercial species (cod, herring, hake, and sole). The work concluded in 2011 with a demonstration of how DNA methods generated by the research could be transferred into a forensic testing framework capable of delivering evidence of IUU fishing to enforcement investigations. The UK government environment department, Defra, has since picked up these outputs and is supporting a project to fully transfer DNA methods into validated fisheries identification tools for use by government agencies, the fishing industry, and non-government bodies. This presentation presents an overview of the work being undertaken within this project to advance traceability of fish and fish products.

Keywords: DNA, Europe, geographic origin, mislabelling.

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## ICES CM 2012/H:06

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### **FishPopTrace: an integrated European programme for tackling illegal, unreported, and unregulated (IUU) fishing and consumer fraud**

G. R. Carvalho and the \*FishPopTrace consortium

\*(<http://fishpoptrace.jrc.ec.europa.eu/about/consortium>)

Although exploited fish have traditionally been managed on a geographic basis, for conservation purposes they should be managed at the population level: the extent and dynamics of population structuring underlies resilience and sustainability. More effective enforcement and conservation demands a focus on identification and monitoring of wild fish populations and traceability of products. An overview of the context and outputs of the European consortium project, FishPopTrace is presented. The programme brings together expertise in fish biology, genetics and forensics to improve the traceability of fish and fish products and protection of consumer interests through enhanced understanding of the dynamics, temporal stability and distribution of major populations of four key exploited fish species: Atlantic cod (*Gadus morhua* L.), European hake (*Merluccius merluccius* L.), Atlantic herring (*Clupea harengus* L.), and common sole (*Solea solea* L.). Three primary traceability tools have been developed to incorporate both on-board sampling (otolith microchemistry and morphometrics) and sampling throughout the food supply chain (single-copy nucleotide polymorphisms, SNPs). The latter are the only current widely used molecular tool that will allow detection of population variability across a range of spatial scales,

and yet has sufficiently high reproducibility and robustness for forensic validation. The framework provided by FishPopTrace will thereby enhance the European Common Fisheries Policy aim to promote sustainability through conservation of genetic resources. Incorporation of population biodiversity (“biocomplexity”) into management instruments and policies will further underpin an ecosystem-based approach to fisheries through increased potential for recovery of declining stocks and associated resilience in trophic interactions.

Keywords: European waters, fisheries forensics, IUU, traceability.

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## ICES CM 2012/H:07

### **FishPopTrace: a new genetic technique for fisheries monitoring and the identification of IUU**

Sarah Helyar, Morten Limborg, Dorte Bekkevold, Martin Taylor, and Gary Carvalho

The importance of marine organisms for both economic and ecological reasons is enormous; and knowledge of population structure and connectivity is crucial for the sustainable utilization and conservation of exploited fish stocks. However, in most cases our understanding of these spatial patterns of natural variation at a genetic level is limited. For marine fish, the maintenance of local stocks containing adaptive diversity is associated with the sustainability and resilience of marine fisheries in the face of climatic and anthropogenic threats. However, many previous genetic studies have observed weak genetic structure in marine fish and, combined with a pelagic larval stage, this has supported the hypothesis that gene flow is extensive and that there is little opportunity for differentiation and local adaptation any scale other than macrogeographic. However, the application of single nucleotide polymorphisms (SNPs) has the potential to demonstrate previously undetected spatial and temporal population structuring and signatures of adaptive variation. In addition, SNPs are uniquely applicable for the identification and monitoring of wild fish populations and the traceability/authenticity of products throughout the food supply chain, allowing effective enforcement of fisheries regulations, and the identification of IUU. Here we demonstrate the utility of SNP panels developed in a European Commission-funded consortium, FishPopTrace, to scenarios that are relevant for the identification of potential illegal fishing and/or mislabelling for a commercially important Atlantic species herring (*Clupea harengus*).

Keywords: authenticity, commercial fisheries, herring, IUU, SNPs, traceability.

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## ICES CM 2012/H:08

### **The power of integrating genetic and otolith analytical approaches into the spatial management of exploited marine fish**

G. E. Maes, E. L. Cuveliers, E. Diopere, A. Cariani, A. J. Geffen, and F. A. M. Volckaert

Exploited marine populations exhibit various degrees of discreteness, ranging from historical evolutionary to contemporary ecological levels of differentiation. An integrated approach combining complementary population discrimination tools such as otolith microchemistry and genetics may capitalize on these different time-scales to improve discrimination and traceability power in management applications. Here, we discuss the most recent integrated results obtained from genetic markers (microsatellites and SNPs) and otoliths (microchemistry and shape data) on juvenile/adult sole (*Solea solea*) populations in the Northeast Atlantic Ocean. While genetic markers provide a clear regional differentiation and local adaptation patterns, otoliths data often provide an improved small-scale geographical resolution. Our results highlight the power of a multimarker approach depending on the required spatial resolution scale in future management scenarios. Monitoring efficiently the resilience of marine harvested populations hence requires interdisciplinarity in research priorities, covering both the evolutionary and ecological components of population connectivity. Such information is pivotal to the reliable development, validation, and later application of integrated traceability tools for fisheries enforcement.

Keywords: assignment, connectivity, isolation-by-distance, microchemistry, microsatellites, traceability.

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### ICES CM 2012/H:09

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#### Unraveling biocomplexity of Northeast Atlantic herring stocks using SNP markers

Dorte Bekkevold, Morten T. Limborg, Sarah J. Helyar, Martin I. Taylor, Einar E. Nielsen, Gary R. Carvalho, and the FishPopTrace Consortium.

Atlantic herring (*Clupea harengus*) exhibit biocomplexity, with widespread, geographically explicit populations that perform long-range migration to common feeding and wintering areas, where they are exploited by fisheries. This means that exploited stocks do not describe discrete units, thereby complicating stock assessment and management. It is therefore of management interest to trace individual population migration patterns and contributions to fisheries. To underpin management and to develop a validated tool for traceability of individuals from mixed-stock samples we applied single nucleotide polymorphism (SNP) markers in Northeast Atlantic herring population samples. Marker panels were targeted to include gene-associated loci to maximize statistical resolution. Application of 281 SNP markers to samples representing different levels of stock complexity showed that the regional origin of individual fish and mixed fish samples could be successfully identified at high statistical power. Our results demonstrate the usefulness of genetic stock identification even in fish, such as herring, exhibiting weak neutral genetic structure, and that such methods allow unprecedented insights into temporal and spatial dynamics applicable to stock assessment methods, as well as presenting a traceability tool for certification of herring and herring products.

Keywords: genetic stock identification, Northeast Atlantic, spatio-temporal structure, traceability.

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### ICES CM 2012/H:10

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#### Population structure of marine fish: a GIS-based tool supporting science and decision development for managing, conservation, and policy-making

Eoin Mac Aoidh and Jann Th. Martinsohn

Molecular technologies facilitating fish species identification and population dynamics analysis are rapidly evolving, shedding new light on the population structure of the fish in our oceans and providing a framework for certified traceability schemes. Meanwhile, as consumer demand for certified fish grows, there is an increased incentive for those engaging in illegal, unreported, and unregulated (IUU) fishing and product mislabelling to create falsely certified produce for illegal economic gain. Improved monitoring, control, and surveillance (MCS) measures which exploit the burgeoning knowledge-base derived from the exploration of population dynamics are critical to curb illegal activity. In practice, the implementation of an effective MCS scheme requires both the development of a tractable framework of independent testing, and the adoption of supporting policies and legislation on a multinational scale. A major impediment to the development of adequate policy and legislative support is the difficulty in communicating complex scientific concepts to non-scientific stakeholders. We examine existing policy and present a web-based geovisualization tool designed to communicate fish population structure acquired from the growing knowledge-base hosted at the European Commission's Joint Research Centre. The interactive map-based visualizations highlight potential links between population structure and the surrounding environment. This serves to underline the importance of sustainable exploitation and gives a simplified visual representation of population structure and dynamics analysis. We conclude by outlining the contribution of this visualization tool to a better understanding of population structure issues among non-scientific stakeholders, the aim of which is to improve future policy decisions and provide improved sustainability in the fisheries sector.

Keywords: conservation, legislation, management, MCS, policy, visualization, stakeholders.

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## ICES CM 2012/H:11

### Where does the cod come from? Panels of gene-associated markers provide vastly improved origin assignment in Atlantic cod (*Gadus morhua*)

Einar Eg Nielsen, Jakob Hemmer-Hansen, Martin Taylor, FishPopTrace Consortium, and Gary R. Carvalho

Methods for determining the geographical origin of individual fish are in high demand for fighting illegal, unreported, and unregulated (IUU) fishing and for independent control of catch certificates and “eco-labels”. Hitherto, genetic origin assignment of marine fish has been hampered by the general low levels of genetic differentiation among populations. By using a new concept of studying gene-associated single nucleotide polymorphisms (SNPs), we show that individual cod can be assigned back to population of origin with unprecedented high levels of precision. We assessed pan-European variation in more than 1200 gene-associated SNPs in cod and found that levels of differentiation for a subset of 132 SNPs was best explained by a model including directional selection. These high-differentiation SNPs were used for designing “minimum panels with maximum power” for a number of case studies relevant for controlling illegal fishing, eco-labels, and fisheries management. Our results demonstrate how application of gene-associated markers will probably revolutionize origin assignment in cod by providing faster, cheaper, and more reliable tools for origin assignment.

Keywords: Atlantic cod, DNA, population assignment, population genetics/genomics.

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## ICES CM 2012/H:12

### The world of illegal, unreported, and unregulated fishing

Michele Kuruc

Illegal, unreported, and unregulated (IUU) fishing continues to plague the world’s fisheries while jeopardizing conservation of the marine environment and threatening sustainability. IUU fishing is pervasive, occurring in all regions of the world; it is found on the high seas, in exclusive economic zones and in near-shore fisheries. High profits, growing global markets for fish, and overcapacity in the fishing industry drive IUU activities. The situation is further aggravated by inadequate capacity and resources to control IUU fishing, underdeveloped regional cooperation, and corruption. Recent estimates indicate that annual global losses due to IUU fishing may range from US\$10 to 23 billion although accurate quantification remains difficult due to the covert nature of the activities. To address IUU fishing, different approaches and tools are needed; there is not a single solution to all situations. Development and implementation of appropriate tools and approaches remain vital. One of the key issues in combatting IUU fishing is the need to improve the likelihood of detection with investigative tools such as those to be discussed in this session. This presentation is intended to provide context to the need for science-based applications to assist in detections of species and populations as essential tools to eliminate IUU activities.

Keywords: illegal, unreported, and unregulated (IUU) fishing, monitoring, control, and surveillance (MCS).

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**ICES ASC 2012/H:13**

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**Patterns and drivers of seafood mislabelling in European markets**

Amanda L. Bréchon and Stefano Mariani

In recent years, seafood mislabelling has been recognized internationally as a widespread phenomenon with evidence from many studies. There is concern that species are being mislabelled because of a shortage of the desired species, therefore, seafood mislabelling is not only an indication of fraud but is, importantly, an indication that global fisheries are in difficulty. Resource scarcity, the potential for economic profits, and poor legislation are the main drivers of mislabelling, the results of which hold implications for the sustainable management and conservation of overexploited marine resources, food safety and even consumer health. Seafood mislabelling is prevalent despite a strong and detailed set of laws on both labelling and traceability of fishery products in the EU. The aim of my research is to look at the prevalence of Atlantic cod (*Gadus morhua*) mislabelling—through mtDNA COI barcoding—across European countries and determine to what extent is the phenomenon a consequence of poor governance and policy implementation. Since cod are being sampled from supermarkets in both European Union member and non-member states, as well as in both cod-producing and cod-importing countries bordering the North Atlantic Ocean, we are able to examine some key political and market-driven factors underlying the phenomenon. The effect of each country's existing management, legislation, and governance aspects on the above prevalence will then be investigated. Further study will also aim to determine at what level within the production chain this problem is taking place, something that is currently unclear.

Keywords: cod, Europe, governance, legislation, seafood mislabelling.

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**ICES CM 2012/H:14**

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**Clinal variation at the pantophysin locus (*PanI*) in northeast Arctic cod (*Gadus morhua morhua* L.) in the Barents Sea**

Daria A. Zelenina, Galina A. Makeenko, Alexander A. Volkov, and Nikolai S. Mogue

A total of 1705 fish from different locations of the open part of the Barents Sea were scored for *PanI* locus. The sample-collection area covered the majority of northeast Arctic cod feeding regions and stretched from Spitsbergen to the southeastern part of the Barents Sea. The compared samples were collected at 19 locations in different years (2009, 2010, 2011) and seasons (winter, spring). The analysis performed displayed a considerable clinal distribution of *PanI* allele frequencies from about 5% or less of allele *PanIA* in the northern regions to almost 50% in the southeast. Interannual comparisons revealed temporal stability of allele frequencies in most of the location throughout the Barents Sea. At the same time, no significant diversity among samples from northern and southern parts of the Barents Sea was shown by microsatellite screening.

Keywords: clinal variation, northeast Arctic cod, pantophysin.

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**ICES CM 2012/H:15**


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**Genomic tools for fishery and conservation of the European hake**

Ilaria Milano, Massimiliano Babbucci, Montserrat Espineira, Miroslava Atanassova, Audrey Geffen, Marco Stagioni, Fabio Fiorentino, Frank Panitz, Rob Ogden, Rasmus O. Nielsen, Martin I. Taylor, Sarah J. Helyar, Gary R. Carvalho, Gregory E. Maes, Alessia Cariani, Tomaso Patarnello, FishPopTrace Consortium, Fausto Tinti, and Luca Bargelloni

Next-generation sequencing (NGS) technologies now offer the opportunity to move from population genetics to population genomics, even in non-model species. In the present study, two NGS platforms, the Roche 454 FLX and the Illumina Genome Analyzer, were used to discover single nucleotide polymorphisms (SNPs) in the muscle transcriptome of the European hake (*Merluccius merluccius*), which represents one of the most important demersal fisheries in Europe. Transcriptome sequencing and de novo assembly into unique contigs, *in silico* SNP detection, and validation by high-throughput genotyping yielded a set of 395 polymorphic SNP loci. Of these, 381 nuclear SNPs were used to scan genomic variation in 19 Atlantic and Mediterranean populations of *M. merluccius*. As all SNPs reside in the functional (transcribed) portion of the hake genome, it is expected that a subset of sequence variants might be located in genomic regions potentially involved in local adaptation, conveying greater resolving power for the detection of spatial structuring on a large and/or local scale. Combining genome scans and correlation analysis between SNP allele frequencies and environmental factors, several candidate loci that are potentially under divergent selection were identified, mainly genes involved in muscles' structural organization/function and protein synthesis regulation, or implicated in energy metabolism. Such "outlier" loci showed high performance in resolving population structure, unveiling distinct genetic clusters at multiple spatial scales, which possibly correspond to locally adapted populations. Following a precautionary approach, these results suggest the need to revise the current management strategies of European hake stocks, particularly within basins.

Keywords: Atlantic and Mediterranean, European hake, outlier, SNPs.

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**ICES CM 2012/H:16      Poster**


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**Consistency between management units and genetic structure in saithe (*Pollachius virens*)? Application of modern genetic tools to an exploited species in the North Atlantic**

Atal Saha, Tina Graceline Kirubakaran, Matthew Kent, Sigbjørn Lien, Jon-Ivar Westgaard, Svein Erik Evolden, Lorenz Hauser, Halvor Knutsen, Steve Cadrin, and Torild Johansen

The identification of isolated populations in widely distributed marine species is complicated by low levels of genetic differentiation caused by large population sizes and recent separation. Modern genetic approaches now allow for the isolation of hundreds of genetic markers, therefore improving the power to identify biologically meaningful management units. Saithe (*Pollachius virens*) is a highly migratory and commercially important fish species in the North Atlantic. The species geographical range is divided into several management units on both sides of the Atlantic, though the genetic population structure is unknown. There are three management units of saithe defined in Northwest Atlantic waters (here named Pollock on St. Pierre Bank, the Scotian Shelf, and in the Gulf of Maine), and six units in the Northeast Atlantic: west of Ireland, west of Scotland, off Faroe Island, around Iceland, in the North Sea, and finally the northeast Arctic unit along the Norwegian coast (62°N). The question of consistency between management units and population genetic structure remains. The present study is aimed at testing for genetic structuring of the species within the North Atlantic. We apply genome-wide sequencing technologies to identify markers (single nucleotide polymorphisms, SNPs) that are most discriminatory between sites across saithe geographical range. A panel of 200 SNPs is used for a detailed analysis of population structure to measure the level of exchange of genetic material in this saithe complex.

Keywords: North Atlantic, population genetic structure, single nucleotide polymorphisms, stock identification.

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**Theme Session I**  
**Joint ICES/PICES Session—Multidisciplinary perspectives in**  
**the use (and misuse) of science and scientific advice in**  
**marine spatial planning**

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**ICES CM 2012/I:01**

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**Multimethod, interdisciplinary, cooperative research to support coastal and marine spatial planning in the Balearic Islands**

Amy Diedrich, Pablo Balaguer, Jorge Terrados, and Joaquín Tintoré

Sustainability is a complex, multifaceted goal influenced by diverse scientific disciplines and sectors of society. Coastal and marine spatial planning (CMSP), in conjunction with integrated management approaches, can support the achievement of sustainability. Research that informs this process should be multimethod, interdisciplinary, cooperative, and adaptable to different spatiotemporal scales and social–ecological contexts. Coastal observing and forecasting systems, such as SOCIB in the Balearic Islands that generate multiple data types (spatial, social, ecological, physical, etc.) in response to science, technology development and civil society needs, are critical to CMSP. Integration of data generated by these systems into environmental planning and governance systems is an important current scientific priority of SOCIB, as is the development of methodologies that link data from natural and social sciences. In this context, this presentation will outline the structure of interdisciplinary tools and methods SOCIB is using to support CMSP in the Balearic Islands and in the wider Mediterranean. Elements of the framework include, among others, sustainability indicators, spatial data analysis, qualitative and quantitative ethnographic research, participatory methods, physical oceanography, and geomorphology. We will showcase an empirical example where we address the environmental management challenge of recreational boating in the islands. In this case, we integrate social, biophysical, and spatial data. Our example is relevant at fundamental (methodological, theoretical) and applied (management) levels and thus should be of interest to scientists and practitioners.

Keywords: coastal and marine spatial planning, coastal ocean observing systems, integrated management, interdisciplinary approach, Mediterranean, social-ecological dimensions.

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**ICES CM 2012/I:02**

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**Petroleum activities in the Lofoten area: What is the worst case scenario?**

Anne Blanchard, Ragnhild Boland, Jan Helge Fosså, Kjellrun Hiis Hauge, Daniel Howell, and Frode Vikebø

The complexity and uncertainty surrounding environmental problems can fuel heated debates between stakeholders with conflicting interests, priorities, and agendas. Many such debates have arisen at the “science–policy interface” relative to calls to open new areas for petroleum activities in the Lofoten area, in the north of Norway. The Lofoten is an especially valuable and vulnerable archipelago, known for its unique landscape and as a key spawning and nursery area for several fish stocks, hosting also the world’s largest known deep-sea coral reef. Introducing petroleum activities brings additional competition for this valuable space, and demands an assessment of the “worst case scenario” of an oil spill to support political decision-making. However, such a complex model introduces numerous uncertainties, which have become contentious both within the scientific community, and in dialogue with the petroleum industry. A comprehensive worst case scenario must look at the possible effects on all ecosystems and species of the area, along every stage of their life-span, together with effects on other sectors of activity (particularly the tourism

and fishery industries), and the socio-cultural characteristics of the region. This paper unpacks the debate surrounding the science and uncertainties of calculating the worst case scenario in the Lofoten, focusing on three key aspects: (i) whether historic oil spills are to be used as supporting empirical data; (ii) assessing the effects of an oil spill on the environment; and (iii) proposing measures to be taken on the basis of the worst case scenario.

**Keywords:** decision-making, petroleum activity, uncertainty, worst case scenario.

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### **ICES CM 2012/I:03**

#### **Multiple interests across European coastal waters: the need for a common language**

Jorge Ramos, Katrine Soma, Øivind Bergh, Torsten Schulze, Anne Sell, Vanessa Stelzenmüller, Timo Mäkinen, Fabio Grati, Vicki O'Donnel, Gianna Fabi, and Ellen Hoefnagel

Many human activities make use of coastal waters and their inherent resources. Besides fisheries and aquaculture, many other coastal activities and uses are canvassed in that scope. Since different activities advance towards dissent—economic, environmental, and socio-cultural objectives—conflicts occur when these multidimensional activities collide, according to different spatial contexts and institutional settings. Therefore such situations invoke adequate planning. The CoExist project consortium in Europe aims to outline a process which avoids unnecessary conflicts or even enhances mutual benefits between different activities in the coastal zone. The project develops and tests the necessary steps within six case studies, representing different levels of complexity. Using a transparent approach based on multicriteria analysis (MCA), we characterize and establish priorities of future development/conservation in the coastal area. Data for this European research project have been obtained by questioning the different groups of stakeholders in each case study. It becomes apparent that the coexistence of multiple activities in the long run will only be possible and sustainable if coastal/marine spatial planning is adequately addressed by means of stakeholders' inclusivity and scrutiny.

**Keywords:** case studies, CoExist project consortium, European coastal zone, multicriteria analysis (MCA).

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### **ICES CM 2012/I:04**

#### **Integrated Bayesian risk analysis of ecosystem management in the Gulf of Finland, the Baltic Sea—How to do it?**

Inari Helle, Jarno Vanhatalo, Mika Rahikainen, Samu Mäntyniemi, and Sakari Kuikka

Human activities may have devastating effects on marine and freshwater ecosystems. The negative impacts can develop gradually (e.g. increased nutrient run-off resulting in eutrophication) or they can be abrupt and catastrophic (e.g. spills of harmful substances). Usually both the frequency and impacts of these events are difficult to predict. In addition, ecosystems are often threatened not only by a single factor, but instead by multiple stressors at the same time. Due to this complexity it is difficult for decision-makers, for example, to realistically evaluate the effects of alternative management options. In this paper we demonstrate how to create a probabilistic decision model to evaluate the effects of several risk factors on different components of the ecosystem in the Gulf of Finland, the easternmost part of the Baltic Sea. The risk elements considered are eutrophication, oil spills, and harvesting. With the model one can estimate the effects of these factors on some examples of species and water quality variables in the Gulf of Finland. The general model is a Bayesian network, which uses various inputs, for example the results produced with 3D ecosystem models and stochastic population dynamics simulation models. Although we use the Gulf of Finland as a case study, the methodology is also applicable to other areas facing multiple risks. The

model can also be developed further to encompass the costs and benefits of alternative management actions.

Keywords: Bayesian networks, environmental management, Gulf of Finland, multiple risks.

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## ICES CM 2012/I:05

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### Key challenges with the use of risk assessments of large accidents in marine spatial planning

Erik Olsen

Understanding the impacts and effects of human activities on the ecosystem are key to successful marine spatial planning. The impacts of regular activities such as fisheries, shipping, and oil production are relatively easy to assess. Impacts of accidents, especially those of a catastrophic proportions, such as large blow-outs on oil fields and meltdowns of nuclear reactors, are much more difficult to assess. Typically, the impacts of such rare, but large accidents are analysed using risk assessments. Traditional risk assessments are based on mathematical models that try to replicate complex (and sometimes poorly understood) ecological processes in a simplistic and mechanistic manner. Risk assessment methods are also dependent on the quality of the input data used to run these models. The resultant estimates of risk are therefore often prone to error stemming from: (i) low ecological realism in the models—complex and important processes are either ignored or overlooked, (ii) lacking spatial and temporal resolution—most risk assessment models are simple linear mathematical models, and (iii) little respect for poor data quality or long-term (decadal) variability in species distribution or population size. Taken together, all these errors make the current risk assessment method unreliable to be used to assess the absolute risk levels to the ecosystem and alternative methods should be used to assess the ecosystem risks.

Keywords: errors, impacts, risk assessments.

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## ICES CM 2012/I:06

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### Petroleum activities in the Lofoten area: What is the scientist's role in the decision-making process?

Ragnhild Boland

On 11 March 2011 the most recent debate on whether to start extracting oil and gas in the Lofoten area came to an end. One of the central questions raised in the debate was if it is possible to combine petroleum activity with justifiable management of other natural resources, especially with the fisheries. Scientists at the Norwegian Institute for Marine Research contributed with work that hopefully could give an answer to this question. As scientists they were asked to fill knowledge gaps while dealing with complex systems and uncertainties that were difficult to reduce, if reducible at all. What to do then, when the scientific conclusion is that there is a profound lack of understanding about connections within the complex systems that may not even be remediated by further research? This situation may leave the decision-makers somewhat helpless. And because of this scientists are sometimes put in situations that amount to considerable indirect pressure on research. This paper will present a reflection on the role of the scientists in matters of uncertainty and complexity, with reference to the Lofoten issue.

Keywords: Barents Sea, natural resource management, petroleum activities.

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**ICES CM 2012/I:07**

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**Mapping inshore fishing activity to inform marine planning in Scotland: a pilot project using stakeholder data in the Pentland Firth and Orkney waters**

Matt Gubbins, Anne McLay, Ian Davies, Gareth Jones, Robert Watret, Elisa Barreto, and David Bruce

Marine planning relies on robust data on human uses of the sea in order to minimize spatial conflicts and account for the cumulative effects of multiple activities in decision-making. Capture fisheries are major users of our seas and it is important to account for the activity of this sector in marine plans. Activity and value data already exist for offshore fisheries in Scottish waters through the use of vessel monitoring systems (VMS) on large (>15 m) vessels. These data have already been used in sectoral planning for the renewable energy industry in Scotland, to help identify areas of least conflict that may be suitable for renewables development. However, the greatest competition for space is in the inshore environment, where most fishing is undertaken by small (<15 m) vessels not fitted with VMS. A pilot study to map inshore fishing activity using stakeholder data is presented here for the Pentland Firth and Orkney waters to the north of Scotland, where there is considerable interest and potential for renewable energy development. This study used questionnaire-based survey methods to identify fishing areas (polygons) in GIS software for each vessel by gear type and species and assign an estimate of relative value to each polygon. These detailed spatial data were then analysed to present anonymous maps of absolute and relative value for different fisheries. It is hoped that roll-out of this approach across Scottish inshore waters will provide data that can be used in spatial models to help inform planning decisions across multiple marine regions.

Keywords: Pentland Firth, marine spatial planning, Scotland, stakeholder data.

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**ICES CM 2012/I:08**

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**Science–policy interactions: between policy fragmentation, integration, and new paradigms for planning and management**

Andreas Kannen

Human activities in marine areas are increasing in number and intensity, and patterns of sea use are changing as a result of political, economic, and societal developments. Associated with the multitude of issues and sea uses are fragmented policy frameworks, not only divided by sectors but also between environmental regimes and the balancing approach of marine/maritime spatial planning. The implementation of resulting management plans is hampered by the potentially conflicting policy objectives and differing jurisdictions at various levels of government in a given geographical area. Furthermore, neither long-term climate change impacts nor future socio-economic and cultural developments can be precisely predicted and put in definite numbers which offer a definitive guide for policy development. Planning under these circumstances can be characterized by the term “planning under uncertainty” and requires a move towards continuous planning processes reacting upon changing contexts instead of mainly data-driven decisions. Today’s prevailing approach of scientific management seems to be ill-equipped to offer solutions under these circumstances, for example in dealing with transboundary cumulative effects or with normative and value-driven conflicts between different actors. This presentation will illustrate such problems and argue for a move towards adaptive, transnational, and participative modes of coastal and marine governance based on research which analyses the particular social, cultural, and normative context of decision-making. It aims to link the context in which institutions act to potential contributions of research and as well as set the stage for further discussions within the session and beyond.

Keywords: marine spatial planning (MSP), science–policy interaction, sea use.

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## ICES CM 2012/I:09

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### **How can the social-cultural dimensions of ecosystem services be incorporated in marine spatial planning?**

Kira Gee

It is commonly agreed that marine spatial planning (MSP) is a cyclical process. Stages usually comprise stocktaking, conflict analysis, the planning stage, implementation, monitoring, and evaluation, with stakeholder involvement and transparency important aspects throughout. Design and quality in MSP so far are based on (i) the quality and validity of data and GIS-based information, (ii) the processes involved in developing and implementing a maritime spatial plan, and (iii) the performance of the plan against its original objectives, with environmental management system theory and reflective practice proposed as a potential theoretical basis. This paper argues that stakeholder values are still a neglected factor in this context. The purpose of MSP is to allocate sea space in the best possible way, acknowledging and balancing the different demands placed on the marine environment. As such, MSP is really a continuous process of negotiation which needs to navigate between the often different value-sets, interests, and priorities of a wide range of stakeholders. In this process of negotiation, it is essential to acknowledge the breadth of values associated with the sea as well as confluences and disagreements of values as one root cause of agreement and conflict. It is also important to acknowledge that these confluences and disagreements may be temporary, leading to shifting alliances over time. The paper will present a framework based on the concept of cultural ecosystem services for assessing stakeholder values and provide an example for its application. It then suggests ways for incorporating “value literacy” as an element of MSP processes.

Keywords: cultural ecosystem services, marine spatial planning (MSP), stakeholder values.

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## ICES CM 2012/I:10

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### **Evaluating the likelihood of meeting environmental objectives using Bayesian belief networks (BBNs): an integrated approach to ecosystem-based management**

Antony M. Knights, Leonie A. Robinson, Helen J. Bloomfield, *et al.*

The marine environment and its coastal margins are heavily exploited and strong negative effects on the ecosystem are seen. To mitigate the impact of resource exploitation, management measures are implemented to limit the exposure of habitats and species to detrimental activities. There are several recent management tools that have adopted an ecosystem approach but evidence of success has been limited. A key challenge has been how to combine cross-ecosystem, cross-sector ecosystem–pressure interactions, and differentiate the contribution of each activity to overall ecosystem vulnerability. This requires: (i) definition of the interactions between sector ecosystem and pressure, (ii) a measure of ecosystem exposure to pressures, and (iii) an assessment of the sensitivity and resilience of the ecosystem to that pressure. Where difficulties lie is that the data necessary to evaluate ecosystem vulnerability can vary in type, scale, and certainty if and when available. When data are unknown or uncertain, other qualitative measures or expert knowledge must be used to express ecosystem vulnerability. Here we combine quantitative and qualitative data with expert knowledge within a Bayesian belief network (BBN) to evaluate the threat of multiple human activities and pressures to European marine ecosystems and illustrate an integrated approach for their management. Using the Marine Strategy Framework Directive as an example, we assess the likelihood of failing its environmental objective of Good Environmental

Status under current use conditions and by way of scenarios, illustrate combinations of management measures most likely to support achievement of GES.

Keywords: Bayesian belief network, ecosystem approach, human activities, marine ecosystem.

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### ICES CM 2012/I:11

#### **“Slightly covered by seawater”: defining the boundaries of science and sandbanks on the Dogger Bank**

Ditte Degnbol

Between 2002 and 2011, the UK, the Netherlands, and Germany have been working hard to determine where in their respective offshore Exclusive Economic Zones the Dogger Bank begins to be a sandbank. The objective has been to define the boundaries of Natura 2000 Marine Protected Areas for the protection of biodiversity, in particular habitat type 1110 in the EU Habitats Directive—“sandbanks slightly covered by seawater all the time”. The prospects of protected areas on the Dogger Bank raise concerns. Among other things the world’s biggest wind farm has been proposed here, and it is an important site for a major fisheries industry. NGOs, on the other hand, hold on to the Habitats Directive as one of the few international conservation initiatives in the marine environment. The national scientific advisors are tasked with providing boundaries that are considered scientifically justified by the interested parties as well as the European Commission. By comparing the parallel designation processes on the German and UK part of the Dogger Bank, this study shows the ways in which scientific advisors, while tasked with producing scientific justification for policy, address stakeholders in their decisions about methodology, data and analysis. The study draws on document readings, qualitative interviews with scientists, stakeholders and managers in the UK and Germany, and observations of a number of meetings. The analysis draws on STS literature on scientific expertise, public understanding of science, mandated science, and laboratory studies. The work is funded by the EU 7th FP project JAKFISH.

Keywords: none

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### ICES CM 2012/I:12

#### **Regulatory gap analysis approach**

Matthew Hardy, Julia Ekstrom, and Roland Cormier

Regulatory instruments (e.g. laws, regulations, policies, practices, etc.) are typically designed to manage activities on a sector-by-sector basis without considering existing management measures or the implications on the interests of other jurisdictions. The consequence can be inability to be effective in meeting ecosystem as well as economic objectives that cross multiple jurisdictions, ineffectiveness of control or mitigation measures, or duplication of efforts. In practice, the complex regulatory landscape that is organized jurisdictionally and spatially can confound accountabilities when attempting to address the cumulative environmental effects of a number of activities. An analysis of existing management strategies can help regulators to assess if enhanced management measures are needed. The resulting understanding of these analyses also allow for the strategic application of control or mitigation measures that can be applied in targeted, environmental effect-centric, equitable across activities, operationally effective and cost-efficient approaches. The regulatory gap analysis approach developed considers the application of existing sector-based measures which control and/or mitigate environmental effects within an ecological unit. A “bowtie analysis” was applied to visualize where the management measures exist for activities and pressures relevant to environmental effects. The outcomes of this work provide several elements of



quality assurance for decision-making in coastal and marine planning. The work can facilitate a joint regulatory validation process through interjurisdictional governance bodies with the purpose of aligning regulatory instruments and leveraging resources for more effective planning and management of activities which contribute to environmental effects.

Keywords: none

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## ICES CM 2012/I:13

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### The science of negotiation

Ina Krueger, Liv Berner, and Rudi Wurzel

Marine spatial planning processes seek to manage decreasing space, as upcoming sectors compete with established sectors for access to the sea. Aspirations for more inclusive governance require decision-makers to balance diverse stakeholder-needs. However, stakeholders may differ strongly in their interpretations of the science on which the management decisions are based. The international negotiations on the newly appointed Dogger Bank Special Area of Conservation (SAC) are a fascinating example of how scientific information is sought and transformed into a management plan, that not only provides the necessary steps to reach the biodiversity objectives of Natura 2000, but can also be widely accepted by a variety of stakeholders. Around the Dogger Bank, a submerged sandbank in the North Sea, national governments and sectorial stakeholders struggle to agree on a regulation which aims at restoring the habitat to a better ecological state. In this novel international process the NS RAC was invited to produce a first proposal for a fisheries management plan. Fierce negotiations unfolded between states, NGOs, and fishers. This paper will elucidate how different stakeholders make use of scientific and lay knowledge, how they question, interpret, and apply it in sometimes conflicting ways to build up arguments, and how this impacts the negotiations.

Keywords: conflicts, Dogger Bank, governance, negotiation, stakeholders.

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## ICES CM 2012/I:15

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### Fishery versus new concepts of the use of sea space—example of the Polish Marine Areas

E. Andrulowicz and W. Pelczarski

This paper attempts to discuss how fishery may coexist with the new technical developments and the large-scale constructions which are planned to be built within the Polish Exclusive Economic Zone of the Baltic Sea. Polish fisheries will face restrictions of their activities as a result of numerous projects on the use of the sea space for functions other than fishing. The proposed activities include: nature conservation areas, areas for energy production (wind farms), new areas for extraction of mineral resources (sand and gravel, oil and gas, shale gas), new navigation channels as well as new routes for pipelines and cables. An attempt is undertaken to discuss how to achieve coexistence with the new users of the sea and to diminish potential conflicts through the marine spatial planning process. Discussion is based on a review of fishing effort in the Polish EEZ, analysis of the monetary and social value of fishery, and the need for valorization of the sea space before introducing new activities. An attempt is also set to indicate those parts of the sea space which are of vital importance for preserving fishery and fish resources and those parts that can

accommodate other activities. The authors assume that the Polish example might be regarded as an useful case study for the other Baltic countries.

Keywords: Baltic Sea, fishery, large-scale constructions, marine spatial planning.

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## ICES CM 2012/I:16

### **Spatial interactions between human activities in the coastal area of the Adriatic Sea**

Fabio Grati, Øivind Bergh, Luca Bolognini, Roberto Gramolini, Torsten Schulze, and Gianna Fabi

The present study has been developed inside the framework of the EU Project Coexist (FP7-KBBE-2009-3), a broad, multidisciplinary approach to evaluate the interactions of human activities with the goal of providing a roadmap for a better integration, sustainability, and synergies between these activities in the coastal zone. Individual processes, as well as their interactions, have been investigated in case studies. The north-central Adriatic Sea is the only Mediterranean case study inside the Coexist Project. The coastal strip of this basin is the seat of several human activities, including commercial and recreational fisheries, and intensive and extensive mussel culture. Among the other human activities, tourism, shipping, and gas extraction are relevant sectors. The combination of these driving forces inevitably results in spatial conflicts and requires an integrated approach to management of the interactions between these multiple pressures. Analysis of interactions have been accomplished by means of GRID (GeoReference Interactions Database), which is a web-based flexible database and tool to analyse conflicts and synergies, specifically developed inside Coexist Project. Interaction matrices evidenced that the most important human activities generate high level of conflicts inside the case study coastal area. Artificial reefs and Marine Protected Areas (MPAs) could mitigate these conflicts, providing efficient management tools. Analysis of future scenarios where a number of new management measures are applied to the actual situation pointed to possible solutions for managing space and allowing coexistence of some coastal human activities.

Keywords: Adriatic Sea, aquaculture, fishery, marine spatial planning.

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## ICES CM 2012/I:17

### **Shetland Marine Spatial Plan: an ecosystem-based approach in formulating marine policy and management options**

Christina Kelly, Lorraine Gray, and Jacqueline Tweddle

Marine environmental policy is an important aspect of the current European, UK, and Scottish environmental agenda. The development of the Shetland Marine Spatial Plan (SMSP) was initiated by the Scottish Government, and it has been implemented on a voluntary basis since 2008. So far, it has successfully been used as a tool to guide developers and others in putting their proposals for changes to existing uses (such as aquaculture and fishing) and introduction of new uses (such as expansion of ports, renewable energy, and oil and gas infrastructure). More recently, it has been used by managers to voluntarily close sea areas to scallop dredge fishing and develop oil spill contingency planning to protect important habitats. Through policy, it provides suggestions, proposes directions and highlights opportunity for development. This presentation will demonstrate the unquestionable benefits of spatial management with a focus on using GIS to map cumulative pressure areas around the Shetland Islands based on an ecosystem-based risk assessment and how this will assist in implementation of marine policy. Simultaneously, by ensuring the provision of clean, healthy, diverse, and productive seas through sustainable marine

policy, other environmental targets such as achieving Good Environmental Status under the Marine Strategy Framework Directive are also implemented.

Keywords: marine, plan, Shetland, spatial.

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**ICES CM 2012/I:19**

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**The role of knowledge and research in two case studies on cross-border marine spatial planning in the southern North Sea**

S. Hommes, M. A. Pastoors, V. Stelzenmüller, D. Goldsborough, F. Maes, T. K. Sørensen, R. Gerits, M. Stuiver, and B. de Vos

Within the southern North Sea, several EU Member States are developing or have already implemented marine spatial plans for their EEZs. However, marine spatial planning (MSP) is usually carried out at the national level and largely ignores the possible mutual benefits of cross-border cooperation. The MASPNOSE project has facilitated two concrete, cross-border MSP initiatives:

- the Thornton Bank area on the border between Belgium and the Netherlands where cross-border coordination could be used to address wind energy development, shipping and fisheries management;
- the Dogger Bank international fisheries management plan developed by the North Sea Regional Advisory Council (NSRAC). Here, cross-border MSP was used to develop a stakeholder perspective on spatial management measures.

The two case studies were in different stages of the cross-border MSP process. In this paper we focus on the role of knowledge and research in these two planning initiatives. We describe the knowledge requirements that have been articulated (e.g. on ecosystem components, spatial-temporal patterns, current and future human use, institutional setting) and how these requirements have been addressed through data workshops with stakeholders, analysis of policy documents and interviews. In the Thornton Bank case study the knowledge requirements focused on the institutional and administrative settings and the identification of policy priorities. In the Dogger Bank case study, stakeholder knowledge was combined with research knowledge to assess zoning options for the Dogger Bank area.

Keywords: cross-border, Dogger Bank, Marine Spatial Planning, North Sea, Thornton Bank.

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**ICES CM 2012/I:22**

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**Can Marine Protected Areas achieve their goals as management tools in northern regions? Practical lessons from Alaska, New England, and Norway**

Susanne F. McDermott, Erik Olsen, Lene Buhl Mortensen, Esben Morland Olsen, Deborah Hart, Alan Haynie, William Stockhausen, Paul Spencer, John V. Olson, Tore Johannessen, Erlend Moksness, and Geir Dahle

Ecosystem-based marine spatial planning is an environmental management approach that recognizes all interactions within a marine system, including humans. Marine Protected Areas (MPAs) have become increasingly popular as management tools of ecosystem-based marine spatial planning. While many MPAs have been successfully established in tropical reef systems, fewer MPA examples exist in temperate or subarctic systems (e.g. North Pacific, Bering Sea) where species diversity is lower, abundance of single species is higher, and many fish species exhibit large amounts of movement in one or more of their life history stages thus covering large geographic areas. In this presentation we will review MPAs in three different ecosystems: in the Northeast Atlantic (Norway), in the northeastern US Atlantic waters (George's Bank, USA), and in the Northeast Pacific (Alaska, USA). We will discuss the effectiveness of these closures with regards to their initial objectives and expected and unexpected effects. We will evaluate the effectiveness of MPAs as management tools in the different ecosystems and management scenarios. This paper was developed as a collaborative project between the Alaska Fisheries Science Center (Seattle), Alaska Regional Office (Anchorage), North East Fisheries Science Center (Woodshole), and the Institute of Marine Research (Bergen).

Keywords: design, implementation, Marine Protected Area, MPA effect, northern boreal ecosystem.

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**ICES CM 2012/I:23**

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**Representation of the use of marine space by commercial fisheries in marine spatial planning**

Andronikos Kafas, Gareth Jones, Robert Watret, Ian Davies, and Beth Scott

Successful marine spatial planning requires that the underlying data and process can gain the confidence of a wide range of stakeholders. Fisheries are major users of our seas, and therefore are of particular importance in marine planning. Appropriate representation of fisheries in marine planning systems, for example as layers in GIS-based spatial modelling, needs to take account of the spatial variability in the use of gears and of landings, and also of the temporal stability of these patterns. An understanding of the year-to-year stability of fisheries patterns can avoid overreliance on data from short periods that may not well reflect longer term patterns. Spatial variability of particular fisheries may also affect the seafloor integrity and identification of areas not impacted by mobile bottom gears may be important for Marine Protected Area (MPA) designation. Vessel monitoring system (VMS) data for Scottish waters in years 2006–2010 have been combined with landings information to develop GIS layers describing annual spatial patterns of landings for defined sections of the fleet. Spatial statistics have been used to quantify comparisons of interannual variability and identify significant spatial differences between years so that informed decisions can be made on the most appropriate representation of landings from VMS (>15 m) vessels.

Keywords: fisheries landings, interannual variability, marine spatial planning, Scotland.

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**ICES CM 2012/I:24**

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**Ecosystem-based maritime spatial planning with focus on use of scientific knowledge**

M. Kopti, R. Aps, K. Aps, and M. Fetissov

Ecosystem approach, place-based management, sea use management, ecosystem-based marine spatial management, and ecosystem-based maritime spatial planning (EB MSP) are increasingly common phenomena. Behind all of them is the ecosystem-based governance of marine spaces that actually means the management of stakeholder relationships based on recognition of their interests. Negotiation that lies at the heart of any participatory processes is seen as the mechanism for finding a solution to a common problem in a collaborative manner while argumentation plays a key role in finding a compromise. The use of law and scientific knowledge as a basis of argumentation in participatory processes related to the Baltic Sea EB MSP are discussed based on the experiences of various EU projects: INTERREG IVA BaltSeaPlan and the EU 7FP GAP2 Project's Baltic Sea case study. In practical terms, the EB MSP can be seen as a process of striking a balance between actual and future interests of the stakeholders involved. The BaltSeaPlan Web application that was used to facilitate the EB MSP actual participatory processes enabled GIS technology-based boundary objects (series of biophysical, socio-economic, and jurisdictional overlays) to be created and used to translate and transfer scientific knowledge between stakeholders, and to support negotiations aiming at building consensus between the interest groups concerned.

Keywords: Baltic Sea, ecosystem-based maritime spatial planning, participatory processes.

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**ICES CM 2012/I:25**

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**Struggle over the nature of the Bothnian Sea: designation of a Marine Protected Area as lessons for marine spatial planning development**

Riku Varjopuro

The Bothnian Sea National Park was designated in 2011 on the Finnish side of the Bothnian Sea. The Marine Protected Area (MPA) protects a 160-km-long north–south strip of nearshore waters in a sea area that has relatively good water quality and that hosts valuable biodiversity. Nevertheless, many features of its submerged nature are unknown. The designation of the MPA was strongly contested in the southern parts of the area, while it was welcomed in the north. A main reason for opposition was a fear that it threatens fishing and fish farming. Tensions between national- and regional-level decision-making power played a part also. In the northern part, positive expectations were based on possibilities of promoting tourism and recreation. The paper analyses the debate during drafting of a law that eventually designated the MPA. A qualitative analysis scrutinizes a debate in the parliament and relevant documents. The arguments supporting and opposing the MPA as well as the way the nature of the MPA changed from a strictly protected area to a national park that allows multiple uses show how a sea area can have several meanings that are attached to heterogeneous activities and entities from natural characteristics to economic uses and even to “correct” borders of a sea area. The paper discusses what an MPA designation can reveal for development of MSP approaches. The main argument calls for an appreciation of pluralism by avoiding single hierarchy definitions of marine space.

Keywords: Bothnian Sea, fishing, Marine Protected Area, marine spatial planning, multiple use conflict.

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**ICES CM 2012/I:26**


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**Evaluating effectiveness of marine spatial management—some basic principles for sustaining European coastal waters**

Katrine Soma, Jorge Ramos, Øivind Bergh, Torsten Schulze, Arie van Duijn, Timo Mäkinen, Anne Sell, Erik Buisman, Vanessa Stelzenmüller, Fabio Grati, Vicki O'Donnel, Hans van Oostenbrugge, Gianna Fabi, and Ellen Hoefnagel

Marine spatial management is confronted with complex situations in European countries because of multiple interests, stakeholders, management possibilities, and contexts. Management assessment in complex situations requires a satisfactory evaluation framework design that can ensure transparent treatment of involvement, interests, and information. The main goal in this article is to identify a suitable evaluation framework, which can be applied in marine management in European countries to assess future possibilities and appropriate management. After reflecting on EU marine management plans, existing assessments of evaluation techniques and defining appropriate principles, a new and innovative framework is provided. The framework is based on the principles of ensuring involvements, transparency, accountability, and legitimacy when assessing the future possibilities. The appearance of these principles in the application process of the framework in six case studies is addressed. Evidently, the coexistence of multiple activities in the long run will require an adequate encompassed stakeholder strategy to obtain sustainable marine spatial planning in European coastal waters.

Keywords: aquaculture, coastal zone, coastal zone management, CoExist, European coastal waters, fisheries, multi-criteria analysis (MCA), sustainable development.

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**ICES CM 2012/I:27      Poster**


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**Trawl fishers' perceptions as complementary inputs in the context of applying an ecosystem approach to the management of the Mediterranean multispecies fisheries**

V. Vassilopoulou, A. Dogrammatzi, A. Palialexis, J. Haralabous, K. N. Papadopoulou, and S. Q. Eliassen

A marine spatial plan should be scientifically appropriate and socially acceptable. It is widely recognized that in certain cases management plans have been proven ineffective due to a failure to use all available sources of information, particularly the knowledge of local stakeholders. In this study Greek trawl fishers' perceptions of issues related to deficiencies of the overall system that need to be tackled towards achieving both environmental and socio-economic sustainability under ecosystem-based management (EBM) are evaluated using a questionnaire approach. Qualitative responses by trawl fishers were recorded through 17 face-to-face interviews in eight ports. Viewpoints on problems facing the Greek trawl fisheries sector include: conflicts relating to competing fishing activities, impacts from other human activities, organizational gaps, issues arising from existing management measures, and financial burdens borne by operational/maintenance costs and market shifts. Among issues of high priority that appear to need immediate actions are measures related to spatial closures considered as unfair and receiving low acceptance, resulting in low levels of compliance. Pollution and marine litter were highlighted as those mainly contributing to the deterioration of ecosystem quality. The need for scientific evidence, drawing upon appropriately designed studies was underlined on many occasions. In general, fishers perceive themselves as not being consulted or involved in the decision-making process, the latter being widely criticized as short-sighted based on poor and unrealistic planning. Our findings suggest that fishers' perceptions can be used as complementary inputs to scientific results in the integrated and iterative process of adaptive management.

Keywords: adaptive management, demersal trawling, northeast Mediterranean, stakeholders.

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**ICES CM 2012/I:28      Poster**

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**The Trilateral Wadden Sea Cooperation—a model for transnational cooperation in marine spatial planning and the Marine Strategy Framework Directive?**

Christian Fischer and Andreas Kannen

The implementation of the Marine Strategy Framework Directive (MSFD) asks for intensified cooperation and coordination between EU Member States, in particular those within the same regional sea. Similarly, the current development in sectors like offshore wind farming requests intensified cooperation in marine spatial planning (MSP) in order to deal with challenges such as cables and grids between countries. Beside formal cooperation procedures, such as those in OSPAR, other forms of cooperation might be needed to successfully deal with transnational challenges in planning. An existing example of cooperation in the North Sea is the Trilateral Wadden Sea Cooperation. The Trilateral Wadden Sea Cooperation is a maritime actor that aims at nature conservation and environmental protection of the Wadden Sea as a part of Europe's North Sea. In this cooperation Denmark, Germany, and the Netherlands have been working together since 1978. The cooperation is seen by some proponents as a "pioneering model for the management of a trans-boundary ecological system of international importance". This poster provides information about research, analysing which factors play an important role for successful collaboration in the Trilateral Wadden Sea Cooperation and which lessons can be learnt from this example for transnational cooperation in the MSFD and in MSP.

Keywords: Trilateral Wadden Sea Cooperation, transnational cooperation.

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**ICES CM 2012/I:29      Poster**

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**Impacts of extended continental shelf delimitation on marine spatial planning**

Juan L. Suarez

In the last decade, national states have started delimiting their continental shelves at a distance greater than 200 miles when their continental margin was considered to have a width extending beyond the outer limit of the exclusive economic zone. This new wave of State jurisdictional expansion translates into a reduction in the sea beds that are assumed to form part of the area declared to be the common heritage of humanity. In certain cases, the consolidation of these claims will translate into major territorial gains with an important geo-political dimension, as they would enable access to new energy resources and the control of geographical areas of high strategic value. The jurisdictional dissociation of the sea floor from the water column could likewise become a source of contention between national interests (the continental shelf) and part of the global commons (the high seas). Marine spatial planning and applying the principle of ecosystem-based management can in this way be extended over new marine areas. Apart from involving greater difficulties, this also implies a new balance in the share of the responsibility that each State shoulders. This poster provides a geographical vision of the phenomenon, particularly in the area of the European Union and its maritime environment: the location of claims made in the various marine regions to date, the affected states, and the quantification of the new areas of seabed included under national jurisdiction.

Keywords: European Union, extended continental shelf, global commons, marine spatial planning, national jurisdiction.

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## Theme Session J

### Beyond routine ageing: otoliths and other bony structures as windows into fisheries, fish ecology, and the environment

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#### ICES CM 2012/J:01

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##### **Tree-ring techniques for age validation, biochronology development, and establishing climate-growth relationships in fish and bivalve species**

Bryan A. Black and Christoph Stransky

Otoliths, shells, and other hard structures from fish, bivalves, and corals serve as continuous chronometers of environmental variability in aquatic ecosystems, and tree-ring science (dendrochronology) offers a powerful suite of techniques for unlocking these climatic and ecological signals. Of critical importance is ensuring that the correct calendar year of formation has been assigned to each growth increment in the dataset through the process of “crossdating”, in which synchronous growth patterns induced by climate are matched among all individuals from a given species and site. If an increment has been missed or falsely added, the growth pattern for that individual will be offset by one year relative to the other samples, identifying the location of the error. Crossdating can be used to greatly improve the accuracy and precision of age estimates. Exactly dated biochronologies can also be generated from growth-increment width measurements to describe long-term growth histories, establish the effects of climate on growth, and integrate with other biological time-series to explore relationships across diverse taxa and ecosystems. In the California Current, for example, rockfish (*Sebastes* spp.) chronologies span as many as 71 years and strongly relate to one another as well as records of seabird reproductive success, underscoring the importance of climate variability to the ecosystem. The potential to apply these techniques, especially exact dating, is also evaluated for several North Atlantic and North Sea species including cod, herring, plaice, saithe, and redfish.

Keywords: biochronology, climate, North Atlantic, otolith.

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#### ICES CM 2012/J:02

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##### **Modelling the mixing of herring stocks between the Baltic and the North Sea from otolith data**

Clara Ulrich, Søren Lorenzen Post, Lotte A. Worsøe Clausen, Casper Berg, Mikael vanDeurs, Henrik Mosegaard, and Mark R. Payne

Herring catches in the western Baltic, Kattegat and Skagerrak consist of a mixture of stocks, mainly North Sea autumn spawners (NSAS) and western Baltic spring spawners (WBSS), which is managed through a single TAC. Catches of these two stocks are split using otolith microstructures from Danish and Swedish commercial landings and surveys samples for the purpose of stock assessment. But the split estimates from sampling data are highly variable and noisy. Better understanding of the migration and exploitation patterns involved could therefore potentially improve the stock assessment as well as provide solutions to the complex management of this mix. The stock-specific seasonal trends in distribution of the two main stocks from otolith data were analysed using a generalized linear mixed model (GLMM) of stock composition. The results show a clear seasonal and age-related pattern and are consistent with existing ideas about the migration patterns of WBSS and NSAS within Division IIIa and adjacent waters. This work therefore provides



the foundation for the development of a more rational management of the herring stocks in this area.

Keywords: autumn spawners, eastern North sea, GLMM, herring, Kattegat, mixing, Skagerrak, western Baltic, spring spawners.

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### ICES CM 2012/J:03

#### Determining sources of capelin recruits in the Saguenay-St. Lawrence Marine Park (Canada) using otolith chemistry

Angélique Lazartigues, Pascal Sirois, Stéphane Plourde, and Julian Dodson

The Saguenay-St. Lawrence Marine Park (SSLMP) is an important feeding area for whales, seals, and seabirds. The reserve includes a large portion of St. Lawrence Estuary, and most of the Saguenay Fjord (Canada). Understanding how capelin (*Mallotus villosus*), a key foraging species, is maintained in the SSLMP is important to preserve this feeding area. Our aim is to determine whether capelin in the SSLMP recruit locally through larval retention or derive from other spawning sites and look at connectivity throughout the fjord–estuary system. Otolith chemistry is a great tool for achieving our objective. Indeed, elements are quasi-permanently stored in the increments of otoliths. Concentrations derive from surrounding waters and are regulated by physiological and environmental parameters. So, otolith elemental signatures in early life stage capelin otoliths may be a witness of the spawning site. The first step consists in characterization of otolith signatures at spawning sites, exploring larval capelins ( $n = 290$ , otolith diameter 10–20  $\mu\text{m}$ ) caught in 2009 throughout the fjord–estuary system, within and beyond the SSLMP boundaries. Multi-elemental analysis was performed using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) adapted to small samples. The second step performs similar analyses of a subsample of 1+ juvenile capelin caught in the SSLMP in 2010 to determine sources of recruits ( $n = 35$ ). Some of the elements that are measured in larval otoliths varied among sampled stations, within the SSLMP, and in other spawning sites upstream and downstream in the estuary and western Gulf. That will form the basis of a mixed-stock analysis to determine the spatial extent and degree of connectivity between the park and spawning areas.

Keywords: connectivity, *Mallotus villosus*, recruitment, Saguenay-St. Lawrence Marine Park.

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### ICES CM 2012/J:04

#### Do fin rays and otoliths tell the same story? Comparing teleost life histories using microchemistries of calcified structures

O. Tzadik and C. Stallings

Calcified structures of bony fish have proven to be effective tools for studies concerning their life histories. For example, ageing studies have found external structures such as fin rays and spines, which may be taken without sacrificing the fish, can be used as effectively as otoliths in age determination. Preliminary studies have suggested that a direct correlation between otolith and fin ray microchemistries also exists. In an effort to derive life histories and preferred habitats of reef fish, this project will first verify the similarities in microchemistries of the two distinct calcified structures from red grouper, *Epinephelus morio* and gray snapper, *Lutjanus griseus*. Otoliths and fin rays from the same individual fish are being compared using inductively coupled plasma mass spectrometry to detect trace element concentrations along an age continuum for each structure. The resulting concentrations are being analysed for variances using a distance-based redundancy analysis. If, as expected, the microchemistries provide statistically similar results, then the

technique will be applied as a non-lethal alternative to investigate life history characteristics and ontogenetic movement patterns of several reef fish in southern Florida. Non-lethal life history determinations will prove particularly useful for species of conservation interest such as the federally protected goliath grouper, *Epinephelus itajara*.

Keywords: fin ray chemistry, Gulf of Mexico, ICP-MS, otolith chemistry.

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## ICES CM 2012/J:05

### Atlantic bluefin tuna stock identification based on otolith stable isotope composition

I. Fraile, H. Arrizabalaga, and J. Rooker

We used otolith microchemistry as a tool for identifying natal origin of Atlantic bluefin tuna (*Thunnus thynnus*) captured in the Bay of Biscay during 2009–2011. Atlantic bluefin tuna is divided into two stocks, the eastern population spawning in the Mediterranean and the western population in the Gulf of Mexico; but mixing of the two stocks occurs in the North Atlantic foraging grounds. Otoliths are able to record the chemical composition of the environment to which the fish is exposed, thus, the chemical fingerprints in otolith cores can be used to identify natal origin of juvenile and adult tunas. Previous studies have demonstrated the use of stable isotopes to reliably predict nursery origin of Atlantic bluefin tuna. In the present study  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  have been measured in 300 otolith cores, and compared to baseline values belonging to yearling bluefin tunas from the eastern and western nurseries. Different size categories and fishing months have been included to evaluate the season and size-dependency of the results. Otolith microchemistry based on  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  suggest little mixing between the two populations during the last three years in the eastern North Atlantic. A large fraction (95–100%) of the Atlantic bluefin tuna captured by the Bay of Biscay fishery originated in the Mediterranean and thus correspond to the eastern population. Juvenile and adult tunas did not differ significantly in their composition. We conclude that trans-Atlantic movements from the western Atlantic to the Bay of Biscay have been not significant during 2009–2011. Therefore, the regional fishery targets almost exclusively the eastern population.

Keywords: Bay of Biscay, bluefin tuna, otoliths, stable isotopes.

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## ICES CM 2012/J:06

### Reconstructing the environmental histories of American eels in the Saint Lawrence River using multi-element profiles of otoliths

José Benchetrit, Mélanie Béguer, Pascal Sirois, Martin Castonguay, and Julian J. Dodson

The American eel, *Anguilla rostrata*, inhabits inland and coastal waters from southern Greenland to northern South America for a significant part of its life. The species' remarkable life cycle, which begins and ends in the Sargasso Sea, has often been regarded as a textbook example of catadromy in fish. However, analyses of [Sr]:[Ca] profiles in otoliths that retrace movements across freshwater, estuarine, and marine habitats, have found that catadromy may in fact be facultative. A diverse set of movement behaviours was indeed observed, with some individuals apparently never entering fresh water. Similar findings were also reported for other species of Anguillid eels. Nevertheless, such studies have, thus far, been limited to relatively small systems that lie in close proximity to the coast. The vast Saint Lawrence River Lake Ontario system has historically been an important recruitment area for the American eel. Despite this, little is known about its movement behaviour between the moment individuals recruit to the system as elvers and when they leave as mature silver eels. Therefore, the aim of this study was to use variations, or lack thereof, in the chemical signatures of otoliths to retrospectively infer patterns of movement during the time spent

in the Saint Lawrence River system. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was used to record the concentrations of a suite of minor and trace elements across a transect from the core to the edge for the otoliths of 129 yellow and silver eels sampled across the Saint Lawrence River Lake Ontario system as well as Lake Champlain.

Keywords: American eel, multi-element, otolith microchemistry, Saint Lawrence River.

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#### ICES CM 2012/J:07

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### High-resolution stock discrimination of Atlantic herring (*Clupea harengus*) based on otolith shape, microstructure, and genetic markers

Henrik Mosegaard, Lotte Worsøe Clausen, and Dorte Bekkevold

One of the most rapidly developing applications of otolith research is shape analysis, often used for population discrimination as well as for species identification. Otolith shape is influenced by the environment through physiology, but also shows consistent and temporally stable differences between populations, which suggest genetic control as well. Thus otolith shape serves as a population marker, suitable for individual assignment. Here we use otolith morphological characteristics (otolith shape and larval otolith microstructure) combined with genetic markers to discriminate between different populations of Atlantic herring (*Clupea harengus*) in the western Baltic and adjacent waters. We analyse a baseline (spawning individuals from several populations validated by genetic markers) for separation of adult herring (2+) based on otolith shape and juveniles using genetically validated otolith shape characteristics as separation parameters. Otolith shape was found to clearly discriminate between individuals at all ages from different spawning populations. The identified distances between populations based on otolith shape matched previously obtained genetic distances and were, when combined with the otolith microstructure, able to discriminate between populations that are spatially different but spawning in the same season.

Keywords: herring, otolith shape, stock discrimination, western Baltic.

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#### ICES CM 2012/J:08      **Withdrawn**

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#### ICES CM 2012/J:09

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### Two methods utilizing fish and otolith morphological measurements for age determination of Baltic flounder

D. Zilniece, T. Baranova, M. Plikshs, and M. Goldmanis

The prevailing method for age determination of Baltic flounder (*Platichthys flesus*) involves counting annual growth rings in otoliths. However, this method is both time-consuming and subject to error and subjective uncertainty. Recently, there has been renewed interest in alternative methods based on statistical decomposition of the sample distributions of fish and otolith linear sizes and weights. In the present paper, we explore the use of fish and otolith size data for age determination in a large sample ( $N = 1800$ ) of flounder caught in Latvian territorial waters during 2011, for which otolith ring-counting data are also available. We utilize two approaches, using size data either as a complete or a partial substitute for age-reading data. In the first approach, we use Bhattacharya's method to decompose aggregate fish length and otolith weight distributions (separated by gender) into their component normal distributions. Each of these distributions corresponds to a separate age class. In the second approach, we use a split-sample imputation

approach, whereby an ordered multinomial regression of age (as read by counting otolith rings) on otolith and fish weights and linear dimensions is estimated on one randomly selected half of the sample, and ages are imputed from this regression on the other half. For each approach, we compare the resulting age distributions to those obtained from traditional age reading and explore their robustness. We also repeat the analysis on data from previous years to assess the stability of the distribution over time as an additional robustness check.

Keywords: age determination, Baltic flounder, otolith biometrics.

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## ICES CM 2012/J:10

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### Boom in boarfish abundance: insight from otolith analysis

Julie Olivia Coad and Karin Hüsey

The boarfish *Capros aper* is a pelagic shoaling species widely distributed along the Northeast Atlantic continental shelf. In recent years, this species has experienced a dramatic boom in abundance in the Bay of Biscay and Celtic Sea. This study aims at resolving the mechanisms responsible for this increase in stock size. Based on annual otolith growth increments, we developed a growth chronology as a proxy for stock fecundity. Growth patterns were similar between geographically separate areas west and south of Ireland, with distinct years of good and bad growth. Good growth was observed in 2004 and 2008, while 2005 was exceptionally bad. In the northernmost areas, growth was significantly influenced by autumn temperatures and food availability, while growth south of Ireland was only influenced by summer temperatures. These months are the primary growing season of the boarfish. Year-class strength was not correlated with growth in the same year. However, year-class strength was significantly correlated with adult growth the previous year, together with temperature during the months following spawning. The age structure shows that this species is very long lived (>30 years), but that a considerable proportion of fish are only aged 4–6 years. These age classes correspond to the year with exceptionally high recruitment. This study has demonstrated that both adult growth as a proxy for reproductive potential and environmental conditions favouring early life stage survival may be the cause for the boom in boarfish abundance.

Keywords: boarfish, growth chronology, recruitment.

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## ICES 2012/J:11

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### Using otolith chemistry to reveal patterns of migration, habitat use, and life history of two deep-sea teleosts in the North Atlantic

C. Longmore, C. N. Trueman, F. Neat, J. A. Milton, and S. Mariani

The study of the chemical characteristics of otoliths is quickly establishing itself as a fundamental tool in fish stock identification. Specifically, trace elements can be used as geochemical tags to examine patterns of spatial and temporal population structuring while the isotopic composition of otolith aragonite can be used to reveal fish location (water temperature) retrospectively and thus infer ontogenetic migratory behaviour. Deep-sea fish are difficult to observe directly, but are increasingly threatened. Information about basic biological characteristics of deep-sea fish such as ontogenetic migrations and population connectivity are currently lacking. This study used the geochemistry of otoliths of two highly exploited deep sea fish (roundnose grenadier and black scabbardfish) to reveal patterns of population structuring, movement, habitat use and life history in the Northeast Atlantic. Analysis of elemental ratios and  $\delta^{18}\text{O}$  values at larval, juvenile, and adult life stages in the roundnose grenadier revealed significant differences between and within life stages, suggesting that this species conducts consistent ontogenetic depth migrations, and the

population is composed of geographically distinct population units that persist throughout their life history. By contrast, both trace element and  $\delta^{18}\text{O}$  values in the black scabbardfish revealed weak geographic separation at each life stage. Absolute  $\delta^{18}\text{O}$  values in the juvenile portions of black scabbardfish otoliths collected from adults from a wide geographic range indicate extensive lateral migrations and common water conditions during larval growth. Both observations imply a relatively high degree of population connectivity. The approach employed improves our ability to unravel the species' life cycles and delivers useful information for management purposes.

Keywords: deep-sea, North Atlantic, otolith microchemistry, stable isotope.

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## ICES CM 2012/J:12

### Growth history of North Sea cod (*Gadus morhua*): suggestions for future scenarios

Rebecca A. M. Lauerburg, Christian Möllmann, Axel Temming, Gerd Kraus, and Peter Grønkjær

The recent four decades have seen pronounced ecological changes in the North Sea ecosystem, including sudden regime shifts and gradual changes. Cod (*Gadus morhua*) is a key species of the North Sea ecosystem; hence the ecosystem changes should have strongly affected its population dynamics. A process of major interest is growth due to its influence on the productivity of a stock. Here we reconstructed a 38-year growth chronology of North Sea cod by means of otolith macrostructure analysis. Age-specific growth was examined for temporal and spatial variations with the goal of detecting linear and abrupt changes. Multivariate statistics revealed temperature to be the most important trigger for cod growth. Furthermore we show spatial differences in growth between the southern and northern North Sea, with generally higher growth in the southern North Sea related to higher temperatures. Moreover a decreasing trend and a sudden shift in growth of southern North Sea cod was observed, indicating thermal conditions to be beyond optimum. Changes in growth were primarily distinct in small cod, with positive changes in age-0 growth and negative changes in age-1 growth, which indicates that young cod are more sensitive to environmental changes. Our study implies (i) that in the future rising sea temperature will have a stronger influence on young North Sea cod than on adults, and (ii) that northern North Sea cod will be able to tolerate increasing temperature more easily than the southern stock component.

Keywords: North Sea cod, otolith macrostructure analysis, temperature, growth.

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## ICES CM 2012/J:13

### Using otolith shape to classify herring into spawning types: investigating possible effects of age and year class

Stijn M. Bierman, Harriët van Overzee, and Mark Dickey-Collas

The Northeast Atlantic herring (*Clupea harengus*) stock consists of a mixture of spawning components, each of which has its own spawning ground to which it returns during its own specific spawning period. Preservation of the diversity of the stock in terms of these spawning components is considered an important management objective. However, tracking population trajectories of individual spawning components is difficult since they mix during the summer feeding season when the main fisheries takes place. Differences in spawning time and location are thought to result in the larvae experiencing different environmental conditions during their development, which in turn may influence the shape of the otolith. Otolith shape parameters (obtained using automatic imaging software) have been used for classifying herring into spawning populations with some measure of success. While obtaining data on otolith shapes is itself relatively inexpensive, it may be costly to obtain independent baseline data for calibration or

training of the classification methods. Here, we examined whether there was evidence of age and year class effects on otolith shape parameters of winter spawned herring. If such effects are present, and they influence the classification of herring into spawning types, this would mean that baselines covering these (combinations of) year classes and ages would have to be used in order to achieve a reliable classification. Significant effects of both age and year class on otolith shape parameters were found, and the consequences of this for the process of classification are discussed.

Keywords: Atlantic herring (*Clupea harengus*), otolith shape analysis, stock discrimination.

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## ICES CM 2012/J:14

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### **Coupling otolith microstructure analysis and hydrographic backtracking suggests a mechanism for the 2000s North Sea herring recruitment failure**

Stine D. Ross, Mark R. Payne, Lotte Worsøe Clausen, and Richard D. M. Nash

The North Sea autumn spawning herring (*Clupea harengus*) has, since the 2002 year class, shown an unprecedented sequence of ten years of sharply reduced recruitment, in spite of a high spawning biomass and low fishing mortality. Recent work has identified this reduction in recruitment level (or stock productivity) as taking place during the larval overwintering phase: however, the underlying mechanism remains elusive. In this study we analysed archived larval samples captured both before and after the onset of the reduced survival to test the hypothesis of a reduction in the larval growth rate. Individual larval growth rates, averaged over the 30 days prior to capture, were estimated for 200 larval otoliths from four different years using a model-based analysis of the ring widths. The otolith measurements were complemented with additional information derived from hydrographic backtracking models (e.g. average temperature experienced, time available for feeding and spawning origin) to reconstruct the recent history of the larvae. A mixed-modelling approach was then employed to analyse the combined data: after correcting for the effect of the other variables, a significant reduction in larval growth rate, associated with the onset of the reduced recruitment, was identified. These results suggest that the reduced recruitment is associated with a reduction in the growth rate of the larval survivors, most probably through changes in either the amount or quality of the available food. Furthermore, this study demonstrates how coupling two different techniques (otolith microstructure analysis and hydrographic modelling) can yield unique insights into fish ecology.

Keywords: growth, hydrographic backtracking, larvae, North Sea herring, otolith microstructure, recruitment.

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## ICES CM 2012/J:15

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### **Fish as biologgers: reconstructing climatic events from chemical compositions of otoliths**

Benjamin D. Walther, Michael Kingsford, and Malcolm McCulloch

For decades, chemical compositions of stationary organisms such as scleractinian corals have been used to reconstruct environmental conditions and pulsed climatic events on contemporary and paleo time-scales. With the development of high-resolution and high-throughput chemical probes such as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), similar methods can also be used with otoliths from fish that are resident in a given habitat for the majority of their lives. We present results from an on-going project on the Great Barrier Reef to monitor water chemistry and associated variability in Ba:Ca recorded in otoliths of a resident pomacentrid fish, as well as from *Porites* coral at inshore and offshore locations. Inshore environments experience periodic monsoonal floods that deliver strong pulses of fresh water correlated with increases in Ba:Ca in coastal waters and also carbonate Ba:Ca ratios. Ba:Ca ratios in both corals and

otoliths therefore act as an effective proxy for natural and anthropogenic influences on nearshore habitats. Also, offshore reefs are exposed to regular upwelling events. Deep waters (>150 m) were richest in Ba:Ca and temporal depositional patterns in both fish and coral were observed. Otolith chemistry assayed in resident fish has the potential to complement records in coral skeletons or other biogenic carbonates and reveal ecological responses of fish populations to high-frequency fluctuations in oceanographic parameters.

Keywords: barium, corals, floods, Great Barrier Reef, otoliths, trace elements, upwelling.

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## ICES CM 2012/J:16

### Examining spatial variation in growth patterns of Irish Sea plaice using an extended double logistic model

M. Zölck, C. Minto, D. Brophy, C. Fox, and D. McGrath

When groups of fish inhabit different environments during early life this may produce variation in pre- and post-settlement growth which is recorded in the otolith, providing a useful marker of larval and juvenile origin. In the present study we describe the early growth of *Pleuronectes platessa* on Irish and Scottish nursery grounds. Plaice were collected throughout August 2009, from five sites in southwestern Scotland and four sites in eastern Ireland. Spatial variation in growth was investigated using otolith increment widths and temperature data. Growth rate over time (increment number), displayed marked individual variation with asymptotic and dome-shaped relationships observed between these variables. These variations, along with the non-independence of measurements within otolith reading and individual fish, necessitated the development of hierarchical double logistic growth models. Temperature effects were investigated in two ways: with growing degree day replacing time and with temperature and time included as explanatory variables. The models were compared to determine the most effective way to describe differences in growth within and between regions. Growth during the larval phase was found to differ significantly between but not within regions. Inferential differences between the methods of temperature inclusion on these regional effects are explored. Variations in growth have implications for survival of plaice. Otolith growth information is useful in stock discrimination, and to assess the influence of environmental factors on growth. Identifying nursery grounds that promote high growth can guide spatial habitat conservation, protecting important sources of recruitment to the adult stock.

Keywords: Irish Sea, survival, stock identification, double-logistic hierarchical growth modelling, temperature mediation.

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## ICES CM 2012/J:17

### Picture this: applying digital imaging techniques to otolith data capture, analysis and interpretation

Joe Scutt Phillips, Joanne Walton, Wendy Dawson, Graham Pilling, Sally Songer, and Ewan Hunter

In recent years, the development of computer digital image capture, manipulation, and storage has opened a new field of otolith research—that of otolith imaging. Highly detailed images captured from otoliths have been used in a wide range of studies involving life histories of juvenile fish, daily growth, and age determination. The principle, the routine capture of otolith images, offers a number of potential advantages, including the development of historical records, the rapid calculation of biological and life history information, and the seamless storage of associated information, which could lead to efficiency savings and advances in otolith and fisheries science.

Here we provide an overview of how imaging is currently used across all areas of otolith science, highlighting best practice where it has been developed. Potential fields for development are identified and a discussion of how these developments could be implemented is given.

Keywords: age determination, automated systems, calibration, incremental growth, morphology.

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## ICES CM 2012/J:18

### Variability and controls of otolith growth in the anchovy of the Bay of Biscay

Pierre Petitgas, Patrick Grellier, Erwan Duhamel, Jacques Massé, and Mathieu Doray

Individual fish growth depends on internal population factors such as phenotypic variability as well as external factors such as past environmental conditions (temperature, food) and selective mortality (predation or fishing). In the anchovy, growth in the first year is key to population dynamics as it determines the potential energy allocated to reproduction as well as the capacity to occupy offshore habitats. Furthermore, in the recent past, the anchovy in the Bay of Biscay has experienced collapse and recovery and the role played by growth in this history is unknown. Since 2001 with the spring acoustic survey series PelGas, we have monitored individual fish growth by measuring in the otolith the increments between annual rings, in addition to age determination. These data now allow us to analyse the growth pattern in the population as well as the effects of temperature and fishing on the apparent growth curve of individuals. We show that growth is related to a spatial pattern where smaller and slower growing individuals are more coastal than offshore larger and faster growers. We evidence a temperature effect on the growth pattern where warm years are also those of faster growth. In contrast, fishing does not seem to affect the apparent growth. We also account for the variability of growth between individuals, which has stayed high throughout the series. The study implies a spatial substructure and segregation in this population where particular habitats could have played a fundamental role for the recovery of the population after its collapse.

Key words: anchovy, Biscay, growth, otoliths, metapopulation.

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## ICES CM 2012/J:19

### Bomb radiocarbon dating of Greenland halibut otoliths in the Northwest Atlantic: where do we go from here?

Karen S. Dwyer, Steven. E. Campana, and Margaret A. Treble

Greenland halibut (*Reinhardtius hippoglossoides*) is a deep-water flounder widely distributed from the Northwest Atlantic and supports a major international fishery off the east coast of Canada that is managed by NAFO. Age estimates for this stock have customarily been obtained by counting annuli on the surface of whole otoliths. It has been suspected for some time that whole otolith estimates do not accurately reflect the age of Greenland halibut, but age validation studies have not been conducted. Studies on age validation of Greenland halibut in the Arctic have concluded that whole otoliths underestimate the true age of this fish as do thin sections, to a lesser extent. These studies indicate slow growth and increased longevity but it is unknown how stocks in the Northwest Atlantic differ from the Arctic and further research was recommended from a recent ICES workshop. Bomb radiocarbon dating of otoliths is a robust technique that has been used to validate ageing methods and is considered one of the best ways to determine accurate age in long-lived fish. Bomb radiocarbon assays carried out on otolith core material indicated that ages based on thin-sectioned otoliths for Greenland halibut ranging in length from 67 to 111 cm were older and more accurate than ages determined from whole otoliths. Slow-growing and long-lived fish are more vulnerable to fishing pressure; therefore it is important to correctly determine longevity



in these populations. Information from this study will have a significant impact on the age-based assessment that is currently carried out for this stock.

Keywords: age validation, bomb radiocarbon dating, Greenland halibut, Northwest Atlantic.

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#### ICES CM 2012/J:20

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### Relative contribution of spring- and summer-spawned bluefish to the adult population: effects of size-selective mortality, overwinter growth, and sampling bias

J. W. Morley, J. A. Buckel, and T. E. Lankford

Length distributions of juvenile bluefish (*Pomatomus saltatrix*) are bimodal, consisting of spring- and summer-spawned fish. Research during the 1990s from the northeast US suggested that the summer cohort contributes little to the adult population and that the overwinter period may be critical for their survival. We examined length distributions of wild juvenile bluefish from before and after winter and found that the mean length of the summer cohort increased during winter. We conducted a winter growth experiment to determine whether changes in mean length were due to selective mortality of smaller fish or growth. Based on water temperatures from the two winters examined, changes in mean length were due to mortality for one year class, and growth for the other. Despite the potential for winter mortality, age-1 summer-spawned bluefish were common in collections following winter. We reexamined the relative contribution of the spring and summer cohorts to the adult population using archived scales from the North Carolina commercial fishery between 1997 and 2000. Cohort origin of adults was determined by back-calculating length at age-1. We found a third of adults to consist of summer-spawned fish, which contrasts with previous research from the northeast. We conclude that summer-spawned bluefish do contribute to the adult stock and suggest that the differences observed between the northeast and southeast US result from different migration strategies of age-1 and 2 bluefish.

Keywords: *Pomatomus saltatrix*, US east coast, size-selective mortality, back-calculation.

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#### ICES CM 2012/J:21

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### Otolith shape analysis to discriminate stock structure for blue whiting in the Northeast Atlantic

James Keating, R. Officer, E. Mullins, and D. Brophy.

Blue whiting (*Micromesistius poutassou*) in the Northeast Atlantic has been of commercial interest since the 1970s. Evidence from morphometrics, meristics, oceanographic modelling, genetics, and otolith microstructure suggest complexity in the structure of the stock in the Northeast Atlantic but the boundaries between stock components or the degree to which they overlap on the spawning grounds is not certain and they are currently assessed and managed as a single stock. This study aims to provide further insight into the stock structure of blue whiting in the Northeast Atlantic. Otolith shape analysis is useful for stock discrimination as it can identify groups of fish that may have been spatially or temporally discrete at some stage in their life history. In this study, blue whiting were sampled from the northern and southern extremes of the spawning ground and from around the Porcupine Bank and Rockall Trough. Spatial variation in otolith shape was examined in an attempt to elucidate boundaries between stock components. The results showed that fish at the northern and southern extremes of the spawning were very distinct in terms of otolith shape and these two groups appeared to mix in the area around 54°N. These findings are consistent with previous observations from otolith microstructure and oceanographic modelling and support the existence of a northern and southern component in the blue whiting stock which may overlap to varying degrees in the centre of the spawning distribution.

Keywords: blue whiting, elliptic Fourier descriptors, stock structure.

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## ICES CM 2012/J:22

### Age validation of Pacific cod using stable oxygen isotopes ( $\delta^{18}\text{O}$ )

Craig R. Kestelle, Thomas E. Helser, Dan G. Nichol, Delsa M. Anderl, Jennifer McKay, John W. Valley, and Ian J. Orland

Measurements of stable oxygen and carbon isotopes ( $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ ) were obtained from Pacific cod (*Gadus macrocephalus*) otoliths using microsampling coupled with mass spectrometry. Up to 9–10 discrete measurements were obtained by micromilling from any one annual growth zone. Otoliths from nine Pacific cod that were tagged with temperature-recording tags and at liberty between one and two years in the eastern Bering Sea and Gulf of Alaska were analysed. The  $\delta^{18}\text{O}$  in the otoliths is partly a function of water temperature. Therefore, sequential  $\delta^{18}\text{O}$  measurements, representing the full lifespan of the fish, were examined for seasonal variations. We further investigated the relationship between temperature and  $\delta^{18}\text{O}$  in the otoliths with the use of an ion microprobe and mass spectrometry. The goals of this study were to: (i) validate Pacific cod ageing criteria of typical growth-zone counts with seasonal signatures of otolith  $\delta^{18}\text{O}$ , and (ii) verify the relationship between otolith  $\delta^{18}\text{O}$  and temperature using archival tag temperatures. In more than half of the samples, Pacific cod otolith  $\delta^{18}\text{O}$  showed the expected cyclical pattern consistent with seasonal variation in temperatures. In some of these, the number of  $\delta^{18}\text{O}$  maxima showed a close correspondence to the estimated age from growth-zone counts, validating standard age interpretation methods, but overall the results were not completely definitive. However, there was a statistically significant relationship between  $\delta^{18}\text{O}$  and archival tag temperatures ( $r = 0.74$ ,  $p < 0.01$ ). The finer resolution measurements from the ion microprobe were compared to those based on micromilling to evaluate otolith  $\delta^{18}\text{O}$  and temperature.

Keywords: age validation, *Gadus macrocephalus*, mass spectrometry, otolith, oxygen isotope, Pacific cod, temperature.

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## ICES CM 2012/J:23

### Effects of spawning history on growth of Northeast Arctic cod (*Gadus morhua* L.)

Arild Folkvord, Christian Jørgensen, Knut Korsbrekke, Richard D. M. Nash, Trygve Nilsen, and Jon Egil Skjæraasen

The effect of prior spawning history on growth of female Northeast Arctic cod (*Gadus morhua* L.) was studied during a two-year sampling programme in the Barents Sea. A total of 150 cod (60–80 cm) were sampled and staged according to prior spawning history using histological examination. Four groups of cod were identified: immatures, first time spawners, skippers, and repeat spawners, and their growth were back-calculated based on otolith increment patterns. We *a priori* hypothesized that skippers could arise from two distinct growth scenarios, one characterized by energy limitation causing reduced growth and condition, the other by compensatory high growth due to shifted energy allocation from gonads to soma following skipped spawning. The estimated growth trajectories did not give unequivocal support for a bimodal growth pattern among skippers, although the growth-at-age typically was lower for reproductively active fish compared to immature fish. Specifically, fish immature at age six years grew more slowly than fish mature at age six years during their first three years, but were subsequently characterized by as high growth rates as the mature fish the following three years. The results are discussed in relation to overall consequences of population age structure and variable food availability on spawning dynamics.

Keywords: back-calculation, growth strategies, maturation, reproduction, skipped spawning.

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**ICES CM 2012/J:24**

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**Traditional and novel techniques to assess age and growth of Atlantic bluefin tuna (*Thunnus thynnus*) in the western Atlantic**

Walter J. Golet, Graham Sherwood, Shannon Calay, and Molly Lutcavage

Atlantic bluefin tuna make annual migrations between temperate and subtropical water masses to satisfy their reproductive and foraging requirements. Satellite pop-up and implantable archival tags used to track these migrations illustrate the large range of water temperatures encountered by these fish on a seasonal basis. Given that accumulation rates of certain elements (strontium) in otoliths are temperature-dependent, we compared traditional age estimates from visual observations with strontium calcium ratios obtained by running transects lines up the ventral arm of the sagittal otolith using laser ablation inductively coupled mass spectrometry. In addition, we compared the assigned ages between different structures (otoliths and dorsal spines) to check for age agreement so that alternative structures may be used when otoliths are not available. Seasonal cycles of strontium calcium ratios suggest this technique may provide a more reliable method of ageing and reduce errors associated with visual readings, particularly with samples which are difficult to interpret due to reduced structural clarity. These results also illustrate the migration preferences at different life history stages for these fish and may prove useful for future stock discrimination studies.

Keywords: age and growth, bluefin tuna, dorsal spine, Gulf of Maine, otolith.

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**ICES CM 2012/J:25**

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**Environmental and physiological influences on otolith chemistry in a fully marine flatfish**

M. Sturrock, C. N. Trueman, and E. Hunter

Otolith microchemistry is frequently applied as a tool to describe fish migratory behaviour and population structure. The design and interpretation of such studies often assumes a direct relationship between otolith and ambient concentrations, however, as a “natural tag” the mechanisms governing incorporation of elements into the otolith are poorly understood. Here, the relative contribution of physiological and environmental influences on otolith composition were tested in a semi-controlled experiment. Mature and immature plaice were maintained for 12 months under ambient but monitored conditions. Water, blood, and otolith element concentrations (Li, K, Mg, Cu, Mn, Zn, Sr, Ba) were measured monthly and associations investigated using mixed effects models. In general, otolith composition did not vary with ambient concentrations, but was strongly influenced by processes affecting the relative partitioning of ions. This was most apparent for Sr/Ca ratios, which were primarily controlled by blood protein concentrations, condition, and growth rate. Patterns in blood and otolith Zn/Ca were attributed to Zn uptake for oocyte development. The results were complemented by observations from wild plaice with “known migrations” based on archival tag records. Again, physiological effects took precedence over environmental effects in explaining otolith Sr/Ca values. By contrast, patterns in Li/Ca and Ba/Ca ratios varied with ambient temperature and water concentration, respectively, providing support for their use as geographic markers. While there was little evidence for “direct” environmental effects on plaice otolith microchemistry, temperature probably influenced elemental concentrations through its control on physiology, which may underpin the success of otolith chemistry as a stock discrimination tool.

Keywords: DST, flatfish, natural tag, otolith microchemistry, trace elements.

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**ICES CM 2012/J:26**

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**North Atlantic ecosystem shifts revealed by otolith growth,  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  chronologies**

P. Grønkjær, J. B. Pedersen, J. Munk Nielsen, P. Steingrund, U. Matras, R. Hedeholm, K. Sünksen, and J. T. Christensen

Changes in climate and exploitation have caused large fluctuations in the productivity of many North Atlantic cod populations and the collapse of many cod fisheries. These fluctuations are probably a result of a combined effect of physical processes and changes in ecosystem trophic structure. To study the link between environmental changes and ecosystem trophic structure we developed long-term chronologies of otolith growth and parallel  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  chronologies by analysing the organic matrix of cod otoliths from the Nuuk Fjord cod population (1927–2009) and the Faroe Shelf cod population (1950–2010). Significant correlations between  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  annual mean values over time were seen in both ecosystems, suggesting  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values were affected by the same overall processes. There was a significant effect of climate variables (temperature, Atlantic Multidecadal Oscillation (AMO), and subpolar gyre index) on  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  chronologies in both ecosystems. Fast Fourier transformations showed the same periodicity in climate variables,  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  chronologies and cod growth and size-at-age. In the Nuuk Fjord ecosystem, discontinuity analyses (STARS) found coinciding shifts in both  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  chronologies, climate variables, cod size-at-age, and inshore cod catches. This indicates a large ecosystem shift in the Nuuk Fjord around 1970 and a smaller shift in 1995 and is further supported by the  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  bi-plot that shows a clear separation in signatures before and after 1970, and suggests that the simultaneous collapse in the Greenland cod fisheries was at least partly caused by a major ecosystem shift.

Keywords: climate, cod, North Atlantic, otolith.

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**ICES CM 2012/J:27**

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**A bioenergetic approach to model and reconstruct individual life traits from fish otoliths**

Ronan Fablet, Laure Pecquerie, Hans Høie, Richard Millner, Henrik Mosegaard, and Sebastiaan A. L. M. Kooijman, J. F. Bardeau, A. Benzinou, A. Chessel, A. Jolivet, M. Labonne, A. Lorrain, Y. M. Paulet, and Hélène de Pontual

Otoliths are biocalcified bodies connected to the sensory system in the inner ears of fish. Their layered, biorhythm-following formation provides individual records of the age, the individual history, and the natural environment of extinct and living fish species. Such data are critical for ecosystem and fisheries monitoring. They often lack validation, however, and the poor understanding of biomineralization mechanisms has led to striking examples of misinterpretations and subsequent erroneous conclusions in fish ecology and fisheries management. From the characterization of the physico-chemical characteristics of fish otoliths, we present a numerical model of otolith biomineralization. Based on a general bioenergetic theory, it disentangles the complex interplay between metabolic and temperature effects on biomineralization. This model resolves controversial issues and explains poorly understood observations of otolith formation. It represents a unique simulation tool to improve otolith interpretation and applications, and, beyond, to address the effects of both climate change and ocean acidification on other biomineralizing organisms such as corals and bivalves.

Keywords: climate, cod, North Atlantic, otolith.

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**ICES CM 2012 /J:28      Poster**

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**Extensive otolith archive opens for reconstruction of fish life history**

Jane A. Godiksen, Audrey Geffen, Arild Folkvord, and Olav S. Kjesbu

The Institute of Marine Research collects about 80 000 otoliths each year through our own surveys, the reference fleet programme (collaboration with fishers), and coastguard surveys. Of these, approximately 60% are samples of gadoids, with the majority being cod, and 30% are from pelagic species, with herring accounting for the majority. Collections of cod otoliths have been conducted since 1920, though the amount of archived material varies among years. Age estimation is often done on board soon after catch, for management purposes, but the use of otoliths to gain other information has been limited until recently. This remarkable archive needs to be used for more than just ageing, and we are therefore in the process of establishing a research centre for advanced analyses of otoliths. Many analytical techniques are available to our institute for management ecology and climate studies. Past work includes: (i) spatial variation in otolith growth phenology among cod and (ii) stable oxygen isotope analyses of historical cod otoliths to reconstruct climate effects. Current work includes: (i) spawning zones and evidence of skipped spawning using otoliths and post-ovulatory follicles (POF) of cod and saithe and (ii) genetic changes in cod populations using DNA extracted from otoliths. Upcoming work includes: (i) trophic history of cod over a 100-year period using stable C and N isotopes from annual growth zones of the otolith and (ii) haddock otolith growth in boom and bust conditions.

Keywords: archive, Barents Sea, gadoids, otoliths.

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**ICES CM 2012/J:29      Poster**

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**Discriminating subpopulations of Baltic Sea sprat by otolith macrostructures and body morphometrics**

Laura Meskendahl, Jens-Peter Herrmann, and Axel Temming

Growth, body condition, and spawning grounds of the small pelagic clupeid sprat are assumed to vary among the different geographical regions of the Baltic Sea. Despite that, Baltic sprat is still managed as one single stock, ignoring the differences in physiological and life history characteristics of subpopulations. In order to identify possible subpopulations, we reconstructed the growth histories of ~4200 female fish caught during peak spawning times (April and May) between 2002 and 2011 in different Baltic Sea regions. Otolith annual ring widths were digitally measured on high-resolution images. For ~700 of these fish we also collected individual data on body morphometrics and condition. Statistical analyses revealed that individuals with high and low growth rates occurred in the central Baltic (Arkona Basin, Bornholm Basin), whereas in the eastern regions only individuals with low growth rates were observed (Gotland Basin, Gdansk Basin). Combining these results with available data on sprat abundances during peak spawning suggests that fish from eastern parts and from the Arkona Basin migrate into the centrally located Bornholm Basin, whereas fast-growing individuals from western regions apparently do not migrate into the more eastern basins. We conclude that the sprat stock in the investigated regions can be separated into at least two subpopulations with different growth patterns, one inhabiting the area around Bornholm and the Arkona Basin, the other mainly spawning in the Gdansk and Gotland Basins, respectively.

Keywords: Baltic Sea, growth, migration, otolith annual rings, sprat.

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**ICES CM 2012/J:30      Withdrawn**

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**ICES CM 2012/J:31      Poster**

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Age determination of Baltic herring: the case of the Gulf of Riga

Ivars Putnis and Georgs Kornilovs

Gulf of Riga herring is a small stock of spring-spawning Baltic herring inhabiting the Gulf of Riga in the eastern Baltic. It differs substantially by size-at-age from the neighbouring herring stock in the central Baltic that also reflects on otolith morphometrics with narrower growth zones and characteristic transition zone, recognized as a region of significant change in the form (e.g. width or clarity) of the annual growth zones. In the otoliths of Gulf of Riga herring it appears in years of bad feeding conditions and poor growth for age 2 and older herring, when summer zones are narrow and darker than in years with good feeding conditions. The older the fish, the more difficult it is to distinguish annuli in the transition zone. The option is age determination using otolith structure patterns, assuming that each year class has its characteristic pattern. Features (“natural tags”) that can be used for pattern identification are width of the growth zone and transition zone appearance in particular years. In recent years transition zones have developed in 2001, 2003, 2006, and 2010. The paper describes alternative age determination of Gulf of Riga herring using information from “natural tags”.

Keywords: age determination, Baltic Sea, Gulf of Riga herring, transition zones.

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**ICES CM 2012/J:32      Poster**

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**Experimental comparison of four preparation techniques on two structures for age estimation of Rajidae: a case study on *Raja clavata***

Ilse Maertens, Annemie Zenner, Martine Moerman, and Els Torrelee

The top four fish landed by the Belgian fleet in 2011 are plaice, sole, rajidae, and cod in order of their landed weight. Rays and skates are hence commercially important for the Belgian fisheries. However, insufficient information on the compositions of catches of these elasmobranchs impede the analyses necessary for sustainable management. Growth and age are important life-history parameters. Starting age-estimation of rays and skates in the ILVO-lab, we have opted to try four preparation techniques on two structures of *Raja clavata*: vertebral centra and dermal denticles. The concentric banding in these structures reflects growth of the individual. Enhancement of the contrast between these opaque and translucent bands can be obtained by sectioning, clarification media, or staining. A minimum of 50 fish will be used, with 5 vertebrae and 5 dermal denticles sampled per fish. Vertebral centra and dermal denticles will be aged either whole or subject to sagittal sectioning followed by addition of a drop of oil on the section or by staining with alizarin red or neutral red. Age estimations will be performed twice by each of two experienced age readers. The effect of preparation techniques and the structures used on contrast enhancement will be evaluated by within- and between-age reader repeatability by means of percentage agreement, average percent error, coefficient of variation, and age-bias curves.

Keywords: alizarin red, dermal denticle, neutral red, *Raja* spp., vertebra.

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**ICES CM 2012/J:33      Poster**


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**Looking into the past: cataloguing Cefas' historical otolith archive**

Sally Songer, Christie Stewart, Glenn Saunders, Suzy Baldry, Mark Smith, Charlotte Jennings, Mike Armstrong, and E. Hunter

In the UK, Cefas have been collecting fish ear-stones (“otoliths”) for use in the routine ageing of exploited fish stocks for over a century. In recent decades scientists have become aware of additional chemical properties of otoliths that can be used to interpret the migratory behaviour of wild fish and aid in stock discrimination, for example by isotopic or genetic analysis. Indeed recent “big science” publications in high-level journals have successfully identified interdecadal climate change and consequent impacts on living organisms, as a result of large-scale collaborative projects mining data reserves held by multiple institutions. As analytical techniques continue to evolve, the value of historical collections should not be underestimated. To date, the Cefas otolith collection has never been fully catalogued. In response to future science needs, we are currently in the process of sorting, cataloguing and re-housing our otolith collection. Since many of the analytical techniques routinely applied are destructive, with a broad-based but distinctly finite supply of material, it is important that decisions about what samples should be provided for different uses should be based on a clear understanding of what is available. Here we present an overview of our archiving experience to date, including highs, lows, and insights.

Keywords: Cefas, climate change, elemental chemistry, historical otoliths, stable isotopes.

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**ICES CM 2012/J:34      Poster**


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**Can otolith chemistry unravel the mysteries of the Newfoundland cod?**

Genevieve D'Avignon and George Rose

The depleted Atlantic cod (*Gadus morhua*) of the Newfoundland and Labrador region have many spawning grounds and complex stock structures, each subject to change during rebuilding under climate change. Management necessitates understanding the dynamics of populations, stock structures, and connectivity among spawning groups. Otolith chemistry has been used as a natural tag enabling discrimination of cod spawning groups in more southerly waters in Atlantic Canada. We investigated the use of laser ablation inductively coupled plasma mass spectrometry to analyse the otolith composition of four spawning aggregations of cod in Newfoundland and Labrador waters (inshore and offshore on the south and northeast coasts). A group-specific fingerprint was established for each spawning aggregation using the elemental ratios of Mg, Mn, Sr, and Ba. The fingerprint differed among groups and was temporally stable, with cod of three cohorts collected in two consecutive years correctly assigned to their spawning group with 89–100% accuracy. Both jackknifed and randomly selected learning sets used to classify the remainder gave similar results. Fingerprint stability suggests that otolith signatures can be used to track cod movements over time, identify distribution shifts that may occur with changing climate, and potentially determine the contribution of each spawning group to fisheries.

Keyword: Atlantic cod, *Gadus morhua*, LA-ICP-MS, natural tag, otolith chemistry.

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**ICES CM 2012/J:35      Poster**

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**Some results of long-term investigations of morphological parameters of Baltic cod otoliths**

T. Baranova, D. Zilniece, and M. Plikshs

The results of a study of morphologic characteristics of Baltic cod otoliths during 1960–2010 are presented. The morphometric analysis of otoliths included measurements of otolith weight (mg), length (mm), width (mm), thickness, and width of annual growth zones on the broken surface of otolith in units of ocular-millimeter. Statistical tests show no significant difference between right and left otoliths and between sexes. The mean index of sulcus length (distance from the anterior edge of otolith to the sulcus notch) to total length was 0.43–0.44 for both populations of the Baltic cod (eastern and western), which is possibly characteristic for the genus *Gadus*. The relationships between otolith size and fish size and age were examined for cod of a number of cohorts from the two different areas of the Baltic Sea. Growth curves and biometric parameters of the fast-growing western Baltic cod and those of the more slowly growing eastern Baltic cod differ considerably. We also tested for a change in the relation between the size of fish and the size of otolith from the early 1980s (when there was a sharp increase in the stock of Baltic cod) to the most recent decade, during which period changes in the growth pattern of cod have resulted in a large overlap in the sizes of fish in adjacent age groups. The revealed strong relation between otolith biometrics and length and age of fish allows its use in age determination.

Keywords: Baltic cod, otolith biometrics, otolith growth.

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**ICES CM 2012/J:36      Poster**

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**Discrimination between Greenland halibut in Greenland and Norwegian waters based on right otolith contours—a case study from 2007**

Alf Harbitz, James Kennedy, and Ole Thomas Albert

Image analyses of whole Greenland halibut otoliths were performed in order to discriminate between stock components across the Northeast Atlantic. In a preliminary analysis, images of right otoliths from 59 Greenland halibut caught in East Greenland in 2007 are compared with 1039 images from fish caught in Norwegian waters the same year. Standardized elliptical Fourier descriptors (EFDs) were calculated based on the otolith contours detected by an image analysis tool (Matlab), limited to the ten first harmonic components (37 variables) as a reasonable representation of the contour shape, and a linear Fisher discriminant analysis was applied. To eliminate possible effects of differences in size and sex, each discriminant analysis was performed by randomly selecting 59 individuals from Egga at a time in such a way that the same sex and length distribution as for the Greenland individuals was obtained. The score was calculated by cross-validation, leaving one otolith out at a time. Based on 1000 simulations, an average score of 78% correctly classified Greenland individuals and 75% correctly classified Norwegian individuals was obtained, with corresponding standard deviations of 3.9% and 5.4%, respectively.

Key words: discriminant analysis, Greenland halibut, otolith morphometrics, stock separation.

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**ICES CM 2012/J:37      Poster**

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**Longitudinal length back-calculations based on otoliths versus scales differ systematically in haddock (*Melanogrammus aeglefinus*)**

Hannes Baumann, Sandra J. Sutherland, and Richard S. McBride

Analysis of scales and otoliths can reveal the growth history of individual fish, when measuring annulus widths and back-calculating individual length-at-age. Such longitudinal data are unbiased by selective mortality, so they are advantageous for disentangling environment, genetic, and fishing effects on fish growth. Despite their proven value, longitudinal data are not routinely incorporated into production ageing programmes because of logistical constraints. Retrieval of these data is further complicated by the fact that many programmes have changed their primary age structure from scales to otoliths. In this study, we compare annulus widths in scales versus otoliths from Georges Bank haddock, one of the most productive groundfish stocks in the Northwest Atlantic. Haddock scales were collected and aged annually from 1931 to 1994, after which otoliths became the primary structure for ageing. In spring 2011, we collected paired scale and otolith samples from haddock and compared the annulus counts (ages) and widths for both structures. While generally similar in number, scale and otolith annuli were found to differ systematically in their relative widths, mainly because initial annuli are deposited closer to the origin in scales than otoliths. Biologically realistic intercepts in the regression model did not remove the systematic bias. To make both structures comparable, we developed an age-independent correction between scale relative annuli widths (RAW) and otolith RAWs:  $\ln(\text{RAW}_{\text{Oto}}) = 0.7202 * \ln(\text{RAW}_{\text{Scale}}) + 0.0712 * \ln(\text{RAW}_{\text{Scale}})^2$ . Such results are a necessary step towards extracting archived longitudinal data to understand decadal drivers of growth processes in exploited fish stocks.

Keywords: age-structure comparisons, Georges Bank haddock, historical archives, reconstruction of individual growth rates.

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**ICES CM 2012/J:38**

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**Episodic events recorded in otoliths—keeping an ear to the ground**

Audrey J. Geffen and Beatriz Morales-Nin

Though we often liken otoliths to tree rings, we rarely make use of the analogy to identify or track major events in the environment that can be recorded as part of otolith growth. Earlier interest in environmental monitoring has more recently been overshadowed by population studies. Advances in the sensitivity of optical and chemical analysis, and better familiarity with biochronology methods should generate renewed interest in studying episodic events. These vary from individual life history events, such as settlement or spawning, to environmental events, such as pollution or severe weather. Using a combination of case study examples and theoretical scenarios, we explore the potential of this underutilized otolith analysis application. Going beyond ageing and growth studies, the unique properties of otoliths can record snapshots of the environment and provide *in situ* evidence for the individual-level responses to episodic events.

Keywords: habitat monitoring, otolith chemistry, pollution.

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**ICES CM 2012/ J:39****A plausible mechanism for uptake of manganese in fish otoliths - evidence and a model**

K. E. Limburg, T. Hayden, G. Jackman, C. Nack, R. Oliveira Monteiro, C. Olson, S. Turner, and Y. Walther.

Aragonitic fish otoliths are well known to incorporate manganese, but the mechanism(s) have been debated. Some species have elevated Mn in the primordium (core), suggesting physiological control. On the other hand, we have shown that Mn incorporated into Baltic cod (*Gadus morhua*) otoliths is correlated with hypoxia, but is otherwise not elevated in the core. Under hypoxic/anoxic conditions, sediment Mn is reduced to Mn<sup>2+</sup> and Mn<sup>3+</sup>, both dissolved forms. Dissolved manganese may remain in the water column for some time even when coming in contact with oxygen. Cod otoliths apparently take up this dissolved Mn when it is available. Here, we explore the uptake of Mn in otoliths of other species, and propose a model of uptake that is a function of both environmental availability of Mn and physiological state. Exceptions to the proposed mechanisms exist, and pose further research fronts.

Keywords: otolith chemistry, manganese, hypoxia, habitat use

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## Theme Session K

### Managing in a complex environment: defining approaches for multiple species and ecosystems

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#### ICES CM 2012/K:01

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##### **FLBEIA: a toolbox for bioeconomic impact assessment of fisheries management strategies**

Dorleta García, Marina Santurtun, Raúl Prellezo, Sonia Sanchez, and Marga Andres

FLBEIA is an R package build on top of FLR libraries. The purpose of the library is to provide a flexible and generic tool to conduct bioeconomic impact assessments of harvest control rule-based management strategies under a management strategy evaluation framework. The operating model is formed by the biological, the fleet, and the covariables components and the management procedure by the observation, the assessment, and the advice components. The model is multistock, multifleet, and seasonal, and uncertainty is introduced by means of Monte-Carlo simulation. The covariables component allows the introduction of variables of interest not present in biological and fleets components. For example, it could be used to introduce relevant ecosystem components in a simple way. Thus FLBEIA can be used to evaluate the performance of multiannual management plans in a mixed fisheries context and can introduce some ecosystem aspects. The library provides several functions to describe the dynamics of each model component and the user chooses the functions to be used in each specific model implementation. Furthermore, if for some of the components, the functions provided within FLBEIA do not fulfil the requirements, the user can code the functions that adequately describe the dynamics of those components and use the existing ones for the rest. Thus we can define it as a toolbox more than as a model. The library is being used in several case studies with very different peculiarities, for example Basque offshore mixed fisheries, Basque inshore sequential fisheries, or seabream artisanal fisheries.

Keywords: bioeconomic model, management strategy evaluation, multiannual management plan, simulation

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#### ICES CM 2012/K:02      **Withdrawn**

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#### ICES CM 2012/K:03

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##### **RTI, a spatiotemporally explicit tariff-based approach for fisheries management considering multiple species and ecosystems**

Sarah B. M. Kraak, Dave G. Reid, Deirde Duggan, Edward A. Codling, Ciarán J. Kelly, and Emer Rogan

Recently we published a “Food for Thought” paper

(<http://icesjms.oxfordjournals.org/content/early/2012/02/24/icesjms.fss033.short>) in which we propose a simple management approach that integrates mixed-fisheries targets and ecosystem objectives. Fishers would be allocated fishing-impact credits, called “real-time incentives” (RTIs), to spend according to spatiotemporally varying tariffs, replacing the conventional landings quota. RTI quotas and tariffs would be based on commercial stock and ecosystem targets, while the relative tariffs can be updated in real time by data acquired through new technologies. The fisher could choose how to spend his or her RTIs, for example, by limited fishing in sensitive areas or by

fishing longer in less sensitive areas. This way ecosystem costs are internalized and fishers have to take them into account in their business decisions. The target fishing mortalities of the commercial species would be set according to agreed harvest control rules (HCRs) but for ecosystem objectives no conventional rules exist yet. When conflicting or non-prioritized impacts are not explicitly handled by the (management) system, this may result in a highly complex implementation, which is not transparent in its objectives. However, a single currency for the various commercial species and ecosystem elements would impose the demand to explicitly trade-off or prioritize different impacts and reach a compromise. In this paper we explore (i) participatory decision-making mechanisms to reach consensus on the relative weightings of the various targets/objectives; (ii) the performance of the single-currency RTI system as compared to a set of multiple RTI quota for each of the targets/objectives; (iii) the robustness of the performance under a range of profit-maximizing fisher strategies.

**Keywords:** ecosystem approach to fisheries management (EAFM), fisher strategies, governance, internalized costs, mixed fisheries management, participatory decision-making, spatiotemporal flexibility, tariffs, trade-off.

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## **ICES CM 2012/K:04**

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### **Evaluation of tuna management and conservation measures with a spatial ecosystem and population dynamics model**

Patrick Lehodey, Inna Senina, John Sibert, and John Hampton

The Western and Central Pacific Fisheries Commission (WCPFC) manages major tuna fisheries exploiting a few tuna species but with different fishing gears and fleets from multiple countries. The WCPFC convention area includes a mosaic of EEZs and international waters. In this complex landscape, strong interactions exist between purse-seine fisheries catching mainly skipjack and yellowfin tuna for canneries and longline fisheries targeting large yellowfin and bigeye tuna for the sashimi and other fresh or frozen tuna markets. The introduction of the drifting fish aggregating devices (FADs) by the purse-seiners added a strong issue because of its related bycatch mortality of juvenile bigeye tuna. Thus, the WCPFC is implementing conservation measures, including spatial closures in the High Seas, to reduce fishing mortality on bigeye stock that has probably been overfished for several years. But in parallel, developing Pacific Islands countries are trying to maximize their economical revenue from the skipjack purse-seine fishery, with the sustainable objective of limiting the spawning biomass decrease to 40%. We apply a spatial ecosystem and populations dynamics model (SEAPODYM) to these species and fisheries to investigate the effects of management and conservation measures. After the optimal parameterization of the model is achieved for each species and its fisheries, using a maximum likelihood estimation approach, various spatiotemporal fishing effort scenarios can be simulated and their impacts on the different stocks of tuna evaluated. Examples are used to illustrate the interest of this new tool for testing management scenarios in a complex framework.

**Keyword:** fisheries, management, modelling, SEAPODYM, spatial population dynamics, tuna.

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**ICES CM 2012/K:05**

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**Delineating ecosystem overfishing: analysis of fishing pressure and environmental thresholds for ecological indicators**

Scott I. Large, Gavin Fay, Kevin Friedland, and Jason S. Link

Both fishing and environmental forces influence the structure of marine ecosystems. To implement an ecosystem approach to fisheries and to understand marine ecosystems, an evaluation of ecological indicators is warranted. To use ecological indicators in this context, it is important to understand the relative contributions of fishing pressure and the environment, and particularly to identify inflection points where these drivers significantly influence ecological indicators. We empirically determined thresholds where environmental forces (i.e. AMO and SST) and fishing pressure significantly influenced the response of ecological indicators for the Northeast US large marine ecosystem. We used generalized additive models (GAMs) to predict a best fit line for univariate comparisons between drivers and response indicators. With this fitted line, parametric bootstrap replicates were used to establish 95% confidence intervals (CIs) for estimated first (i.e. slope, or short-term trend) and second (i.e. inflection, or threshold) derivatives for each univariate comparison. A significant trend or threshold was noted when first or second derivative CIs passed beyond zero, allowing us to delineate the level at which drivers influence the rate and direction of ecosystem indicators. We identify reference levels where environmental forces and fishing pressure result in ecosystem change by looking at aggregated responses of multiple ecological indicators. By extending this approach into the multivariate, evaluation of simultaneous and relative effects of different drivers impacting these thresholds was elucidated. Identifying trends and thresholds on aggregate ecosystem properties is important in establishing the foundation for a more holistic basis for managing fisheries.

Keywords: ecosystem health, derivative analysis, ecosystem responses, ecosystem-based fisheries management, generalized additive modelling, GAM.

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**ICES CM 2012/ K:06**

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**Global comparison of the relative effects of fishing and the environment on ecological indicators**

Scott I. Large, Hervé Demarcq, Caihong Fu, Nicolas Hoepffner, Leigh Gurney, Ben Knight, Jason S. Link, Gabriel Reygondeau, Anthony Richardson, Dawit Yemane, and the IndiSeas Working Group

In addition to fishing, environmental and climate drivers ranging from local to global scales may also influence the structure of marine ecosystems. To understand these systems and progress towards implementing an ecosystem approach to managing fisheries, ecological indicators of change help convey the status of fished ecosystems. To use ecological indicators in this context, it is important to understand the relative contributions of fishing pressure and the environment upon the response indicators. Here, we assess the relative importance of fishing pressure and the environment on ecological indicators selected by the IndiSeas program from 35 marine ecosystems worldwide. To facilitate comparison between unique ecosystems, we used a generalized linear model (GLM) approach to partition the influence of environmental factors (i.e. local, basin-specific and global environmental/climatic factors) and fishing pressure on ecological indicators. We identify instances where environmental forces are more important than fishing pressure in influencing the response of ecological indicators and vice versa, and attempt to provide some generic rules under which the assessed ecological indicators can be expected to be specific to fishing pressure or to environmental changes.

Keywords: climate, ecosystem-based fisheries management, generalized linear model.

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**ICES CM 2012/K:07**

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**Building fleet-based management plans, a pathway to implement an effective ecosystem approach to fisheries management in European Seas**

Didier Gascuel

The ecosystem approach to fisheries management (EAFM) aims at ecological sustainability, economic profitability, and social fairness. We present here the pragmatic approach developed by the Scientific, Technical and Economic Committee for Fisheries (STECF) working group on EAFM and show that a fleet-based approach is the pathway to build multispecies and ecosystem long-term management plans and to implement an effective EAFM. It especially allows trade-offs between the three pillars of the sustainable development of fisheries to be analysed. First, a simple diagnosis on the health of each ecosystem is proposed, based on the analysis of stock-based and ecosystem indicators. Then, a fleet-based analysis is presented using indicators of the ecological impacts and the socio-economic performances of the major fleets operating within each ecosystem. We show whether each fleet segment, on average, sustainably exploits the stocks; ecosystem indicators measure the fleet's impacts on habitat and on the foodweb. Although the method still needs improvements and results are preliminary because of the poor quality of available data, the analysis showed that simple indicators can be estimated and clearly highlight contrasts between fleet segments. Such an approach can contribute to progress from a stock-based to an ecosystem-based management. It could be used to determine which fleet segments would have to be reduced and which ones could be developed. Fleet-based environmental assessments should be used to guide the definition of long-term management plans, including fishing effort and access right regulations. It could also be the basis to introduce positive or negative economic incentives in order to encourage fleets to improve their fishing practices.

Keywords: ecosystem approach, ecological impact, economic performances, European fisheries, fleet-based management.

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**ICES CM 2012/K:08**

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**Towards ecological and economical realism – modelling trade-offs in multispecies fisheries**

Rudi Voss, Martin F. Quaas, Jörn O. Schmidt, Olli Tahvonen, and Christian Möllmann

Ecosystem-based management (EBM) is an integrated approach to management that considers the entire ecosystem with the goal of providing the full suite of ecosystem goods and services that humans want or need. Today, fisheries management is largely single-species, ignoring the ecology of fisheries target species. Moreover, socio-economic outcomes and consequences of different management actions are seldomly considered. When implemented successfully, a basic characteristic of EBM is that conflicting interests of a number of interest groups are reconciled. This implies that trade-offs have to be made in order to provide advice for management that is accepted by various stakeholder groups and assures a sustainable use of marine living resources. As a future tool for EBM we developed a coupled ecological–economic fisheries model that incorporates ecological realism by considering age-structure dynamics of interacting populations. Using optimization routines, the model is able to address different ecological but especially also economical trade-offs that have to be made in EBM. We applied our coupled model to the Baltic Sea, a suitable ecosystem for our study because of its simplicity, with only three interacting commercially important species (i.e. cod, herring, and sprat). We examine the effects of moving from pure single-species advice to multi-species advice by computing optimal harvesting scenarios for varying fishery management priorities. We demonstrate that economically efficient multispecies management will result in winners (i.e. the cod fishery) and losers (i.e. the small pelagics fisheries), a fact that has to be frankly communicated to the stakeholder community.

Keywords: Baltic, ecological–economic model, ecosystem-based management, trade-offs.

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**ICES CM 2012/K:09**

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**Mixed fisheries forecasts—lessons learned from their initial application to North Sea fisheries**

S. J. Holmes, C. Ulrich, and S. A. Reeves

Mixed fisheries and technical interactions in European fisheries have been a subject of research for many years. The establishment in 2010 of an ICES Working Group tasked with producing annual mixed fisheries forecasts and advice for North Sea demersal fisheries represents a commitment to use these approaches in routine scientific advice for the first time. The demersal fisheries of the North Sea provide a particularly interesting context for this work because of their high complexity in terms of the numbers of fleets, gears, métiers, and species involved, and also because mixed-fishery effects have contributed to the lack of recovery of the North Sea cod stock. The implementation of mixed-fishery forecasts which account for the fishery complexity and thus allow mixed-fishery effects to be modelled has posed a number of challenges relating to issues such as data requirements and the need to integrate the work with the existing single-stock assessments. The explicit representation of the complexity of the fisheries also raises questions about the extent to which mixed fisheries science can be used to give "advice" in the traditional sense. This paper addresses the challenges and issues that have arisen through the practical implementation of mixed-fishery forecasts, then discusses the further developments that will be required to progress towards more integrated multistock management using mixed-fishery management plans.

Keywords: advice, forecasts, mixed fisheries, North Sea.

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**ICES CM 2012/K:10**

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**Trade-offs between commercial fishing fleets, marine mammals, and finfish biomass**

Laurel Col, Robert Gamble, Sarah Gaichas, and Jason Link

Shifts of dominance in commercial fishing fleets and changes in the magnitude of marine mammal consumption can alter populations of fish prey groups, and perhaps competing species that eat the same prey, although the direct and indirect effects are often not considered in fishery models. We used a multispecies production model to test the interactions between mixed fleet fisheries, their target species, and marine mammals in a complex ecosystem representation of the Northeast US continental shelf. We simulated biomass and catch trajectories and calculated associated biological reference points for commercially important finfish caught by gillnet, dredge, and two bottom-trawl fisheries. Three levels of marine mammal predation were then introduced to determine the effects on their prey and competing finfish populations. Changes in the biological reference points for finfish groups, as a result of marine mammal consumption, were examined. In addition, thresholds of minimum prey biomass required for pinnipeds, odontocetes, and baleen whales were compared to prey biomasses in each scenario. This type of evaluation of trade-offs between mixed fishery fleets and protected species requirements is essential as we transition to ecosystem-based fisheries management.

Keywords: competing fishing fleets, ecosystem-based fisheries management, multispecies modelling, protected species requirements, reference point determination, trade-off evaluation.

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**ICES CM 2012/K:11**

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**Objective specification of a multi-stakeholder interface to ecological models for the ecosystem approach to fisheries management**

Deirdre Duggan, Keith Farnsworth, Sarah Kraak, and Dave Reid

The increased involvement of stakeholders in the ecosystem approach to fisheries management presents a challenge in (i) priority-setting among competing interests and (ii) the communication of complex ecological information among diverse stakeholders. This study reports the first stage in the creation of an interface between stakeholders and ecological models, enabling stakeholders to evaluate management plans using ecological indicators. The interests of 90 stakeholders are catalogued and organized according to four management objectives: yield, profit, employment, and ecosystem preservation. Numerical analysis of these interests leads to an objective categorization of stakeholders. We find that six quantitative categories better describe stakeholder interests than five typical qualitative allocations (environmental, managers, fishing industry, academic, and other). Accordingly, the quantitative categories are used when identifying combinations of ecological indicators matching particular stakeholder interests. From the interests, a set of objective quantitative questions is assembled, which can be answered using ecological indicators from the models. For this, 177 indicators are identified from the published literature and categorized according to (i) the pressure–state–response concept, (ii) four management objectives, and (iii) broad fisheries themes. From these three categorizations, we attempt to identify the best combinations of indicators for stakeholder interests. Finally, a network connecting indicators to stakeholders and metrics, such as connectivity and link strength to prioritize indicator delivery, is discussed.

Keywords: ecosystem approach, indicators, quantitative analysis, stakeholders.

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**ICES CM 2012/K:12**

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**Towards multistock management plans for European fisheries**

Stuart Reeves, Peter Hopkins, Kenneth Patterson, and Stefanie Schmidt

Long-term management plans are an established part of European fisheries management. The current reform of the EU's Common Fisheries Policy (CFP) anticipates more extensive use of long-term management plans, and notes that: "Multi-annual plans should where possible cover multiple stocks where those stocks are jointly exploited. The multiannual plans should establish the basis for fixing fishing opportunities and quantifiable targets for the sustainable exploitation of stocks and marine ecosystems concerned, defining clear timeframes and safeguard mechanisms for unforeseen developments." This extension of the scope of management plans to cover both multiple stocks and other components of the marine ecosystem raises a number of questions with regard to the design and implementation of such plans. These include how to handle biological and technical interactions between stocks, and the definition of objectives for multistock plans. This paper describes the background to the plans that are under development for the Baltic and North Seas. We focus particularly on the policy background to these developments but also discuss the scientific basis for these approaches, and the possible science needs for further development of such plans.

Keywords: long-term management plans, mixed fisheries, multispecies, MSY.

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**ICES CM 2012/K:13**

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**Evaluating trade-offs for multispecies management procedures for exploited marine populations using bootstrap for highly disparate datasets**

Bjarki Þór Elvarsson and Guðmundur Þórðarson

Over the years, considerable effort has been put into devising and negotiating management procedures for exploited marine populations. As an example, the International Whaling Commission agreed on a whaling moratorium while examining different management procedures. Other international bodies have also called for more sustainable management of marine resources. The World Summit on Sustainable Development (WSSD) set out a goal for the maintenance and restoration of fish stocks to the maximum possible yield (MSY) to be a part of management plans no later than 2015. Management procedures commonly encompass a range of socio-economic objectives, but their biggest concern is the maintenance or restoration of stock to an acceptable production level, typically  $B_{msy}$ . Extending these procedures to include multispecies interactions introduces a number of questions and possible trade-offs that need to be studied further. How does, for example, fishing close to  $F_{msy}$  for one species affect another species that is harvested in tandem? In this study, a recently developed bootstrap approach for disparate datasets is used to evaluate possible trade-offs. A model of tusk and ling in Icelandic waters that model the simultaneous harvest of both species is used as a case study.

Keywords: bootstrap, management procedures, multispecies models, technical interactions, uncertainty.

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**ICES CM 2012/K:14**

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**Setting maximum sustainable yield targets when yield of one species affects that of other species**

Anna Rindorf, David Reid, Steve Mackinson, John Mumford, Mark Dickey-Collas, Ralf Döring, Louize Hill, Alexander Kempf, Raúl Prellezo, Katrine Soma, George Tserpes, and Rudiger Voss

The exploitation of interacting stocks requires management targets beyond and more complex than the usual single-species versions. As the yield of one species can affect that of another, stocks can no longer be managed independently and the yield of one species must be weighed against that of other species. But how should we prioritize and identify most appropriate targets? Do we prefer to maximize by focusing on total yield in biomass across species, or are other measures targeting maximization of profits or preserving high living qualities more relevant? And how do we ensure that targets remain not only relevant but also consistent with ecosystem, economic, and social dimensions of sustainability and that they will gain a wide acceptance with scientists, the fishing industry, managers, and other stakeholders? Here, we present results of a MYFISH workshop bringing together a total of 70 scientists, industry, managers, and NGO representatives. The workshop was designed to identify variants of maximum sustainable yield (MSY) which account for the necessary trade-offs and estimate the preferences of the workshop participants for each of these variants across five regional groups: the Baltic Sea, Mediterranean, North Sea, western European waters, and widely ranging pelagic stocks in European waters. During a well-prepared process designed in this workshop, the participants contributed with a broad variety of knowledge and perceptions, and in our view allowed an understanding of MSY in a much broader and consensual way than is normally granted.

Keywords: MSY variants, stakeholder consultation, sustainability.

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**ICES CM 2012/K:15**


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**Spatial indicators for multispecies commercial catch-based management**

Verena M. Trenkel, Jonathan Beecham, Julia Blanchard, Charles T. T. Edwards, and Pascal Lorance

Analytical stock assessments are generally based on commercial catches and scientific survey data. However, survey data are not always readily available, because of distributions spanning large spatial scales, difficulty and high-cost in adequately sampling their habitats. This is the case for many deep-water fish populations for which commercial catch and effort data are the sole available information. The deep-water fishery to the west of the British Isles is a multispecies fishery with one or two target species which change seasonally and over time. The jointly exploited species have different life-history traits and spatial distributions. Using spatial simulations we explore the impact of managing a given species at maximum sustainable yield (MSY) on (i) the dynamics, (ii) the catch per unit effort (cpue) data of the non-target species and we evaluate different methods to derive indicators of spatial distribution changes in terms of the robustness with which each species is targeted. The tested methods include fitting spatial ellipses and counting occupied rectangles. The methods are also compared for logbook data from the French deep-water fishery.

Keywords: cpue, indicators, multispecies, spatial.

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**ICES CM 2012/K:16**


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**(Re)moving the goalposts**

David C. M. Miller

The use of target reference points (e.g.  $F_{MSY}$ ) in fisheries management is fraught with problems. While the theoretical basis for such targets may be sound, there are numerous obstacles to applying them in practice. Calculating target reference points is difficult, especially when trying to incorporate the known uncertainties, and calculated values may be invalid due to the unknown uncertainties. Furthermore, fisheries management in ICES tends to call for fixed target reference points, though as ecosystems and fisheries change, so to do the reference points. In an ecological context, defining a fixed target in a changing ecosystem makes little sense, while continually redefining reference points (moving targets) is an inappropriate form of management. In a mixed fishery context, it is challenging to balance progress towards possibly conflicting targets of the mixed fish stocks as changes in the fishery (e.g. gears, locations, markets) change the relative pressure on each stock from year to year. Fortunately, having broad long-term objectives does not necessitate management in the short term on the basis of long-term target reference points. It is proposed that long-term sustainability could equally be achieved in the absence of target reference points, while limit reference points can still be of use to ensure stocks are maintained within sustainable bounds. Using the North Sea demersal mixed fishery as an example, a system is proposed whereby short-term management on the basis of stock or ecosystem indicator trends can be used to aim towards long-term management objectives.

Keywords: fisheries management, mixed fisheries, multispecies, target reference points.

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**ICES CM 2012/K:17**


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**Testing the robustness of harvest control rules applied to Baltic pelagic stocks**

Ernesto Jardim, Iago Mosqueira, Colin Millar, Chato Osio, and Tomas Groehsler

This work tests the robustness of harvest control rule (HCR) reference points of Baltic pelagic stocks (herring and sprat) to mis-specification of population dynamics. Reference points (RP) are suggested that guarantee the delivery of management objectives, and alternative HCR slopes are explored to increase robustness. The analysis is carried out by stochastic simulation. It is clear that

there are pairs of values that have a high probability of driving the stock to unsustainable levels. The levels of overcatch do not change the wider perspective, although above 20% there are pairs of RP that may collapse the biomass. HCRs are not robust when there were inconsistencies between the biomass trigger and population dynamics, and mismatches between the biomass trigger and the target fishing mortality—when exploitation objectives generate biomasses lower than the biomass trigger.

Keywords: Baltic, management, pelagic, reference points, stochastic simulation.

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## ICES CM 2012/K:18

### **Towards ecosystem-based management of the Norwegian Sea using coupled biophysical and fisheries models**

Kjell Rong Utne, Jens Christian Holst, Geir Huse, and Dankert Skagen

Present fishery management is built around a system where each stock is regarded as a separate unit managed using a single stock harvest control rule (HCR). This management regime does not take into account species interactions or variation in ecosystem productivity and structure. This can be a major shortcoming when stocks have strong interactions or a pronounced effect on the ecosystem. Hence, there is now an increasing understanding that we need to move towards ecosystem-based fishery management. The Norwegian Sea harbours large stocks of herring, blue whiting, and mackerel. These stocks have a major predatory effect on the zooplankton, which results in food competition. There is also potential for interaction through predation on eggs and larvae. Furthermore climate affects recruitment in the stocks, and warm periods are in general associated with high recruitment. We therefore need tools that can integrate the biogeography and climate variability of the ecosystems with the trophodynamics. An operational multispecies management model to evaluate ecosystem-based harvest control rules (EBHCR) for the stocks is developed. In the talk we will present the model and simulation results based on the EBHCR that take into account total stock biomass of the pelagic complex. The EBHCR are evaluated with regard to long-term yield, stability in catch and population abundance and compared to the existing HCRs for the three species. Finally we will test the harvest control rules in a fully coupled 3D ecosystem model and evaluate the ecosystem impacts of different harvest strategies.

Keywords: ecosystem-based fisheries management, blue whiting, multispecies model, Norwegian spring spawning herring, mackerel, Norwegian Sea.

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## ICES CM 2012/K:19

### **Indicator-based control rules for ecosystem-based fisheries management: evaluating practical approaches for synthesizing the effects of fishing and the environment**

Gavin Fay, Scott I. Large, Jason S. Link, and Robert J. Gamble

Successful implementation of ecosystem-based fisheries management (EBFM) requires practical methods of translating information on system status into management actions. Ecological indicators have been used to describe the status of marine ecosystems. Indicator-based control rules that use stock biomass or fishing mortality are commonly applied for single-species fisheries management. Multivariate fishery control rules in a single-species context are rare. Equivalent control rules for providing tactical advice for EBFM must have a multivariate perspective to incorporate multiple impacts and sector uses. We describe alternative approaches for developing ecological indicator based control rules for EBFM. These approaches include sets of reference points based on empirical analyses and expert elicitation, non-linear indicator thresholds obtained

from generalized additive modelling approaches, and canonical correlations from ordinations of driver, pressure, and response indicators. We use management strategy evaluation (MSE) to evaluate the performance of these control rules for setting ceilings on annual catches, both for the entire system and particular species groups. We use two ecosystem models developed for the Northeast US large marine ecosystem: (i) MS-PROD, a multispecies production model of the finfish community, and (ii) Atlantis, an end-to-end system model that includes environmental and socio-economic indicators. Results are compared to those obtained when implementing traditional single-species management approaches. Results suggest that threshold values in ecological indicators can be used successfully to set system ceilings on catches. However, the relative performance of different approaches varies with the set of indicators used and with the objectives associated with indicator reference values.

**Keywords:** Atlantis, ecological indicators, ecosystem-based fisheries management, management strategy evaluation, MS-PROD, Northwest Atlantic.

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## ICES CM 2012/K:20

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### **Balancing policy and stakeholder drivers towards ecosystem-based long-term management plans**

M. Fitzpatrick and D. G. Reid

Multi-annual recovery and long-term management plans (LTMPs) have been successful in some EU fisheries in recovering stocks (e.g. northern hake and Celtic Sea herring). We present a preliminary analysis of current LTMPs for European fisheries revealing that they are framed by a very small number of reference points or harvest control rules. While generally satisfying maximum sustainable yield (MSY) requirements, we show that these plans fare less well when assessed on their implementation of the ecosystem approach. Based on research aimed at developing a fisheries ecosystem plan for Celtic Sea herring and the FP7 project SOCIOEC, which examines industry responses to management measures, we present an analysis of what other factors could or should be included in future complex LTMPs. Influential elements in the fisheries management system identified by stakeholders are assessed on their suitability for LTMP inclusion according to criteria including: data availability including new MSFD-derived data; degree of uncertainty; measurability and associated reference points; relevance to an ecosystem approach. Our results present something of a reality check to the potential for stakeholder development of complex LTMPs, as the influence of wider environmental factors and species interactions are not well developed or prioritized in management objective preferences. Industry stakeholders display a strong hierarchy of concerns within which support for management measures focused on target stocks, such as spawning box closures and substock protection measures is high but appetite for broader environmental protection measures is weak. These aspects are better addressed through strong policy-drivers such as expanded ecosystem requirements in LTMP rules or market-driven certification incentives.

**Keywords:** ecosystem approach, fisheries, long-term management plans.

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**ICES CM 2012/K:21**

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**Institutional organization and the ecosystem approach for science and advice: a social network analysis of ICES expert groups**

Dorothy J. Dankel, Jörn Schmidt, and Doug Wilson

ICES is the world's oldest intergovernmental organization dedicated to marine science. The ICES mission statement is "To advance the scientific capacity to give advice on human activities affecting, and affected by, marine ecosystems." The ICES Mission calls for an "establishment of effective arrangements to provide scientific advice" and for coordination for "enhancing physical, chemical, biological, and interdisciplinary research". Today, over 1600 scientists from 20 member countries are affiliated with and conduct science and formulate advice as part of an overall ICES network that is given its most concrete form in the attendance of expert groups. How are these individual scientists organized in the vast landscape of over 100 ICES expert groups and what does this mean for the scientific and advice capacity of ICES as an institution? Based on a short questionnaire, we visually and analytically examine the human links between expert groups. The questionnaire results match expert group attendance to types of expertise, both the types that scientists offer and what chairs see that they need, and particularly those they lack. A number of questions relevant to the management of ICES knowledge production can be examined using this data. For example, are there groups that centralize the flow of particular kinds of knowledge? Are there groups that act as knowledge brokers? The results outlined in this paper give us a picture of how the ICES network is actually working and insight to how it can more effectively give advice in support of an ecosystem approach to marine management.

Keywords: action, ecosystem-based advice, ecosystem-based science, institutions, knowledge, organization, social network analysis.

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**ICES CM 2012/K:22**

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**Identification of potential target levels for Central Baltic Sea fishing mortalities, taking multispecies interactions into account**

Morten Vinther, Stefan Neuenfeldt, Margit Eero, Michele Casini, and Henrik Sparholt

The main biological interactions between Baltic cod, herring and sprat have been modelled in a stochastic multispecies (SMS) model. Based on this, a simple approach has been developed to quantify candidates for  $F_{MSY}$  proxies (fishing mortality that produces the maximum sustainable yield) in a multispecies context. Multispecies  $F_{MSY}$  is higher for cod than single-species  $F_{MSY}$  values, due to cannibalism. The actual  $F_{MSY}$  for herring and sprat, and cod's influence on prey yield, depend on assumptions about density-dependent growth and spatial overlap between predator and prey. The results are ready for implementation in management, however, the multispecies aspects depend on predation data mainly from the 1980s and there is an urgent need to update the information base. The current productivity regime and spatial distribution of fish stocks in the Baltic is different from the earlier period when predation data was collected. Also, prey-to-predator feedback mechanisms should be more understood before implementation in management.

Keywords: Central Baltic Sea, stochastic multispecies model, stock assessment.

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**ICES CM 2012/K:23**


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**Movement towards sustainable development of large marine ecosystems in Asia, Africa, and the Arctic**

Anne E. Hawkins

The National Oceanic and Atmospheric Administration (NOAA)'s Large Marine Ecosystems Program has developed a modular approach to ecosystem management based on five scientific and socio-economic indicators. This approach holds promise for advances toward sustainable development of large marine ecosystems across the globe by monitoring (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socio-economics, and (v) governance on an ecosystem level. The successful application of these models to date indicates potential for the long-term viability of complex multispecies and multivariate management plans. The unprecedented base funding for these programmes has recently been augmented by a replenishment of nearly one billion US dollars from the Global Environment Facility to develop large marine ecosystem programmes in Southeast Asia, Sub-Saharan Africa, and the Arctic. Examples of successful implementation of the modular concept will be discussed, along with recent developments and future growth for the large marine ecosystem approach.

Keywords: ecosystem management, large marine ecosystems, sustainable development.

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**ICES CM 2012/K:24**


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**Attaining multispecies maximum sustainable yield (MMSY) using simple linear population models**

Axel G. Rossberg

How complex do community models have to be to reliably determine multispecies–multifleet MSY reference points? It is shown that, in principle, simple autoregressive models fitted to population time-series can already do the job. MSY is attained in the single-stock case when the harvesting rate equals the population's return rate to equilibrium (independent of the production function). If the two rates are not equal, an improved harvesting rate can be found following a simple update rule. The generalization of this result to many interacting species and multiple fleets shows that MSY will be high only when the distribution of the fleet's fishing mortality over stocks is orthogonal to all eigenvectors of the community's interaction matrix, corresponding to small eigenvalues. Any model, simple or complex, has to reproduce the community's linear dynamics near the MSY equilibrium in order to predict the correct reference points. However, for complex models it might be more difficult to reproduce the small eigenvalues of the community matrix, implying the risk of unintentional overexploitation.

Keywords: analytic theory, MSY, reference points, time-series analysis.

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**ICES CM 2012/K:25**


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**Penalizing yield: maximum sustainable yield (MSY) and bycatch**

Simon Northridge, Sophy McCully, and Sophie Smout

Non-target species such as marine mammals and elasmobranchs are bycaught in commercial fisheries (despite technical measures designed to alleviate such risks) and this may result in population declines for these species. We investigate the relationship between fishing effort and bycatch, taking account of relevant covariates, to enable the prediction of bycatch resulting from different levels of fishing. Using data on life-history parameters for bycaught species (e.g.

fecundity, natural mortality rates) we explore methods to evaluate the impact of additional bycatch mortality on their populations. The MSY-based management of fisheries relies on optimizing an objective function such as net catch of target species or net profit. We explore some methods whereby such a function can be modified to take account of bycatch. The simplest approach, given perfect knowledge of the system (e.g. of target and non-target populations) would be to set absolute limits to the bycatch (and fishing effort) permissible. However, neither our knowledge nor our model-fitting is perfect, and in the light of the resulting uncertainty, more subtle approaches to penalizing the objective function (e.g. a penalty that is a monotonically increasing function of effort) may be more useful.

Keywords: bycatch, cetacean, elasmobranch, MSY, PBR.

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#### ICES CM 2012/K:26      Poster

### A pre-emptive modification of the harvest control rule for Northeast Arctic cod related to expected food availability for the stock

Bjarte Bogstad and Harald Gjøsæter

The harvest control rule for Northeast Arctic cod (*Gadus morhua*) has been in use for some years now, and seems to give satisfactory results both in terms of stock and catch development. However, the increasing stock size has raised the issue of whether there is, and in the future will be, a sufficient food supply for the cod stock. Capelin is the main food item for cod in the Barents Sea, and they show large stock fluctuations. In some periods of low capelin abundance individual growth of cod has been reduced, dependent on the amount of other food available. Thus, it could be plausible to increase fishing mortality on cod prior to periods of low capelin abundance, in order to adapt cod stock size to the amount of available food. It is discussed how far ahead of time a capelin stock collapse can be predicted, and how the harvest control rule could possibly be modified to decrease cod abundance prior to a capelin collapse. Simulations with a multispecies model for the Barents Sea are needed to investigate whether such a harvest control rule would be an improvement from the one presently in use.

Keywords: Barents Sea, capelin, cod, harvest control rule.

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#### ICES CM 2012/K:27      Poster

### Ecological, economic, social, and governance indicators for responsive fisheries management systems: an ECOFISHMAN approach

Hugo Mendes, Maria Fatima Borges, Michaela Aschen, Marta Ballesteros, Aida Campos, Rosa Chapela, Paul George Fernandes, Kristófer Gunnlaugsson, Olavur Gregersen, Anna Karlsdóttir, Alberto Murta, Ólafur Ögmundarson, Laura Wise, José Luis Santiago, Sigríður Sigurðardóttir, Jónas R. Viðarsson, and Anna Kristín Daniélsdóttir

Fisheries outcome targets and their associated indicators can be classified in four dimensions: ecological, economic, social, and governance. As outlined in the ECOFISHMAN project, ecological indicators measure the trends in the state of ecological functions, economic indicators measure the state of the human component in activities that increase conventional gross national product and trends in production accounts and economic growth, social indicators measure the human dimensions focusing on communities, household demographics and their wellbeing, and governance indicators measure the performance of rules and institutions, of the mechanism and processes to articulate interest, and of the interactions and roles of the state, civil society, and private sector in fisheries management. The four main dimensions of a fishery are associated with different criteria that represent those properties that will be affected by the process of sustainability. Here we propose and discuss a list of selected ecological, economic, social, governance indicators for outcome targets

relevant in responsive fisheries management systems (RFMS) using results-based management (RBM).

Keywords: fisheries, indicators, RBM, RFMS.

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**ICES CM 2012/K:28      Poster**

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**Using one fish community to predict another: dynamic models of predator distribution based on lower trophic level community structure and other habitat features**

Joshua P Kilborn, David F Naar, and Ernst B Peebles

This project aims to evaluate associations between larger predatory reef-fish distributions and communities of smaller species collected by fisheries-independent trawl surveys of the West Florida Shelf (WFS) in the eastern Gulf of Mexico. The distributions of the “underlying” communities of smaller species will be investigated for dynamic behaviour using a broad spectrum of static and dynamic habitat features, with the dual goals of increasing the efficiency of future stock-assessment sampling designs and predicting responses to future perturbations. The Southeast Area Monitoring and Assessment Program (SEAMAP) has conducted fisheries-independent groundfish trawl surveys on the WFS annually since 2008; catch-per-unit-effort (cpue) data, as well as a comprehensive set of standard environmental variables, are available. Canonical ordinations and non-parametric techniques will be applied to the SEAMAP database to determine how the spatial distributions of different underlying communities respond to potentially explanatory variables obtained from satellite remote sensing, shipboard acoustic techniques, and variables measured during the SEAMAP trawl surveys. Large predator distributions will be obtained from ongoing longline surveys conducted in the same sampling domain as the SEAMAP trawl surveys. The WFS is a large ecosystem that spans a variety of ecotypes, and is subject to intense commercial and recreational fishing pressure throughout the year. By identifying the statistically significant variables across the WFS, and understanding the complex relationships between environment and multispecies habitat selection, predictive algorithms can be developed to manage fisheries, especially sampling efforts, more efficiently from an economic and ecological standpoint.

Keywords: canonical ordination, Gulf of Mexico—West Florida Shelf, habitat association, multispecies assemblage.

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## Theme Session L

### Evolution of management frameworks to prevent overfishing

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#### ICES CM 2012/L:01

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##### **Canada's sustainable fisheries framework**

Derek Osborne, Marc Clemens, Guillaume Côté, and Jake Rice

In 2009, Fisheries and Oceans Canada (DFO) introduced the Sustainable Fisheries Framework (SFF), an overarching policy framework for the management of fisheries in Canada, which provides the foundation of an ecosystem-based and precautionary approach to fisheries. The science-based framework augments existing fisheries management policies with new and evolving policies, and tools to monitor and assess progress in implementing the policies in fisheries and identify areas for improvement. The SFF responds to numerous drivers, including international and domestic commitments to sustainable fisheries management and a general need for increased accountability and transparency in fishery decision-making processes. The SFF currently includes three core fisheries policies: the Fishery Decision-Making Framework Incorporating the Precautionary Approach, Policy for Managing Impacts of Fishing on Sensitive Benthic Areas and Policy on New Fisheries for Forage Species. The SFF is viewed as an adaptive framework, in which new policies and tools will be added over time to support the sustainable management of fisheries and the evolution to an ecosystem-based approach. DFO is currently developing a bycatch and discards policy, as well as several tools to support existing policies including guidelines on stock rebuilding.

Keywords: Canada, ecosystem-based, precautionary approach.

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#### ICES CM 2012/L:02

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##### **The "some good and mostly bad about maximum sustainable yield" as a management target**

Sidney Holt

This paper will briefly review the technical and political origins and history of this concept, its features and qualitative and quantitative properties, and the methods of calculating maximum sustainable yield (MSY) values. Attention will be given also to the varieties of the concept of "overfishing". It will concentrate on determinations of the steady states of fish populations from empirical data used in age- and size-structured population models which provide estimates of the sizes and compositions of "sustainable" catches as functions of fishing intensity and the selectivity of fishing operations. Attention will be focused on ways of applying the concept and suggested modifications of it (such as sustainable economic yield, the precautionary approach and the ecosystem approach to management, to multiple fisheries—by species and gears—in one region, with the EEZs of the European Union mainly in mind but with ocean-wide and global implications. The general consequences for fishing industries and communities of imposing alternative management targets will be examined briefly. Lastly, options for implementing management procedures to meet well-defined catch targets, especially by setting catch and size limits, and fishing power and deployed effort controls, will be compared.

Keywords: management, North Atlantic, overfishing, population dynamics.

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**ICES CM 2012/L:03**

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**The evolving international policy context for “overfishing” and “sustainable”**

Jake Rice

While fisheries management frameworks have been evolving, the policy context in which they are implemented and the standards that they should meet have been moving targets. The UN Fish Stocks Agreement is an important benchmark, delineating performance standards, and responsibilities for fisheries management agencies as of the early 1990s. At that time fisheries policy was set by fisheries policy-makers, and almost exclusively concerned with conservation and sustainable use of the fishery resources exploited directly. In the early 1990s, UN Conventions on Biological Diversity (CBD) and Climate Change were also ratified. The CBD reflected increasing policy interest in the state of global ecosystems, and impacts of human activities on them. This triggered activity by marine conservation ecologists, who increasingly considered fisheries a major, often poorly regulated pressure on marine biodiversity. Fisheries agencies responded to these activities by acknowledging ecosystem concepts as a legitimate part of fisheries management (e.g. the Reykjavik Declaration, 1999). Through the 2000s, both the fisheries and the biodiversity governance streams have continued to expand the policy frameworks in which fisheries management must function. However most developments have been in parallel: fisheries focused on the UNGA Sustainable Fisheries Resolutions and the work they trigger through FAO, RFMOs, and Fisheries Ministries. Biodiversity interests have focused on the UNGA Ocean and Law of the Sea Resolutions, and the subsequent CBD and UNEP Decisions. The paper will provide a timeline of additional expectations placed on fisheries management by each stream, and summarize their implications for national frameworks for sustainable fisheries management.

Keywords: biodiversity, fisheries, marine policy, sustainability.

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**ICES/CM/2012/L:04**

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**Scientific support for status determinations, stock rebuilding, and annual catch limit forecasting for US fisheries**

Richard D. Methot Jr. and co-authors

The 48 fishery management plans for 500+ stocks in the US are designed to comply with strict guidelines with regard to status determinations, stock rebuilding, and annual catch limits that will prevent overfishing. The status determinations are strongly related to the concept of maximum sustainable yield (MSY) such that overfishing is determined to be occurring if the fishing mortality rate exceeds the rate that would produce long-term MSY, and the stock is determined to be overfished if its abundance falls below a level considered to jeopardize its capacity to produce MSY. With the 1996 changes, overfished stocks must have a rebuilding plan, which cannot exceed 10 years except in certain situations. In 2006, a new requirement was established for annual catch limits in all fisheries such that overfishing does not occur. Guidelines for implementation of this provision recognized the uncertainty in all assessment products and established protocols by which scientific uncertainty should be taken into account when setting the annual catch limit below the catch level that would correspond to the overfishing limit. Although annual total allowable catch management systems had been in place in several fishery management plans for decades, the extension to all fisheries has highlighted the challenges associated with quota management where full assessments are not available. The uncertainty-based buffer also has highlighted the need for risk assessments involving biological and economic trade-offs between the degree of certainty in prevention of overfishing and the degree to which short-term fishing opportunities are reduced.

Keywords: forecasting, overfishing, rebuilding, stock assessment.

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**ICES CM 2012/L:05**

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**Changing attitudes 1970–2012—evolution of the Norwegian management framework to prevent overfishing**

P. Gullestad, J. Krog, S. Johansen, J. Williams, O. A. Misund, Å. Aglen, Å. Bjordal, and I. Røttingen

The Norwegian spring-spawning herring was overfished in the 1960s with fatal consequences. This event, and the successive rebuilding process of the stock, was paramount to the Norwegian management view on the necessity to prevent future overfishing. Nevertheless, overfishing continued on several of the larger stocks due to national regulations, illegal fishing, or lack of agreement on TAC division between coastal states. International processes within the UN, independent scientific advices through ICES, quotas in most cases set through agreements in regional fishery management organizations (RFMOs), detailed, fleet-based regulations, catch control at sea and during landing, and legal prosecution of irregularities were developed as the main structural elements of the Norwegian fishery system throughout the 1970s and 1980s. Following implementation of the precautionary approach in the scientific advices given through the ICES system in the mid 1990s, harvest control rules have been agreed upon for the major fish stocks during the last decade through cooperation with neighbouring coastal states/unions in respective RFMOs. At a national level the fisheries system has been integrated in holistic, area-based, ocean management plans, and a new Marine Resources Act has been enforced. Fishery and fish stock-specific priority tables to prioritize the management and research tasks to cope with the challenges of the Marine Resources Act have been introduced. We describe a close collaboration, but distinct roles between scientists, fishery managers, politicians, and fishers, in building a solid framework to prevent overfishing.

Keywords: harvest control rules, management, Norwegian/Barents Sea, scientific advice.

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**ICES CM 2012/L:06**

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**A discussion of the NAFO precautionary approach framework**

W. Brodie, P. Shelton, E. Couture, and K. Dwyer

In 2004, the Fisheries Commission of the Northwest Atlantic Fisheries Organization (NAFO) adopted a precautionary approach (PA) framework for the management of NAFO fish and shellfish stocks. The framework, which operates on a single stock at a time, identifies five zones into which a stock can be classified, depending on the status of the stock with respect to fishing mortality and biomass. The framework specifies various reference points which define the zones, as well as corresponding recommended strategies and management actions. In NAFO, scientists working within the Scientific Council have responsibilities to provide advice on stock status and reference points, while it is managers working within the Fisheries Commission who specify the management objectives, courses of action, time horizons, and acceptable levels of risk. Development and implementation of the framework has sometimes been accomplished through NAFO Working Groups consisting of scientists and managers. A more recent initiative within NAFO has been the development of conservation plans and rebuilding strategies for some stocks, which have drawn on the current PA framework in establishing harvest control rules. This process has also resulted in some questions around the existing framework. This paper will document the development of the NAFO precautionary approach framework, the current status of implementation and its many challenges. The paper will also discuss implementation in the context of the recently developed rebuilding strategies for depleted groundfish stocks such as cod and American plaice on the Grand Banks.

Keywords: NAFO, precautionary approach framework.

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**ICES CM 2012/L:07**


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**ICES Advisory Framework 1977–2011: from MSY to precautionary approach and back**

Hans Lassen, Ciaran Kelly, and Michael Sissenwine

The ICES Advisory Committee on Fishery Management (ACFM) was established in 1977 as a replacement of the Liaison Committee. The ACFM advised at the time based on a formalized set of scientific principles and objectives for developing such advice. These included two concepts: (i) the simple maximum sustainable yield (MSY) concept and (ii) an integrated management objective which establishes the exploitation level at a slightly lower level than  $F_{\max}$  (i.e.  $F_{0.1}$ ) to avoid some of the inherent risks in an MSY-based strategy. The ACFM adopted a policy of recommending gradual reductions in fishing mortality to address what the Committee identified as the widespread overexploitation of fish stocks. Also, the ACFM in the early 1980s moved towards “exploratory” advice and away from the “normative” advice. The ACFM further (1983) recommended that its biological advice should not be considered entirely separately from economic considerations. The next development came in 1986 and 1987 with the introduction of “safe biological limits”, laying down the basis for the later “precautionary approach” with its aim of restricting fishing within limits that would not impair reproduction. A new form of advice was adopted by the ACFM in 1991, and the Committee defined its own objective as “to provide the advice necessary to maintain viable fisheries within sustainable ecosystems”. Based on the adoption of the Fisheries Agreement in 1995, ICES introduced the precautionary approach (avoiding impairing reproduction plus a buffer) in 1998 and worked with this concept until the introduction of the MSY framework in 2009. The MSY of today is distinct from the  $F_{\max}$  concept introduced by Beverton and Holt in the 1950s, as the stock productivities (stock recruitment but also other changes in stock productivity) are modelled into the estimation of the reference point where appropriate. The advisory history shows how ICES swung between two viewpoints: one with a focus on fishing mortality-based advice (e.g.  $Y/R$  based) to another where the emphasis is on biomass-oriented advice (avoiding impaired recruitment) to assure sufficient spawning-stock biomass. The fishing mortality is closer related to fisheries management as it relates directly to fishing effort while the biomass orientation is more natural in a biological oriented modelling environment with its focus on energy transfer in the ecosystem. As ICES delivers its advice in the context of its clients’ needs, the advisory approach is thus interrelated with the managerial environment. The paper will consider how that environment has influenced the advice, both in terms of the way in which it is delivered and principles upon which it is based.

Keywords: none

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**ICES CM 2012/L:08      Withdrawn**


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**ICES 2012/L:09**


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**Evolution of New Zealand’s fisheries management frameworks to prevent overfishing**

Pamela M. Mace

Since 1986, New Zealand has managed its fisheries using a quota management system based on individual transferable quotas. As is the case for many other fisheries organizations, our Fisheries Act requires that we base our management target on maximum sustainable yield (MSY), although the specific wording implies that this should be achieved by maintaining the stock biomass near or above the biomass level associated with MSY (i.e.  $B_{\text{MSY}}$ ). The interpretation and implementation of this management target has evolved considerably over the last 25+ years. Initially, two alternative interpretations were developed: a constant catch approach and a constant fishing mortality approach, both of which included the concept of maintaining high catches with “an acceptable level of risk”. Subsequently, a Harvest Strategy Standard that includes biomass limits, biomass or

fishing mortality targets, risk tolerance criteria, and specifications for rebuilding plans has been formulated and endorsed. The Harvest Strategy Standard is supported by operational guidelines in which methods for defining and estimating fishing mortality in multifleet, multifisheries situations have been developed, and approaches for defining realistic (“real world”) rather than deterministic estimates of  $B_{MSY}$  are currently underway. Throughout, New Zealand has put considerable effort into rebuilding overfished stocks and attempting to define and use appropriate proxies for MSY-based reference points for low knowledge stocks.

Keywords: fisheries management, maximum sustainable yield, New Zealand, overfishing.

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## ICES CM 2012/L:10

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### Experience with formal harvest strategies in Australia

Malcolm Haddon, Keith Sainsbury, Tony Smith, and David Smith

Australia adopted a formal harvest strategy policy for federally managed fisheries in 2007. Key features of this policy include a specific economic target (maximum economic yield) and explicit statements about tolerable risk levels to exceed limit reference points. Many state fishery jurisdictions have also implemented formal harvest strategies for their more important commercial species. This paper describes the antecedents to this process, the key features of the federal policy, and experience in its implementation to date. This experience spans the range from data-rich to data-poor fisheries. The role of harvest strategy policy in broader fisheries management will also be described.

Keywords: Australia, economic target, hard limit.

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**ICES CM 2012/L:11**

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**Rebuilding depleted fishery stocks under environmental variation: a flexible approach to maximum sustainable yield biomass targets**

Steven Murawski, Michael Sissenwine, Pamela Mace, and William Hogarth

One outcome of the United Nations World Summit on Sustainable Development (WSSD), also known as Earth Summit II in 2002, was that nations committed to restore depleted fish populations using principles of maximum sustainable yield (MSY) by 2015. While some nations and international fishery management RFMOs (regional fishery management organizations) had already adopted MSY concepts, there is increasing emphasis globally on quantifiable metrics of maximum fishing mortality rate thresholds and minimum biomass targets now as the WSSD timetables approach. One of the difficulties inherent in time-certain rebuilding schedules, as implemented in the US, and by some RFMOs, is that environmental variation will alter attainable biomass levels over the course of rebuilding plan under a fixed fishing mortality rate scenario. Simulating rebuilding schedules at the outset of 10-year or longer rebuilding schedules requires some quantification of recruitment and its variation over the span of the rebuilding plan. If early recruitment levels are lower than projected in simulations, then rebuilding tempos will lag, often necessitating even more steep reductions in fishing mortality to compensate for the lack of productivity. While laws such as the Magnuson Stevens Act allow for flexibility in setting and adjusting biomass goals in stock rebuilding, it is difficult to recognize when productivity regimes have changes, necessitating an adjustment (either up or down) in biomass targets. Rapid rebuilding from low levels in some cases has justified relatively high biomass targets for depleted stocks. This paper will explore aspects of dynamic biomass target setting for rebuilding fishery stocks.

Keywords: biomass reference points, flexibility, MSY, rebuilding depleted stocks.

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**ICES CM 2012/L:12**

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**Canada's fishery decision-making framework incorporating the precautionary approach**

Ghislain A. Chouinard, Marc Clemens, Peter A. Shelton, Jake Rice, Daniel Duplisea, Rob Kronlund, and Estelle Couture

In 2009, Canada introduced a fishery decision-making framework for implementing a harvest strategy that incorporates the precautionary approach (PA) following a decade of development by scientists, fisheries managers, and policy experts. The framework includes a removal reference (e.g. fishing mortality) for three stock status zones (critical, cautious, healthy) delineated by a limit reference point (LRP) and an upper stock reference (USR). Stock status is represented by spawning stock biomass or a proxy. The LRP is the stock level below which productivity is sufficiently impaired to cause serious harm while the USR is the stock level threshold below which the removal rate is reduced to prevent the stock from falling below the LRP and to rebuild it to the healthy zone. A target reference point (TRP) determined by biological considerations and social and economic objectives for the fishery is to be identified within the healthy zone in addition to harvest decision rules for each of the status zones. The framework provides some guidance for identifying reference points, harvest rules, and the treatment of uncertainty and risk in making management decisions. Implementation of the framework is ongoing: reference points have been identified for several stocks and harvest rules defined for some stocks. In addition to a description of the framework, we provide an analysis of its coherence with international standards as well as Canada's framework for the application of precaution in science-based decision-making. We further discuss the current status of implementation, challenges, best practices, and issues that require future work.

Keywords: precautionary approach, reference points, stock status, harvest rules, removal rate.

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## ICES CM 2012/L:13

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### **New England groundfish management: lessons learned and lessons forgotten**

Michael Sissenwine and Stephen Murawski

Overfishing of New England groundfish has had a profound influence on fisheries management. This paper discusses lessons learned and forgotten, and their broad significance. The paper highlights:

- The International Convention for the Northwest Atlantic Fisheries (ICNAF) era from 1950 to 1976, when mesh regulations gave way to some of the first TAC management of fisheries. There was also a “second tier TAC” for all species.
- US fisheries management beginning in March 1977, when the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) took effect. Groundfish TACs inherited from ICNAF were discredited because of miscommunication and distrust. Fisheries management returned to mesh regulations.
- In the 1980s, the emphasis was on preventing recruitment overfishing. %SSB/R was used to define it. A technical monitoring group (TMG) was established to report on performance. With documentation of overfishing from the TMG, an environmental non-governmental organization (NGO) sued the government. In 1994, when a court ruled against the National Marine Fisheries Service (NMFS), large area closures were implemented. Limits on days at sea were added as a conservation measure.
- In 1996, Congress put “teeth” in the law to prevent overfishing. It also required overfished stocks to be rebuilt within 10 years if possible. Some influential members of Congress targeted New England groundfish overfishing. In 2000, environmental NGOs sued the NMFS again and the court ruled against the NMFS. Management became increasingly restrictive. From about 2002 to 2010, few catches exceeded target TACs and some stocks rebuilt.
- In 2007, the law was amended again to strengthen requirements to prevent overfishing and rebuild stocks. In 2010, the New England Fishery Management Council (NEFMC) amended groundfish management to allocate shares of a “hard TAC” to fishery sectors. In spite of adhering to scientific advice since the early 2000s and rarely exceeding target TACs, overfishing of several stocks continues, and some stocks are lagging behind their schedule for rebuilding.

Keywords: MSFCMA, New England groundfish, overfishing, rebuilding.

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## ICES CM 2010/L:14

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### **Marine Stewardship Council experiences in developing an operational interpretation of fisheries management best practice**

David Agnew, Daniel Hoggarth, Nicolas Gutierrez, and Amanda Stern-Pirlot

The Marine Stewardship Council (MSC) developed its Standard, expressed through its Principles and Criteria, in 1997, following an extensive stakeholder consultation using as source documents international agreements such as the FAO Code of Conduct for Responsible Fisheries. The Principles and Criteria are relatively high-level expressions of intent that are translated into specific

scoring criteria before a third-party Conformance Assessment Body (Certification Body) can assess a fishery. The MSC initially allowed CABs to develop their own specific scoring issues for each fishery under assessment, but from 2008 has defined a standard set of indicators and scoring guidelines (known as the “default assessment tree”) to ensure consistency in application by CABs and in the inclusion of sustainability indicators. Although the top-level Principles and Criteria have not changed over the years, the default assessment tree is evolving as global fisheries management, and fisheries science, develop. For instance, the understanding of best practice management for enhanced/freshwater fisheries, ecosystem, and benthic impacts, target and limit reference points, and low trophic level fisheries has advanced considerably since the mid-1990s. This paper will explore the challenges and lessons learned by the MSC in developing ways to assess the practical application and effectiveness of fisheries management systems, and in maintaining a fisheries standard as a reflection of global best practice and scientific understanding. Examples are also presented of the improvements that have been made to some management systems as a result of the incentive to meet the MSC’s standard.

Keywords: certification, ecolabelling, global fisheries management best practices, MSC.

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## ICES CM 2012/L:15

### Evolution of management to prevent overfishing in New England

Brian J. Rothschild and Yue Jiao

In 2009, fisheries management in New England transitioned from a days-at-sea management system to a catch-share system. Policy statements claimed that the catch-share system would result in “increasing conservation of species, specifically ending overfishing”. Despite this claim, management authorities now report that stocks continue to be overfished or subject to overfishing. Or are they? First, definitions of overfishing vary, so by one definition, a single stock might be overfished, whereas by a different definition, the same stock might be underfished. Second, definitions of overfishing are arbitrary, so it is easy to change the standard that determines whether or not a stock is overfished. Third, because the differences between overfishing and underfishing are frequently small, it is often difficult to resolve whether or not a stock is overfished or underfished. And fourth, in fisheries where there are multiple stocks, it is not clear whether the overfishing definition should pertain to single stocks individually, or to the aggregate of all stocks in the fishery. The paper reflects on these observations to point out that it is genuinely difficult to say whether or not the evolution of the catch-share system has prevented overfishing. One of the reasons for this is that the term overfishing has become a metaphor, and the management system has accreted complexity that exceeds scientific understanding and available data. The paper closes with a discussion of components of a simpler, more transparent management system.

Keywords: management, New England, overfishing.

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## ICES CM 2012/L:16

### JAKFISH policy brief: coping with uncertainty, complexity and ambiguity in fisheries management through participatory knowledge development

M. A. Pastoors, C. Ulrich, D. C. Wilson, C. Röckmann, D. Goldsborough, D. Degnbol, L. Berner, T. Johnson, P. Haapasaari, M. Dreyer, E. Bell, E. Borodzicz, K. Hiis Hauge, D. Howell, S. Mäntyniemi, D. Miller, R. Aps, G. Tserpes, S. Kuikka, and J. Casey

The legitimacy of the scientific underpinning of European fisheries management is often challenged because of perceived exclusion of fishers’ knowledge and the lack of transparency in



generating scientific advice. One of the attempts to address this lack of legitimacy has been through participatory knowledge development. In this paper, we will present the results of the JAKFISH project (Judgement and Knowledge in Fisheries Management involving Stakeholders) that focused on the interplay between different actors in constructing the underpinning of policy decisions for sustainable fisheries. We tested participatory modelling as a tool to enhance mutual understanding and to increase legitimacy and found that it can be instrumental in developing a broader knowledge base for fisheries management and in building up trust between scientists and stakeholders. However, the participatory approach may not always work. Through social network analyses we found that the number of connections and the frequency of interactions between individuals in different groups (science, fisheries, environmental NGOs, policy) provides an important clue on the potential effectiveness of participatory approaches. Moreover, there are different requirements for the use of science to underpin policy decisions. In situations with high stakes and high uncertainties, scientific justification of policy decisions needs to involve a broader peer community consisting of scientists, policy-makers, NGOs, and fisheries. When stakes are low and uncertainties modest, scientific proof-making through traditional scientific peer review would be sufficient. We used three concepts to evaluate the role of scientific knowledge in policy-making: salience, legitimacy, and credibility. We argue that many of the management frameworks to prevent overfishing focus too much on the scientific definitions of overfishing (credibility, saliency) and too little on the legitimacy of the scientific knowledge.

Keywords: credibility, fisheries management, legitimacy, management plan, participatory modelling, salience, social network analysis.

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## ICES CM 2012/L:17

### The estimation of $F_{msy}$ for selected Baltic stocks, using analytical equilibrium curves for yield and biomass

Jan Horbowy and Anna Luzeńczyk

The equations for equilibrium yield and biomass using different stock–recruitment relationships are presented. These equations are applied to estimate the  $F_{msy}$  for several Baltic stocks (cod, herring, sprat, flounder). The method combines yield-per-recruit (YPR) and spawning stock-per-recruit (SPR) analysis with different stock-recruitment relationships (Ricker, Beverton, and Holt, hockey-stick). The sensitivity of estimated  $F_{msy}$  to assumed values of biological parameters (growth, maturity, mortality) is evaluated. In addition, the effects of different functional forms of stock–recruitment relationship on the  $F_{msy}$  are tested. The derived  $F_{msy}$  are compared with their standard proxies (e.g.  $F_{max}$ ,  $F_{0.1}$ ,  $F_{35\%}$ ,  $F_{40\%}$ ) and the differences between the  $F_{msy}$  and these proxies are evaluated and discussed.

Keywords: Baltic, management, maximum sustainable yield, reference points.

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## ICES CM 2012/L:18

### Science in support of Canada's Sustainable Fisheries Framework

Kim Houston and Ben Davis

The Sustainable Fisheries Framework, introduced in 2009, incorporated existing fisheries management policies with new and evolving policies to support conservation and sustainable use of Canada's fisheries resources. The Framework was intended to provide the foundation for an ecosystem-based and precautionary approach to fisheries management in Canada. The Framework was developed through engagement with resources users and other stakeholders and comprises two main elements: conservation and sustainable use policies; and planning and monitoring tools. The conservation and sustainable use policies are intended to describe how precautionary and

ecosystem approaches are to be integrated into fisheries management decisions. The intent is for these policies to be implemented using planning and monitoring tools. For example, Integrated Fisheries Management Plans identify goals related to conservation, management, enforcement and science for individual species. The plans also describe biological and socio-economic considerations that are factored into management decisions of the fishery. The implementation process of the Sustainable Fisheries Framework uses adaptive management principles and new policies and tools are still being developed. We will examine the science foundation of the Framework, describe the science input, how the Framework can influence science, and provide specific examples of Framework application.

Keywords: ecosystem-based management, precautionary approach, sustainable fisheries framework.

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## ICES CM 2012/L:19

### **Communicating science recommendations for management decisions: the Kobe tuna regional fishery management organization (RFMO) efforts to harmonize scientific assessment practices and communication methods**

Keith Chanon

Sound scientific advice is paramount to making good management decisions that ensure the sustainability of healthy fisheries. Yet, it is difficult to define “best available science” and to overcome scientific uncertainty when making management decisions. Under the Kobe process, governments are taking steps to harmonize assessment methodologies and the communication of stock assessment results across the five tuna regional fishery management organizations (RFMOs) through the use of the Kobe Plot and Kobe II Strategy Matrix. This effort is designed to strengthen the scientific advice that is provided to the RFMO Commissions and establish decision parameters that would lead to ending overfishing or to rebuilding overfished stocks. However, some scientists are critical of this effort as it requires making future projections by presenting probabilities for meeting management goals within certain time frames. For example, the Strategy Matrix could show the probability of reaching an 80% biomass target within five years under a specified total annual catch level. The level of uncertainty and difficulty in quantifying the uncertainty is of primary concern. Based on interviews with RFMO managers and scientists, this paper addresses the challenges faced by decision-makers and the expectations they have regarding scientific information and advice. It also describes the challenges facing the RFMO science committees in meeting the needs of managers, obtaining necessary data for robust assessments, and communicating complex science to policy-makers without oversimplification. Thus, the Kobe process demonstrates the important linkage between the science and management enterprises that is needed to support effective fishery management decisions.

Keywords: Kobe, Kobe Plot, RFMO, science advice, stock assessment, strategy matrix.

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## ICES CM 2012/L:20

### **The Baltic Sea fisheries—a case of regulatory overfishing**

R. Aps and H. Lassen

This paper addresses the phenomenon of regulatory overfishing in internationally regulated Baltic Sea fisheries and the forces driving long-term overexploitation of the fishery resources. Building on a concept of regulatory overfishing introduced by Eagle and Thompson in 2003 and using the published evidence for the period 1977–2007, the relative importance of potential sources of overfishing in the Baltic Sea fisheries is analysed. These sources include: (i) the scientific uncertainty/error related “scientific overfishing”, (ii) “decision overfishing” when managers

deliberately choose to disregard scientific advice, (iii) “implementation overfishing” when managers fail to ensure that the quotas are enforced, and (iv) “illegal overfishing” that occurs where fishers make illegal or unreported catches that result in fishing over the quota. Based on the evidence available, the fishing fleet overcapacity can be considered to be a major cause of persistent overfishing because it creates a strong incentive to catch more than is sustainable and generates high political pressure to increase short-term fishing opportunities at the expense of the future sustainability. In addition, many subsidies in the fisheries sector have been fostering overcapacity and overexploitation of fish stocks. It is concluded that regulatory overfishing and not the management framework *per se*, could be the reason for the failure of the Baltic Sea depleted fish stocks to recover.

Keywords: Baltic Sea, fisheries management, regulatory overfishing.

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## ICES CM 2012/L:21

### **Diverting the bureaucratic juggernaut of top-down control: the case of crab fishers off Devon, UK**

Paul J. B. Hart

A complex global network of treaties and agreements sets goals for the management and conservation of marine resources. Examples are the United Nations Convention on the Law of the Sea (1982), the Rio Declaration (1992), the UN Convention on Biological Diversity, Agenda 21, and the FAO Code of Conduct for Responsible Fisheries (1995). All these include recommendations as to how nations should regulate fisheries. This top-down approach says little about how fishers can continue to supply the demand for fish products whilst complying with the regulations. Only Agenda 21 specifically mentions the involvement of fishers as partners in the management process, where it is recommended for example that governments should provide incentives to fishers to manage their natural resources in a sustainable way. Despite this, the bureaucratic juggernaut of top-down control has been difficult to divert in a way that hands power to fishers. In this paper, a bottom-up path to sustainable management is illustrated by a case study on the Devon, UK inshore fishery for crabs. The fishery has evolved from a beach-based activity to the present-day fleet which uses larger boats operating from harbours. Along the way, conflict with the towed gear fleet has led to a voluntary management system that both conserves biodiversity and exploits resources sustainably. The inshore fleet is now challenged by the possibility of nationally determined catch limits and Marine Protected Areas. In the establishment of these measures the crab fishers have only been allowed to play bit parts. The consequences of this are analysed.

Keywords: bottom-up, conservation, crabs, history, inshore fisheries, management, top-down.

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## ICES CM 2012/L:22

### **The strategic scientific framework of the ecosystem approach to fisheries in Norway: adaptive management of living marine resources by integrating different data sources and key ecological processes (ADMAR)**

Dorothy J. Dankel, Padmini Dalpadado, Gjert Dingsør, Joël Durant, Anne Maria Eikeset, Katja Enberg, Dag Hjermann, Geir Huse, Knut Korsbrekke, Richard Nash, Geir Ottersen, Leif Christian Stige, Nils Olav Handegard, Mette Skern-Mauritzen, Michael Pennington, Samuel Subbey, Jon Helge Vølstad, Nils Chr. Stenseth, and Olav Sigurd Kjesbu

The ecosystem approach to fisheries has been adopted into national law in Norway through the Norwegian Ocean Resource Act (*Havressursloven*). This requires explicit management action for over 40 fish stocks and species, including those of minor commercial importance. Strategic national

funding for the science needed to support the Ocean Resource Act has paired expertise from the Institute of Marine Research in Bergen and the University of Oslo's Center for Ecological and Evolutionary Synthesis together in the ADMAR project. The overall goal of ADMAR is to create a framework that streamlines the route from improved survey design and data collection to parsimonious ecosystem models, and finally to operational harvest control rules. To meet this goal, different data sources are integrated (survey data, fisheries statistics, life-history traits), including their error structures, to derive key parameters from time-series and statistical refining of stock assessment models, including quantifying uncertainties. In parallel, ADAMR incorporates length-based foodweb interactions providing a basic understanding of ecosystem functioning. These models are particularly useful in data-poor situations, for which Norwegian scientists are mandated to give management advice. Finally, the ADMAR framework connects survey design, statistical understanding of data and ecosystems to harvest control rules (HCRs) for target fish stocks under different ecological scenarios, where species interactions continuously change within and among species over the course of harvesting and environmental changes. This presentation specifically outlines the progress the ADMAR team has achieved the last two years as well as the challenges of operationalizing the framework for data-poor stocks.

Keywords: data-poor stocks, data-rich stocks, ecosystem approach to fisheries, fish stock assessment, harvest control rules, length-based ecosystem models, marine ecosystem management.

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## ICES CM 2012/L:23

### Unintended consequences of MSY proxies for defining overfishing

Steven X. Cadrin

Maximum Sustainable Yield (MSY) and the fishing mortality that produces MSY ( $F_{MSY}$ ) have been global standards for fishery management for decades. However, a common practice is to replace  $F_{MSY}$  with proxies that do not require an understanding of recruitment dynamics. Many  $F_{MSY}$  proxies have nearly the same long-term yield, but they allow substantially different short-term yield and much different stock biomass expectations (e.g. rebuilding targets). The justification for using  $F_{MSY}$  proxies to define overfishing is that the stock–recruitment relationship is not well defined. Several examples from the northeastern US show that the default application of default proxies (e.g.  $F_{40\%}$ , the fishing mortality that is expected to conserve 40% of maximum spawning potential) leads to either unsustainable fishing or substantial foregone yield. These results suggest that overfishing should be based on direct estimates of  $F_{MSY}$  if possible. In situations where a functional form of stock–recruitment cannot be supported with the information available, stock–recruitment information can be used to evaluate the appropriateness of candidate proxies.

Keywords: overfishing, MSY, proxies.

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## ICES CM 2012/L:24

### Transboundary quota enforcement with an application to the Northeast Arctic cod fishery

Rodney Beard and Linda Nøstbakken

In this paper, we conduct an empirical analysis of international quota enforcement in the Northeast Arctic cod fishery. We empirically estimate a dynamic game theoretic model of the fishery. In previous work, we developed a model of a shared renewable resource for which there already exists an international agreement that determined each country's share of total quotas. Each government was responsible for the enforcement of their national quota. The countries could cheat on the sharing agreement by reducing enforcement efforts and thereby inducing their firms to violate quotas. We analysed the effects of this in a differential game framework. There were two games: a Stackelberg game between the government and the firms within each country, and an

enforcement game at the international level between different governments. Using this model, we characterized the long-run equilibrium and identified factors that affected the outcome. We also identified the socially optimal quota, given the reaction functions of both governments and firms. That model is used in our proposed paper as a theoretical framework for an empirical analysis of the Northeast Arctic cod fishery. Our empirical model analyses the dynamics of the Northeast Arctic cod stock over a 64-year period and then estimates the optimal feedback strategy functions of those nations involved in the fishery, finally we consider an empirical based policy simulation of the consequences of changing the total allowable catch quota.

Keywords: bioeconomic model, game theory, Northeast Arctic cod fishery, statistical analysis.

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## ICES CM 2012/L:25

### Reconsidering historical definitions of overfishing and the balance between sustainable use and overexploitation

Daniel R. Goethel, Steven X. Cadrin, and Brian J. Rothschild

Overexploitation and sustainability have been core concepts in the management of renewable resources since the 1600s. Traditionally, these terms were directly linked to one another, so that overexploitation was truly unsustainable. In fisheries management, the connection between them was severed when maximum sustainable yield became the guiding principal for many management bodies in the 1950s. The current tendency is to consider fishery management a failure if a stock is "overfished". However, the abuse of such terms has led to inappropriate negative perceptions of management systems and the fishing industry. By tracing the origins of the term "overfishing" we demonstrate that modern management systems which link overfishing to an optimal fishing mortality reference point do not adhere to the traditional concept. We suggest a revival of historical definitions of overfishing, based on short-term time horizons. Such a reinterpretation would define sustainable use as harvesting up to the reproductive surplus of the resource, while overexploitation would be indicated by harvesting more than could be naturally replaced in a given year. This approach would alter rebuilding plans to focus on increasing population biomass on a year-to-year basis as a means to achieve long-term reference point targets, while eliminating arbitrary rebuilding timelines. By reassociating overfishing with values of fishing mortality that are unsustainable and lead to detrimental impacts on biomass, the inappropriate negative perception of fisheries can be avoided and, ultimately, instil incentive to promote conservative fishing techniques.

Keywords: fisheries management, ICES history, overfishing, sustainability.

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## ICES CM 2012/L:26

### The collapse of the Norwegian spring-spawning herring stock: overfishing or environmental change?

Ingolf Røttingen and Sigurd Tjelmeland

The stock of Norwegian spring-spawning herring collapsed at the beginning of the 1970s. The collapse has been explained by overfishing, but changing environmental conditions have also been given as a explanatory factor for the collapse. The combination of overfishing and changing environment has also been given as reasons for other stock collapses (i.e. cod at Newfoundland). The aim of the present paper is to seek out the relative importance of overfishing and changing environmental factors as reasons for the collapse in Norwegian spring-spawning herring. In 1999 the agency for the management of Norwegian spring-spawning herring (coastal states regional fishery management organizations) decided on a harvest control rule that at present forms the basis for the annual TAC. The starting point for the present paper is a counter-factual that

considers the effect from the fishery on the stock if this harvest control rule had been applied from 1949, 50 years before it actually was implemented. A central part of the paper is an analysis of stock–recruitment relations that incorporates climate (temperature) changes that took place in the period 1950–1990.

Keywords: climate change, fishery, Norwegian Sea, stock collapse.

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## ICES CM 2012/L:27

### The Baltic Sea RAC: from positional to collaborative interest-based negotiation

K. Aps, M. Fetissov, and M. Kopti

The aim of the EU 7FP GAP2 Project's Baltic Sea Case Study is to build up the Baltic Sea's Regional Advisory Council's (BS RAC's) stakeholder capacity for informed participation in a process of ecosystem-based sound governance of the Baltic Sea marine space, including fisheries. The BS RAC was set up in March 2006 with the aim of contributing to sustainable use of the Baltic Sea fishery resources under EU Common Fisheries Policy. The BS RAC is seen as an international boundary organization mixing scientific and political elements, and mediating between the institutions of science and politics. However, it is stated that a non-consensual way of formulating recommendations on total allowable catches has become a central feature of the BS RAC over the years. The focal question is how to increase collaboration and consensus among BS RAC members in negotiating the advice on management of the Baltic Sea fisheries on behalf of the fisheries sector and other interest groups in order to achieve a successful common fisheries policy? According to our working hypothesis it is expected that a possible move from primarily positional negotiation format to a more collaborative interest-based negotiation format based on mutual learning events would facilitate consensual decision-making by the BS RAC. This paper addresses the formal logical approach to collaborative interest-based negotiation and explores, based on the published evidences available, the BS RAC's opportunities to contribute to the removal of incentives for regulatory overfishing in internationally regulated Baltic Sea fisheries.

Keywords: Baltic Sea, BS RAC, collaborative negotiation, regulatory overfishing.

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## ICES CM 2012/L:28      Poster

### The role of fish life-history evolution in a marine ecosystem: ignoring evolution can lead to overfishing

Asta Audzijonyte, Anna Kuparinen, and Elizabeth A. Fulton

Fishing is considered one of the key drivers of plastic and evolutionary life-history changes in marine organisms, but the ecosystem-level consequences of fisheries-induced evolution remain unknown and unaccounted for in fisheries management. Using the Southeast Australian marine ecosystem and its implementation to the Atlantis Framework as a study system, we investigate how changes in life histories of five key species targeted by fishing affect the projected biomasses of the species. To this end, three scenarios for fishing intensity and two relatively conservative scenarios for the rate of evolution were contrasted to a scenario with no fishing and no evolution. Species responses to fishing differed, but omitting evolution generally led to higher biomass estimates. This pattern arises from increased natural mortality and vulnerability to predation along with declining body size. The results of the study suggest that (i) an ecosystem-based model is needed to account for differing species responses to life-history changes through fishing, and (ii) omitting evolution is likely to cause overestimation of fish biomass and, thus, can lead to overfishing.

**Keywords:** Atlantis, ecosystem, fisheries-induced evolution, life history, overfishing.

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## Theme Session M

### Joint ICES/ESSAS/PICES/AOSB Session—Subarctic—Arctic interactions: ecological consequences

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#### ICES CM 2012/M:01

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##### **Higher growth efficiency of Arctic compared to Atlantic heterotrophic bacteria in the Barents Sea Polar Front area**

Knut Yngve Børsheim and Kenneth F. Drinkwater

The northern Barents Sea Polar Front forms east of Svalbard where water from the Arctic Ocean meets modified Atlantic water moving north. Organisms residing in these two water types have distinctly different climatic histories. It is reasonable to assume that microorganisms in the Arctic water are selected for success at low temperatures, whereas Atlantic waters are comparatively warm. As Atlantic water travels north it loses heat, and in the northern Barents Sea both Arctic and Atlantic waters are found at comparable temperatures and otherwise similar climatic conditions. We investigated bacterial production rates in the Polar Front area between 75.5° and 77°N in the late summer of 2007. When specific growth rates of bacteria were compared according to temperature, the rates in Arctic water were always higher than the rates in Atlantic water. This systematic difference implies that the heterotrophic bacteria from the Arctic have adapted towards higher growth efficiency than the bacteria in Atlantic water. Higher respiratory losses in temperately adapted heterotrophic bacteria compared to cold-adapted populations imply more efficient conversion of organic material into CO<sub>2</sub>. If temperature increase extends the distribution of temperately adapted populations at higher latitudes, such shifts may influence general functions of the carbon cycle, for example the rate of ocean acidification in the Polar region.

Keywords: advection, Arctic, ecology, Subarctic.

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#### ICES CM 2012/M:02

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##### **Spatial distribution and new migration patterns of Northeast Atlantic mackerel during 2007–2011**

Leif Nøttestad, Kjell R. Utne, Gudmundur J. Óskarsson, Jan Arge Jacobsen, Jens Christian Holst, Øyvind Tangen, Valantine Anthonypillai, Hector Pena, Kjell Arne Mork, Matteo Bernasconi, Høgni Debes, Leon Smith, Sigurður Þ. Jónsson, Sveinn Sveinbjörnsson, and Aril Slotte

Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) is one of the key ecological and commercially most valuable pelagic fish species in the Atlantic Ocean, providing annual revenue of nearly 2 billion euro. Mackerel is distributed over several million square kilometres during the major feeding period in July–August. There have been substantial changes in the overall distribution and migration pattern of mackerel in general during the last decade and particularly during the feeding season in summer over the last five years. Information from research surveys show that the mackerel have expanded both to the north and west in the Norwegian Sea and surrounding waters, possibly due to a combination of increased population size, new feeding opportunities and significantly warmer waters. Centre of gravity of its summer distribution has progressively moved north and especially west from 2007 to 2011. These significant changes in migration have resulted in alterations in zonal distribution (biomass \* zone \* time) of mackerel between exclusive economic zones (EEZs). The Nordic Seas have experienced record high temperatures in the upper water column in summer for the last years with a peak around 2007–2009 compared to the average temperature over the last 20 years. The mackerel has shown interannual dynamics with a typical length-dependent migration pattern with the largest and



oldest specimen distributed furthest to the north and west, where the most favourable zooplankton concentrations were located. Possible ecological consequences (spatial overlap, food competition, and predation) to other pelagic species because of mackerel expanding into new territories are discussed.

Keywords: feeding, geographical expansion, interannual dynamics, length-dependent migration, mackerel, new distribution pattern, zonal distribution.

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### ICES CM 2012/M:03

#### Ecological impacts of recent extension of feeding migration of Northeast Atlantic mackerel into the ecosystem around Iceland

Gudmundur J. Óskarsson, Sveinn Sveinbjörnsson, Asta Gudmundsdóttir, and Thorsteinn Sigurdsson

Climate changes have caused alterations in the feeding migration of pelagic fish stocks. Changes in migration can be expected to have both “bad” and “good” impacts on the invaded ecosystem through, for example, predation on native species, competition with native species for limited food resources, and/or being a prey for native species. Since around the mid-2000s Northeast Atlantic mackerel (NEAM) has been extending its summer feeding distribution towards north and west, associated with increased sea temperatures in the area. The objective of this paper is to evaluate the ecological meaning and impacts of this extension on the ecosystem around Iceland through (i) exploration of its diet composition in comparison to those of two herring stocks feeding in the same area, (ii) providing estimates of weight gain and total food consumption of NEAM there, and (iii) exploring the interannual variation in body condition of the three fish stocks. The results show that Calanoida comprised highest mass in NEAM stomachs in most areas while Calanoidea and Euphausiacea were highest in herring. Fish prey were in a higher proportion in NEAM than in herring. NEAM in Icelandic waters increased in weight by 42%, 43%, and 55%, during the summers in 2009–2011, respectively. Considering its abundance estimates in 2010 and 2011 in Icelandic waters, this corresponds to consumption of around 2.2 million tons each year. This invasion does not have apparent impacts on interannual variability in body condition of the herring stocks, while NEAM shows a decreasing trend in condition in the area.

Keywords: consumption, diet composition, ecological impacts, extended migration, mackerel, *Scomber scombrus*.

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### ICES CM 2012/M:04

#### Distribution, abundance, and biology of polar cod, *Boreogadus saida*, in Icelandic waters

Olafur S. Astthorsson

Distribution, abundance, and biology of polar cod, *Boreogadus saida*, was studied in the waters around Iceland based on material sampled during demersal fish surveys in March 1985–2011 and in pelagic 0-group surveys in August–September 1970–2003. Demersal polar cod were most often caught on the outer shelf to the northwest of Iceland but during the years of highest abundance and most widest distribution it was also caught on the north and northeastern shelves. Pelagic 0-group polar cod was only caught sporadically and was confined to the waters over the outer part of the northwestern shelf. Distribution and abundance of demersal polar cod demonstrated most extensive distribution and peaks in abundance in the cold years of 1989–1999 and 1994–1995, however, somewhat lower peaks were also observed in the warm years of 2002 and 2008. On average, the highest numbers of polar cod per station were caught at temperatures of  $-1.5$ – $1.0^{\circ}\text{C}$  but at two depth ranges (i.e. between 0–100 m and 300–400 m). The length of demersal polar cod ranged from 5 to 32 cm while the fish caught in the pelagic trawl ranged from 2.2 to 19.0 cm. The polar cod in north Icelandic waters most likely originates from East Greenland or Svalbard waters.

Keywords: abundance, biology, distribution, Icelandic waters, Polar cod.

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## ICES CM 2012/M:05

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### A radiolarian tracer for mesoscale eddies from coastal areas in the central subarctic Pacific

Takahito Ikenoue, Hiromichi Ueno, and Kozo Takahashi

Based on a 15-year-long time-series observation on radiolarian fluxes at the central Subarctic Pacific, we found a close relationship between mesoscale eddies and *Rhizoplegma boreale* (a radiolarian species) abundances. A sediment trap was deployed at Station SA (49°N 174°W) during 1990–2005. Altimetry observations provided tracks of mesoscale eddies and indicated that mesoscale eddies propagating around the sediment trap station were coincident with high *R. boreale* fluxes at Station SA. The mesoscale eddies probably provided the pelagic region of the central Subarctic Pacific with coastal nutrient-rich waters around the Aleutian Islands, and helped microzooplankton productivity in the Subarctic Pacific.

Keywords: coastal water, long-term monitoring, mesoscale eddy, radiolaria, *Rhizoplegma boreale*, sediment trap.

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## ICES CM 2012/M:06

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### Towards a more balanced view of marine ecosystems

Charles H. Greene

Frank and colleagues recently hypothesized that the Scotian Shelf ecosystem's slow recovery to its structure prior to the early 1990s is a result of the oscillatory, runaway consumption dynamics of the forage fish complex. Their hypothesis is based on the underlying assumptions that this ecosystem's dynamics are governed by top-down forcing, predator-prey role reversals, and a trophic cascade extending from demersal predatory fish, especially cod, all the way down to the level of nutrients. In an earlier paper, Greene and Pershing called into question the underlying assumption of an extended trophic cascade. They argued that while top-down forcing can be important at higher trophic levels in many Northwest Atlantic Shelf ecosystems, its impacts on zooplankton, phytoplankton, and nutrients are minor or non-existent. Instead, they argued that lower trophic-level dynamics in these ecosystems are governed by climate-associated, bottom-up forcing. Observations over the past three decades are consistent with predictions from the climate-forcing hypothesis proposed by Greene and Pershing, while those from the past decade demonstrate that the trophic cascade hypothesis as proposed by Frank and colleagues should be rejected. A closer examination of these observations also calls into question the hypothesis of ecosystem recovery in the Northwest Atlantic being governed by the oscillatory, runaway consumption dynamics of the forage fish complex.

Keywords: bottom-up forcing, northwest Atlantic, regime shifts, salinity anomalies.

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**ICES CM 2012/M:07**

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**The feeding ecology of pelagic fish in the southwestern Norwegian Sea—interspecies food competition between herring (*Clupea harengus*) and mackerel (*Scomber scombrus*)**

Høgni Debes, Eydna í Homrum, Jan Arge Jacobsen, and Hjálmar Hátún

The Nordic Seas are the main feeding area for the three large pelagic fish stocks: Norwegian spring-spawning herring (NSS herring), Northeast Atlantic mackerel (NEA mackerel), and blue whiting. In this paper we focus on the southwestern Norwegian Sea. This area is dominated by two different water masses separated by the Iceland–Faroe Front, which, because of its high productivity, attracts large numbers of pelagic fish during their summer feeding migration. After spawning, NSS herring migrate westward into the Norwegian Sea to feed, and in the last couple of years an increasing number have been observed to reside in the southwestern Norwegian Sea for a prolonged time during summer. At the same time NEA mackerel has increased in stock size and expanded its feeding area, and has been observed in large amounts overlapping with NSS herring during summer. In this paper we focus on the foraging ecology of NSS herring and NEA mackerel in May during the period 2007–2011. We investigate the spatio-temporal variations in the diet of NSS herring and NEA mackerel in relation to hydrography. We analyse potential interspecies food competition between NSS herring and NEA mackerel and relate it to interannual variations in hydrography and plankton composition. Possible food selectivity is furthermore analysed by comparing stomach content to the *in situ* prey composition.

Keywords: feeding, food competition, herring, mackerel, southwestern Norwegian Sea, spatio-temporal variation.

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**ICES CM/2012/M:08**

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**Framework for impact analysis of offshore Arctic operations Identification, prioritisation and mitigation**

M. J. van den Heuvel-Greve, and B. C. Bolman

Wageningen University and Research Centre in the Netherlands is well known for its work in the field of regional development of rural areas. Decades of experience is now being used for regional development related to upcoming economic interests in the Arctic. One of the elements in the Wageningen approach is to work with the industry in sustainable development of their activities. IMARES, the institute within Wageningen UR, has developed a framework for a structured assessment of the impact of offshore Arctic operations. The framework facilitates analysis to identify, prioritize, and mitigate impacts of offshore activities. It looks beyond emissions by assessing the actual consequences of emissions for the Arctic environment. The framework follows an ecosystem-based approach, starting with the biotic and abiotic elements of an Arctic ecosystem that are key in the functioning of that system. It comprises the vulnerability (i.e. the resultant of sensitivity and recovery potential) of these elements for the disturbances caused by the various activities related to the Arctic operation under study. Currently, a study has been initiated with the Dutch offshore sector which is already involved in many offshore operations related to the production of oil and gas. IMARES performed a gap analysis on Barents2020 and ISO19906, being the basis of further assessment. Preliminary results from this study will be shown, together with results of previous studies in order to illustrate the framework approach.

Keywords: Arctic, assessment, impact, sustainability.

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**ICES CM 2012/M:09**

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**On the role of advection on the ecology of Arctic and Subarctic seas**

Kenneth F. Drinkwater

A brief review of water mass advection between Arctic and Subarctic regions and the effects on their ecology will be presented. The influence of Arctic outflows through the Fram Strait, the Barents Sea, and the Canadian Archipelago on the Subarctic regions and the inflow of Pacific waters through the Bering Strait and of Atlantic waters through the Fram Strait and the Barents Sea on the Arctic will be discussed. In addition to describing temperature and fresh-water fluxes between the two regions, the role of advection of sea ice from the Arctic and its associated flora and fauna to the Subarctic will be mentioned. Nutrient fluxes and influences on stratification will be presented in terms of their effects on phytoplankton production. Advection of water masses also transports zooplankton communities between the two regions, as well as some ichthyoplankton. Brief mention will be made of the role of fronts between outflowing Arctic water and inflowing Pacific and Atlantic water. Possible future changes in advective fluxes between the Arctic and Subarctic will be highlighted, along with their possible effects on the marine ecosystem.

Keywords: advection, Arctic, ecology, Subarctic.

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**ICES CM 2012/M:10**

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**Secondary productivity in the Barents Sea—role of phytoplankton and climate effects**

Padmini Dalpadado, Kevin R. Arrigo, Solfrid Hjøllø, Randi B. Ingvaldsen, Are Olsen, Geir Ottersen, Franciso Rey, Leif C. Stige, and G. L. van Dijken

The temporal and spatial dynamics of primary and secondary production in the Barents Sea were examined using remote sensing data, observations, and models. The response to climate effects was explored using several physical predictor variables such as temperature, distribution of water masses, and open water area (area free of sea-ice cover). Remotely sensed chlorophyll *a* was used to calculate net primary production (NPP), while mesozooplankton biomass and production estimates for different seasons and years were generated using NORWECOM.E2E, which is a fully coupled physical/primary production/individual-based *C. finmarchicus* end-to-end model. Field observations of mesozooplankton biomass, temperature, salinity, and chlorophyll *a* data for transects (different seasons) and large-scale surveys (autumn) were used for validation of the remote sensing products and modelling results. Preliminary results show that the seasonal dynamics and magnitude (from a section at the western entrance to the Barents Sea) between observed and satellite chlorophyll is significantly correlated. The area of open water in the Barents Sea seems to lead to increased area integrated NPP, possibly influencing secondary biomass/production in the Barents Sea. The links between NPP, secondary production, and fish production are explored using statistical time-series analysis.

Keywords: Barents Sea, climate effects, models, observations, production, remote sensing.

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**ICES CM 2012/M:11**

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**Comparison across 42 North Atlantic fish stocks of temporal patterns in recruitment dynamics, including the role of spawning stock biomass and temperature**

Geir Ottersen, Leif Christian Stige, Joel M. Durant, Tristan Rouyer, Kenneth Drinkwater, and Nils Chr. Stenseth

Both environmental, density-independent drivers during the egg and larval stages, and density-dependent survival in the juvenile phase have been proposed to be of key importance for

recruitment to marine fish populations. As a step towards further understanding of “the recruitment problem”, the present study examines the general validity of a set of hypotheses regarding long-term changes in the relationship between recruitment, spawning stock, and temperature. Statistical modelling is employed to study 42 commercially harvested fish stocks, mainly gadoids and clupeids in the northern North Atlantic. Counter to expectations for these largely heavily fished stocks, there was no clear pattern of the age composition of the spawning stock having been skewed towards younger ages. Further, and perhaps consequently, no evidence was found for the earlier suggestion of the temperature-recruitment relation systematically being strengthened with decreasing mean age of the spawning stock. We found temporal shifts in recruitment dynamics for 30 of the stocks of which 27 displayed statistical evidence for long-term changes in pre-recruit survival associated with long-term changes in spawning stock biomass. By adding non-linear (smoothed) temperature terms to Ricker stock–recruitment models, we found that 24 of the 42 stocks showed temperature effects on pre-recruit survival that were significant at the 10% level. Additional examination of 15-year moving window temperature–recruitment correlations revealed considerable variations for many stocks, but no consistent overall pattern of the variability.

Keywords: North Atlantic, recruitment, statistical modelling, temperature.

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## ICES CM 2012/M:12

### **The Barents and Chukchi Seas: comparison of two Arctic shelf ecosystems**

George Hunt, Amy Blanchard, Peter Boveng, Padmini Dalpadado, Ken Drinkwater, Russell Hopcroft, Kit Kovacs, Paul Renaud, Andy Whitehouse, Rebecca Woodgate, Lisa Eisner, Brenda L. Norcross, Marit Reigstad, and Hein Rune Skjoldal

The Barents and Chukchi Seas are high-latitude, seasonally ice-covered, Arctic shelf-seas. Both have strongly advective regimes, and receive water from the south. Water entering the Barents comes from the deep, ice-free, and “warm” Norwegian Sea, and contains a rich supply of zooplankton that supports larval fish in spring. Bering Sea water entering the Chukchi in spring is cold, and may be depleted of zooplankton, having traversed the shallow ice-covered northern Bering Sea in winter. Fish biomass is three orders of magnitude greater in the Barents than in the Chukchi. The numbers of marine mammals in the Barents and Chukchi are roughly similar, as are the numbers of nesting seabirds, though Chukchi benthic biomass may be greater. We suggest that warmer conditions in the southern Barents and in the deep Atlantic water underlying Arctic water permit boreal fish to survive there. In contrast, the Chukchi in winter is well-mixed with subzero temperatures, thereby preventing the survival of fish that lack antifreeze proteins. If climate change warms the Barents Sea, thereby increasing the open water area via reducing ice cover, productivity at most trophic levels is likely to increase. In the Chukchi, warming should also reduce sea ice cover, permitting a longer production season. However, the shallow northern Bering and Chukchi Seas will continue to be ice-covered in winter, so water in there will continue to be cold in winter/spring and is likely to continue to be a barrier preventing the movement of temperate fish into the Chukchi Sea.

Keywords: Arctic shelf seas, benthos, climate impacts, fish stocks, marine mammals.

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**ICES CM 2012/M:13**

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**What impact has climate change had on Irish fisheries?**

Rodney Beard

The potential impact of climate change on industry is frequently speculated about, but the actual historical impact of climate change on industry is rarely studied. Studies of the impact of climate change on fisheries have been largely simulation-based or speculative and rarely use historical data. No studies of climate change test to see whether economic factors or physical and biological factors have a greater impact on the fishing industry. If policy-makers are to make informed climate policy decisions, environmental economists need to forecast the likely consequences of climate change on industry and be able to judge whether these consequences are large or small compared with changes due to other causes. In this paper, the impact of climate change on Irish fisheries is examined using a panel dataset of 528 observations, consisting of 48 cross-sectional units and 11 longitudinal units. A comparison is made of the impact of economic factors and the impact of climate change on fisheries catch. It is concluded that climate change has had a considerable impact on the Irish fishing industry. An attempt is made to quantify the monetary impact of climate change on Irish fisheries and the loss to specific Irish fishing ports.

Keywords: climate change, environmental economics, fisheries economics, Irish commercial fisheries.

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**ICES CM 20120/M:14**

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**Studying the effect of migrating whales on the ecosystem of the Barents Sea using an end-to-end model**

Cecilie Hansen and Mette Skern-Mauritzen

The top-down effects of whale consumption on the ecosystem has been discussed in several studies, as has the timing proportion of whales emigrating from the Nordic and Barents Seas during the winter season. However, recent studies show that a significant number of whales may stay in the area also during the winter. This study investigates the effects of timing of baleen whale migrations and varying proportions of emigrating baleen whales on different trophic levels of the Barents Sea. This is compared to a control run where all whales migrate out of the area during the winter. The study also considers the condition, reproduction, and growth for the whales that stay in the Nordic and/or Barents Sea throughout the whole year compared to that of the migrating individuals. The study is performed using an end-to-end model, Atlantis, built for the Nordic and Barents Seas. Atlantis was originally developed in Australia, however the Nordic-Atlantis is a new version adapted to the sea ice, large seasonal variations in light conditions and colder climate. Nordic-Atlantis includes 52 different species and groups, covering all trophic levels from phytoplankton to polar bear, including benthos.

Keywords: baleen whales, end-to-end modelling, seasonal migration, top-down effects.

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**ICES CM 2012/M:15**

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**Some biological signs of the Northwest Pacific regime shift in the late 2000s**

Boris N. Kotenev, A. S. Krovnin, and N. V. Klovach

A sharp drop in the Pacific Decadal Oscillation (PDO) index in the winter of 2007/2008 was not accompanied by a change in dominant large-scale mode of the air–sea coupling in the North Pacific. It occurred only at the end of 2011. However, changes in ecosystem structure in the Kuroshio–Oyashio area started even earlier. A reduction of the Japanese anchovy population dominating the ecosystem has been observed since 2004. The stock of Pacific squid substantially decreased from 2009 to 2010, while a very strong year class of Pacific sardine appeared in 2010. A

tendency for decrease in pink salmon catches in even-numbered years off East Sakhalin and South Kurils began in 2006, and catches of pink salmon in odd years and chum salmon there started to fall in 2009. A decrease in volume of chum salmon near the continental coast of the Okhotsk Sea and Kamchatka was observed from 2010 (i.e. from generations of the 2007 and 2008 years). Similar tendencies were noted for the southern salmon populations in the Northeast Pacific. We have established that regime shifts in the North Pacific coincided with extremes of variance of tidal oscillations in the Earth's rotation velocity (with period of 18.6 years). Thus, the regime shifts in 1976/1977, 1988/1989, 1998/1999, 2007/2008 correspond to the following years of variance extremes: 1978 (min), 1989 (max), 1996 (min), 2007 (max). The possible biological consequences of new climatic regimes in the Northwest Pacific are discussed.

Keywords: climatic regime shift, marine ecosystem, Northwest Pacific, Pacific sardine, salmon.

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## ICES CM 2012/M:16

### Across an Arctic front: zooplankton in relation to their environment

Cecilie Broms, Webjørn Melle, and Tor Knutsen

This study is part of the NESSAR project, focusing on the physical and biological processes at the fronts separating Subarctic Atlantic water and cold Arctic water. During June 2007, an intensive field study of the Arctic front south of Jan Mayen in the Norwegian Sea was carried out. A transect across the front was repeatedly sampled with high spatial resolution. Information about zooplankton horizontal and vertical distribution and egg production was collected along with the physical, chemical, and lower trophic environment inhabited by the zooplankton. The transect penetrated typical Atlantic and Arctic water masses on both sides of the front, enabling us to examine zooplankton responses to environmental gradients and contrasting ecosystem characteristics of the Subarctic and Arctic habitats. In addition to standard plankton sampling, a towed multisensor platform (MESSOR) continuously collected environmental data and plankton data using an optical plankton counter. The biological gradients across the fronts seemed less distinct than the physical gradients, and several peaks in abundance were observed. Interestingly, surface peaks were accompanied by higher abundance also in deeper water. *Calanus finmarchicus* dominated surface water both in Arctic and Subarctic water, while *C. hyperboreus* had a significantly deeper distribution. Despite a abrupt alteration in hydrography across the front, the main occupation depth of each *Calanus* copepodite stage was unaltered between Atlantic and Arctic water. High zooplankton concentrations were observed just east of the front, in Atlantic water. Preliminary results indicate the presence of eddies in this area, and we suggest that both the front and eddy activity may influence the zooplankton density.

Keywords: Arctic front, *Calanus*, eddy, zooplankton.

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## ICES CM 2012/M:17

### A comparison of phytoplankton growth conditions and photosynthetic performance at the Jan Mayen Front in the Norwegian and the Polar Front in the Barents Sea

Svein Rune Erga, Nicolausi Ssebiyonga, Børge Hamre, Øyvind Frette, Francisco Rey, and Ken Drinkwater

The present study, aiming at resolving fine-scale changes in the plankton community structure across the front, is based on a cruise to the waters around the island of Jan Mayen in the Norwegian Sea in June 2007 and to the waters between Hopen and Storbanken in the Barents Sea in August 2007. The Jan Mayen Front is located to the east of the Jan Mayen Ridge and separates

warm, salty Atlantic water and colder, less salty Arctic water. The Polar Front in the Barents Sea, which separates Atlantic and Arctic waters, was observed along the eastern slope of Spitsbergenbanken and the western slope of Storbanken. At Jan Mayen, chlorophyll *a* (Chl *a*) values seldom exceeded  $1.0 \text{ mg m}^{-3}$  outside pure Atlantic water, while elevated concentrations ( $3\text{--}4 \text{ mg m}^{-3}$ ) developed at depth (20–30 m) east of the Front in Atlantic water. Also at the Polar Front, phytoplankton biomass was generally low with Chl *a* concentrations lower than  $2 \text{ mg m}^{-3}$ . The highest values were found as subsurface maximum over Spitsbergenbanken. For both front systems the quantum efficiency was strongly influenced by nutrients, suggesting nutrient limitation of phytoplankton biomass at the fronts. Lowered nutrient concentrations were seen shallower than 10–20 m. At the Jan Mayen Front, silicate was more severely depleted than nitrate, whereas at the Polar Front the opposite appeared to be the case. We conclude that the fronts did not have a stimulatory effect on phytoplankton biomass enhancement and photosynthetic performance.

Keywords: Barents Sea, front, Norwegian Sea, phytoplankton.

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## ICES CM 2012/M:18

### Subarctic–Arctic interactions: seasonal variation in fish–prey interaction in the Barents Sea

Edda Johannesen, Andrey Dolgov, Åge Høines, Randi Ingvaldsen, Geir Odd Johansen, Pavel Murashko, Andrey Sokolov, and Rupert Wieneroither

The Barents Sea is the largest of the Arctic shelf seas and an important transition zone between boreal and Arctic faunas. These faunas are partly decoupled and have different adaptations and are thus likely to respond differently to climatic changes. One important mechanism, however, coupling the Arctic and Atlantic parts of the Barents Sea is seasonal migration. In summer, migrating species (especially fish) are extending their distribution range northwards, and boreal species intrude into the Arctic part of the Barents Sea, feeding on arctic species. For some fish stocks the migration patterns are well documented, but for others the extent of migration is not known. In this work we compare survey data from different seasons to infer the degree of seasonal displacements for various fish species. Furthermore, diet data are used to evaluate trophic interactions between Arctic and boreal species in the Arctic part of the Barents Sea during summer.

Keywords: Barents Sea, diet, migration, seasonality, spatial distribution.

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## ICES CM 2012/M:19

### On the front lines

Ken Drinkwater, Ilker Fer, Marek Ostrowski, and Kjell Arne Mork

The physical structure of the fronts between Arctic and Atlantic waters is discussed based upon field studies during 2007 and 2008 on the Jan Mayen Front in the Norwegian Sea and the Polar Front in the Barents Sea. Conductivity, temperature, and depth (CTD) measurements of the large-scale water mass properties as well as small-scale turbulence from a microstructure profiler are described. Hydrographic data also are obtained from autonomous gliders and these gliders together with ship-mounted ADCP data provide information on the current structure in the vicinity of the fronts. The fronts in both regions exhibit strong horizontal gradients in temperature and salinity but weak density gradients owing to density compensation of the water mass characteristics on both sides of the fronts. Intense interleaving of the water masses occurs at these fronts along isopycnals, resulting in large variability in the vertical profiles of the temperature–salinity characteristics. Although there are elevated turbulence levels in the vicinity of the front, owing to both current shear and double diffusion, turbulence levels are not strong enough to create



strong vertical mixing. Comparisons between the two regions as well as with other fronts in the Nordic Seas and in the Arctic will also be presented. Finally, we will speculate on the effects of climate change on the intensity and location of these fronts.

Keywords: fronts, Arctic, Atlantic, interleaving, Subarctic, turbulence.

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## ICES CM 2012/M:20

### Effects of climate change on fish distribution, and relation to fishery and economy; experiences from the FishExChange project

J. E. Stiansen, S. Mehl, B. Ådlandsvik, G. O. Johansen, C. Kvamme, R. Hannesson, N. A. Ekerhovd, E. Eriksen, R. Ingvaldsen, F. Vikebø, and E. Johannesen

The FishExChange project, funded by the Norwegian Research Council, ended last year. The project's principal objectives were to "evaluate the effect of climate change in the Barents Sea and adjacent areas on distribution of fish stocks, in perspective of national marine areas. Further, evaluate what effect this will have on division of national fish quotas and economical consequences for the fisheries". A spatial ecosystem database, the "FishExChange-database", has been developed and provides a common reference system in time and space for storing data from different sources. This facilitates user access and subsequent analyses of historic relationships between abiotic and biotic ecosystem components. The historic analyses establish a basis for studying future effects of climate change on fish stocks through increased ocean temperature, and the implications for geographical distributions of fish stocks and their abundance and reproduction. In addition, socio-economic implications of climate change have been studied with focus on international quota allocations, cost, and revenues in the fishing industry, and fleet structure and activities. In this presentation we summarize the results from the project, including topics such as: development of a temperature atlas and database; effects of change in the spawning location on larval drift; temperature envelope and change in abundance and distribution of 0-group and adult fish; ecosystem dynamics; effects on fisheries; and socio-economic implications.

Keywords: climate change, economy, fish distribution, fishery.

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## ICES CM 2012/M:21

### Potential movement of fish and shellfish stocks from the Subarctic to the Arctic Ocean: part A evaluation of exposure

Harald Loeng, Anne B. Hollowed, and Benjamin Planque

An assessment of the likelihood that 17 fish or shellfish stocks or stock groups will move from the Subarctic areas into the Arctic Ocean is conducted. In this paper we assess the environmental changes to Arctic and Subarctic ecosystems resulting from climate change. We compare the rate and magnitude of change expected to occur in five ecosystems: the Barents Sea, the Eurasian shelves of the Arctic, the Bering Sea, and the Chukchi and Beaufort Seas. These comparison reveal that the Arctic Ocean will become ice free during the summer season, and when this happens new areas will open up for plankton production, which may lead to new feeding areas for fish stocks. Biophysical boundaries separating Arctic and Subarctic ecosystems differ in the Pacific and Atlantic systems, with the probability of exchange being higher in the Atlantic system. Changes in summer sea ice extent, ice thickness, and regional upwelling are expected to impact the timing and magnitude of ice algal and phytoplankton blooms with associated impacts on regional pelagic and benthic productivity. In the near-term, decadal and multidecadal variability is expected to continue to be a significant driver of Arctic and Subarctic marine systems.

Keywords: Arctic, fish, phytoplankton, shellfish, Subarctic.

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**ICES CM 2012/M:22**

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**Potential movement of fish and shellfish stocks from the Subarctic to the Arctic Ocean: part B evaluation of the vulnerability of fish and shellfish stock to changing environmental conditions**

Anne B. Hollowed, Harald Loeng, and Benjamin Planque

An assessment of the likelihood that 17 fish or shellfish stocks or stock groups will move from the Subarctic areas into the Arctic Ocean is conducted. In this paper we assess the vulnerability of fish and shellfish stocks to exposure to climate induced changes in Arctic and Subarctic ecosystems resulting from climate change. We assess the sensitivity and adaptability of 17 stocks from five ecosystems: the Barents Sea, the Eurasian shelves of the Arctic, the Bering Sea, and the Chukchi and Beaufort Seas. These comparisons reveal that several species are considered as candidate species to migrate into the high Arctic in the future, but it is anticipated that only six stocks have a high probability of establishing viable resident populations in the region. The ability of species to survive in the Arctic depends on how they respond to the physical and biological conditions of the region. Marine fauna that currently reside in the area exhibit adaptations that make them well suited for the challenging conditions of the Arctic. Examples of these adaptations include the following: (i) capability of rapid growth to maximize the benefit of a short production season; (ii) specific physiological characteristics to survive in cold conditions; (iii) capability of inhabiting deep-ocean conditions to avoid ice in winter; (iv) diversity of diets; (v) broad spawning range, with low site fidelity, (vi) high migration/dispersal rates; and (vii) phenotypic plasticity.

Keywords: Arctic, fish, phytoplankton, shellfish, Subarctic.

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**ICES CM 2012/M:23**

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**Carbon flux through the microbial foodweb in the Barents Sea and the Beaufort Gyre**

Peter Lavrentyev, Gayantonia Franzè, Konstantin Solovyev, Camilla Sevensen, Kelly Young, and Jennifer Putland

With sea ice cover rapidly diminishing over the Arctic, an area of special interest is the immediate fate of pelagic primary production since the most dominant higher trophic levels depend on its efficient transfer through the food grazing chain. Microbial foodweb dynamics and trophic links to mesozooplankton were examined in the Barents Sea in May and August–September 2010 and June 2011 and in the Beaufort Gyre in July–August 2011. Thirty-two shipboard grazing experiments were conducted at sea temperatures ranging from  $-1.8^{\circ}\text{C}$  to  $8.6^{\circ}\text{C}$  in the ice-covered and open waters ( $70^{\circ}$ – $79^{\circ}\text{N}$ ). In the Barents Sea, microzooplankton herbivory was a significant factor controlling phytoplankton (on average 85% of their daily primary production) and often exceeded that by pelagic copepods. In turn, the predominant calanoid species *Calanus glacialis* and *C. finmarchicus* derived 40% of their daily carbon ration from microzooplankton in the Arctic and Atlantic-influenced waters, respectively. These copepods and *Oithona atlantica* and *Metridia longa* fed selectively on ciliates even during the diatom bloom. In the ice-covered waters of the Beaufort Gyre, ca. 30% of the diet of the large polar copepod *C. hyperboreus* consisted of microzooplankton, whereas their contribution to *C. glacialis* diet was  $>80\%$ . These data indicate that the microbial foodweb plays a critical role in the carbon flux through both productive shelf and deep oligotrophic systems in the Arctic. The effects of microzooplankton mixotrophy and bacterivory on the pelagic carbon flux will be discussed.

Keywords: Barents Sea, Beaufort Gyre, microzooplankton, *Calanus*.

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#### ICES CM 2012/M:24

### Broad-scale comparisons of productivity patterns in Subarctic ecosystems: energy flow to larval fish

Trond Kristiansen, Charles Stock, Elizabeth Siddon, R. Gregory Lough, Franz Mueter, Enrique Curchitser, Ken Drinkwater, and Ron Heintz

Global warming is changing the physical and biological structure of marine ecosystems. However, we do not understand how these changes will affect fisheries recruitment, distribution, and abundance. We did a retrospective analysis (1950–2010) of how broad-scale productivity patterns affect fisheries recruitment during warm and cold climate phases. Our study focused on major spawning grounds off the coast of northern Norway (Lofoten), the east coast of the US (Georges Bank), and the southeastern Bering Sea. Across these habitats we estimated phytoplankton and zooplankton production using a coarse-scale ocean ice hindcast simulation with the COBALT ecosystem model (carbon, ocean biogeochemistry, and lower trophics). We then coupled the COBALT model results with an individual-based model for simulating the feeding, growth, behaviour, and survival of larval and juvenile fish. Our results suggest that warm and cold phases strongly affect the feeding and growth of larval and juvenile fish in Subarctic seas, with consequences for larval fish survival and fish recruitment. The coupled model system enables us to identify key drivers (e.g. light, temperature, prey abundance) in a mechanistic framework for key fisheries habitats across the Subarctic regions. These results will serve as the basis for understanding how ecosystems will respond differently to climate variability.

Keywords: climate change, ecosystem comparison, larval fish, mechanistic understanding, recruitment variability.

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#### ICES CM 2012/M:25

### Circumpolar biodiversity: results of climate fluctuations and intermingling of Atlantic and Pacific species?

K. E. Jørstad and A.-L. Agnalt

The early taxonomy of closely related Pacific and Atlantic species are mainly based on general life-history characteristics. One example is the Atlantic herring (*Clupea harengus*) and Pacific herring (*Clupea pallasii*), which are both commercially important species in the northern hemisphere. Based on morphology, vertebrae number, and spawning characteristics, Svetovidov considered the herring in White Sea and northwestern Russian areas as subspecies of Pacific herring, *Clupea pallasii*. New molecular methods have recently revealed that some of the herring populations in Northeast Atlantic are genetically closer related to Pacific herring than to Atlantic herring. Such genetic links have also been detected in studies of other fish species (*Gadus chalcogrammus*), shellfish (*Macoma baltica*), and copepods (*Calanus marchallae*). Recently, snow crab (*Chionocetes opilio*) has established as self-sustaining populations in the Barents Sea, and preliminary genetic studies cannot exclude linkage to the snow crab population in the Bering Sea. The present situation is possibly a result of historical climate variations in the Arctic region—long interglacial periods with low ice coverage enabling free migrations between the Bering and Barents Seas. To evaluate the effects of future climate changes, there is an urgent need for more comprehensive mapping of biodiversity in the Arctic regions.

Keywords: arctic biodiversity, Atlantic and Pacific species, biodiversity response, climate change.

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**ICES CM 2012/M:26**

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**Climate change effects on marine Arctic ecosystems**

Ingrid H. Ellingsen, Dag Slagstad, Ole Jacob Broch, Paul Wassmann, and Richard Bellerby

A fully coupled hydrodynamic–ice–chemical–biological model system, SINMOD, has been used to investigate effects of predicted climate changes on the marine ecosystem. We have used high-resolution data from REMO for the IPCC SPRES scenarios A1B and B1, downscaled for SINMOD. Lateral boundaries were taken from the Bergen Climate Model, with corrected bias using measured data from the 1990s. The model predicts decreased ice extent during the twenty-first century. Transitions to ice-free areas are abrupt and are usually accompanied by large interannual variability. Changes in ice conditions may have a great impact on the physical environment of the ocean by altering water mass composition, for example in the northern Barents Sea. There is great variability in primary production in the present Seasonal Ice Zone (SIZ). Due to changes in ice conditions there will also be changes in the geographical position of the SIZ and less variability in areas that no longer have a seasonal ice cover. The model predicts that annual primary production will decrease in areas dominated by Atlantic Water. These changes are mainly driven by decreasing nutrient content of the inflowing Atlantic Water and by reduced winter mixing. The most severe response to climate change predicted by the model is the disappearance of the zooplankton species *Calanus glacialis* in the northern Barents Sea. This change happens abruptly in response to a great rise in water temperature, mainly as a result of changes in water mass composition.

Keywords: arctic, climate change, coupled models, zooplankton.

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**ICES CM 2012/M:27    Withdrawn**

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**ICES CM 2012/M:28**

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**Habitat and the shifting climate: species distributions and interactions in Arctic and Subarctic systems in the North Pacific**

Matthew Baker and Anne Hollowed

Several mechanisms drive ecosystem structure and stability in marine systems, including competition between species, climate, and fisheries extraction. Species dynamics and interactions across systems are uniquely influenced by the constraints of physical habitat and differential response of species to common physical variables. We examine species dynamics at multiple trophic levels, both within and between functional guilds in the Bering Sea and the Gulf of Alaska as a means to compare and contrast Arctic and Subarctic systems. We examine evidence for compensation, resource partitioning and common forcing via external drivers and examine how habitat governs species interactions. Despite relatively similar assemblages of species, these systems differ dramatically in terms of the extent and steepness of the continental shelf and the influence of water temperatures and residual sea ice in the northern Bering Sea. We apply random forests to determine the importance of environmental variables on individual species distributions. We then extend these methods to species assemblages, synthesizing cross-validated coefficient of determination and accuracy importance measures from univariate analyses to quantify compositional turnover along environmental gradients. These outputs are applied to define distinct regions within large marine ecosystems, based on unique aggregations of community composition and physical habitat. We then explore how these habitats vary in extent as climatic variables shift in these systems. We integrate these methods to inform approaches to examining relative effects of various drivers of species abundance and community composition through multivariate autoregressive state–space models.

Keywords: climate forcing, community dynamics, compensation, ecosystem structure, multivariate autoregressive models, resource partitioning, species interactions, Subarctic–Arctic interactions.

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#### ICES CM 2012/M:29

### Long-term fluctuations of species structure of the most abundant copepods in latitudinal zone of the Barents Sea

Emma L. Orlova, Viktor A. Ivshin, Andrey V. Dolgov, Valentina N. Nesterova, and Irina P. Prokopchuk

Based on data 1980s and 2000s quantitative ration of main biomass-forming copepod species (*Calanus finmarchicus*, *C. glacialis*, *C. hyperboreus*, *Metridia longa*) in the Barents Sea was considered. Such changes were related to advection of Atlantic waters, temperature and ice conditions during different climatic periods. Borders of these species distribution areas and peculiarities of their species composition and biomass in various part of the Barents Sea are analysed. The most remarkable changes were observed during the last warm decade. The main features were a shift of the distribution area of Arctic copepod species northwards, providing a longer production time period for these species as well as a smaller distribution area and more southern distribution of *C. finmarchicus*. As a result, the zone of the highest copepod biomass (>10 g/m<sup>2</sup> DW) was located in the northeastern Barents Sea. In addition, abundance and biomass of copepod community was impacted by planktivorous fish (especially capelin) predation.

Keywords: Barents Sea, biomass, copepods, species composition.

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#### ICES CM 2012/M:30    Withdrawn

#### ICES CM 2012/M:31    Poster

### Microzooplankton growth and herbivory impact in the Barents Sea

Gayantonia Franzè and Peter Lavrentyev

The diminishing ice cover in the polar shelf seas is expected to lead to increased pelagic primary production with a greater contribution from pico- and nano-sized phytoplankton. Microzooplankton are well-established grazers of small phytoplankton in the tropical and temperate ocean. However, little information exists on their role and response to climate change in the Arctic. During three cruises in the Barents Sea (70°N to 79°N) in May and August–September 2010 and June 2011, 21 shipboard dilution experiments were conducted at –1.8°C to 8.6°C to determine microzooplankton growth and grazing rates in open and ice-covered waters. The phytoplankton growth rates ( $\mu$ ) ranged from 0 to 0.87 d<sup>-1</sup> with the highest value recorded under the ice. The microzooplankton herbivory rates ( $g$ , 0.06–0.95 d<sup>-1</sup>) increased with temperature ( $p < 0.05$ ). The impact of microzooplankton herbivory on primary production (the  $g:\mu$  ratio displayed a similar but less significant trend. On average, microzooplankton removed 85% of daily primary production. Similarly, the microzooplankton grazing rates on picophytoplankton increased in the warmer Atlantic water, but their grazing impact did not correlate with temperature. The microzooplankton community biomass turnover rates ( $P/B$ ) also showed no relationship to temperature and ranged between 0.01 and 0.46 d<sup>-1</sup>. The maximum growth rates of abundant ciliate and dinoflagellate species ranged between 0.33 and 2.04 d<sup>-1</sup> and 0.55 and 2.26 d<sup>-1</sup>, respectively.

These data indicate that microzooplankton are well adapted to a wide range of ambient conditions in the Barents Sea and in most cases control phytoplankton primary production.

Keywords: Barents Sea, herbivory, growth rate, microzooplankton.

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## Theme Session N

### Examining the implications of complex population structure on fish resources, fisheries, assessment, and management

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#### ICES CM 2012/N:01

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##### **Fidelity within and connectivity among subpopulations of Atlantic cod**

Douglas Zemeckis, William Hoffman, Micah Dean, Michael P. Armstrong, David Martins, and Steven X. Cadrin

The Gulf of Maine stock of Atlantic cod is rebuilding after decades of overfishing. Many historic coastal spawning components have been depleted, causing reductions in spawning diversity, recruitment, and productivity. We used acoustic telemetry to study the movements of a coastal spawning component in the western Gulf of Maine since 2009. We found spawning site fidelity at a relatively fine spatial scale (<100 m) over several years. Individual cod remained on the spawning site for approximately 3–7 weeks, exhibiting infrequent movements away from the spawning site. Movements inferred from data storage tags and t-bar anchor tags identify a connection between coastal spawning sites up to 45 km apart. The expression of spawning site fidelity identifies complex population structuring within the Gulf of Maine stock, which may be best described as a metapopulation, comprising several semi-discrete spawning components. Furthermore, biological processes and population structuring operate on a much finer scale than the spatial management unit. Stock assessments and management plans that recognize the complex population structure within the Gulf of Maine cod stock are expected to help prevent continued declines in spawning diversity and promote rebuilding.

Keywords: acoustic telemetry, Atlantic cod, Gulf of Maine, population structure.

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#### ICES CM 2012/N:02

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##### **Improving the assessment and management of the plaice stock complex between the North Sea and the Baltic Sea**

C. Ulrich, J. Boje, M. Cardinale, P. Gatti, M. Andersen, J. H. Hansen, N. Hintzen, K. B. Håkansson, J. B. Jacobsen, D. C. M. Miller, E. E. Nielsen, A. Rijnsdorp, C. R. Sparrevohn, H. Svedäng, and H. Wennhage

Plaice in Kattegat and Skagerrak have traditionally been considered as one stock unit. However the collected information on biology and fishery in areas between the North and Baltic Seas suggest changes are needed in assessment units as well as in management areas. Plaice in Skagerrak (Division 20) is now considered to be closely associated with plaice in the North Sea and is proposed to be included in the North Sea plaice stock assessment, although it is recognized that local populations are present in the area. Therefore, specific management of the Skagerrak plaice is suggested. Plaice in Kattegat (Division 21), the Belts (Division 22), and the Sound (Division 23) is considered a stock unit and is proposed to be assessed as such. However, separate management by area is also suggested to assure the preservation of the local populations. Plaice in the Baltic (Divisions 24–32) is considered a stock unit and is proposed to be assessed and managed as such. Pragmatic options are suggested for empirical harvest control rules accounting for the dynamic of local abundance, using a survey-based biomass indicator. For the future, new scientific analyses should be developed to better inform the origin of the catches, provided that additional resources are allocated to the annual monitoring of different stocks and components. Such information would provide on-going quantitative information on the degree of mixing of the various

components, potentially allowing a more accurate assessment, management, and conservation of the status of these.

Keywords: Kattegat, local populations, management plan, plaice, Skagerrak, stock assessment.

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### ICES CM 2012/N:03

#### **Incorporating spatial population structure in stock assessment models of marine species**

Daniel R. Goethel, Lisa A. Kerr, and Steven X. Cadrin

Centuries of fisheries research demonstrate that marine species exhibit complex spatial structure. Yet, spatially explicit population dynamics models have only begun to gain popularity in the last two decades. Ignoring the spatial complexities of subpopulation structure can be detrimental to sustainable fisheries management and lead to loss of biocomplexity. Recently, spatially explicit assessment models have been developed in an attempt to match the spatial scales of natural populations. These models can incorporate a variety of spatial population structures, but are limited by data constraints. We describe a generic spatially explicit tag-integrated stock assessment framework and the advanced data requirements for successful implementation of these types of models. Application of tag-integrated assessments requires knowledge of the population structure, fine-scale data, and information on connectivity between population components, often in the form of tagging data. Spatially explicit, tag-integrated models also use more conventional assessment information, such as catch-at-age and indices of abundance. The increase in resolution and realistic biological characteristics of spatially explicit models comes at the cost of data sample size and associated increases in uncertainty. However, the development of fine-scale population models is imperative to effectively assess and manage spatially structured marine populations.

Keywords: movement models, population structure, stock assessment, tagging models, tag-integrated models.

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### ICES CM 2012/N:04

#### **Preliminary spatially disaggregated stock assessment of northern hake, a widely distributed stock of the Northeast Atlantic**

Michel Bertignac, Carmen Fernández, and Richard Methot

European hake (*Merluccius merluccius*) is widely distributed over the Northeast Atlantic shelf, from Norway to Mauritania. Despite its large distribution (covering ICES Division IIIa, Subareas IV, VI, and VII and Divisions VIIIa,b,d, from Norway to the Bay of Biscay) and a complex population structure, the so-called northern stock of hake is currently assessed as a single unit using a spatially aggregated implementation of the Stock Synthesis assessment model. In this study, a preliminary spatially explicit implementation of Stock Synthesis is developed which accounts for the distribution of the hake population during its life cycle (nurseries and spawning areas) and the distribution of the fleets (trawlers, gillnetters and longliners) exploiting the stock at various life stages. By explicitly incorporating spatial structure, the model can make consistent use of survey indices that only cover part of the stock distribution area. The model is fitted to commercial fishing data (landings, discards, and quarterly size composition) and survey indices corresponding to the geographical areas defined in the model. Parameter estimation is carried out using the maximum likelihood estimation approach. Little information is currently available on exchange rates between main distribution areas and population structuring, so several hypotheses are tested. Implications in terms of stock assessment and management are discussed.

Keywords: northern hake, population structure, spatial dynamics, spatial stock assessment.

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**ICES CM 2012/N:05**

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**The use of zero-inflated generalized additive models to predict aggregate functional group distributions for the Gulf of Mexico**

Michael D. Drexler and Cameron H. Ainsworth

The National Oceanic and Atmospheric Administration (NOAA) has identified the immediate need to incorporate ecosystem principles into ocean and coastal resource management. The Atlantis ecosystem modelling framework is well situated to address many of these issues as it integrates biology, physical, chemical, and anthropogenic impacts to provide a holistic view of the ecosystem. Development of an Atlantis Gulf of Mexico ecosystem model (Atlantis-GOMex) is currently underway at the University of South Florida. Spatially explicit ecosystem models of all types require an initial allocation of biomass on varying spatial scales which can be problematic due to the lack of comprehensive stock assessments for more than a handful of commercially valued species. Previous spatial modelling efforts have relied on a variety of methods to distribute the biomass of their respective taxa including expert opinion, similarity matrices, and outside modelling. A generalized additive modelling (GAM) approach was used to estimate functional group biomass over 64 irregular polygons throughout the Gulf of Mexico. Two GAM models are developed, respectively, describing the probability of occurrence at all sampling locations and the population density at non-zero locations. These are combined using the Delta method to yield an overall abundance. The GAM models use zero-inflated Poisson distributions to characterize catch per unit effort rates from the Southeast Area Monitoring and Assessment Program (SEAMAP). Regional climatology from the National Oceanographic Data Center was used to predict seasonal functional group biomass throughout the Gulf of Mexico, including Mexican and Cuban waters.

Keywords: biomass distribution, ecosystem modelling, functional group, Gulf of Mexico.

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**ICES CM 2012/N:06**

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**The Gordian knot: managing herring (*Clupea harengus*) bridging across populations, fishery units, management areas, and politics**

Lotte Worsøe Clausen, Henrik Mosegaard, Casper Berg, and Clara Ulrich

The management of western Baltic spring spawning (WBSS) herring is challenged by the highly complex stock structure with a temporal and geographical distribution leading to conflicting interests among different stakeholder groups. The stock is exploited in the Baltic Sea (Subdivisions 22–24) and the North Sea (Division IIIa) by various EU—and in the latter case also non-EU—fishing fleets. For the two separate management areas, TACs are set at different times in the yearly TAC-setting process by the EU and negotiating countries, which often result in conflicts over quota allocations among different management units. The WBSS herring stock spawns in the western Baltic Sea and migrates into the Kattegat and Skagerrak areas, where it mixes with North Sea autumn spawning (NSAS) herring. Recent development of otolith shape analysis has enabled a high-resolution separation of herring stocks in these waters, giving a more detailed picture of the actual stock mixing potentially undermining the current assumption of only three population components. We discuss how a higher resolution of spawning components may facilitate the estimation of local population-related productivity, and how this in turn may be applied in an advanced future management of several populations within one management unit.

Keywords: herring, management, population structure, western Baltic.

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**ICES CM 2012/N:07**

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**Assessment and management of northwest Ireland herring as part of a larger metapopulation**

Maurice Clarke, David O'Sullivan, Andy Campbell, Ciaran O'Donnell, and Ciaran Kelly

Herring populations off the northwest coast of Ireland consist of autumn, winter, and spring spawning components. These populations are assessed and managed together within the boundaries of ICES Divisions VIaS and VIIbc. However, this spatial unit does not contain the stock outside spawning times, and during the summer the stock moves across the boundary to mix with other stocks in neighbouring Division VIaN. The only available tuning index contains fish from several stocks, and until now no split of this index has been possible. Given these considerations, a definitive stock assessment has not been possible to date. This paper presents several new approaches to assessing the stock. A number of different assessment methods have been taken, relying on a differing levels of data quality. These approaches were applied at both the individual stock and metapopulation levels. Results are presented in the context of the current management framework. The implications of these results for management of the stock and the wider metapopulation are discussed.

Keywords: herring, management, metapopulation, stock assessment.

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**ICES CM 2012/N:08**

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**The costs of ignoring stock structure**

Colin Millar, Ernesto Jardim, Iago Mosqueira, and Chato Osio

This simulation study investigates the robustness of harvest control rule (HCR) reference points to misspecification of stock structure—specifically the case where there are multiple subpopulations exploited by one fishery. Three factors are investigated: initial population size, population productivity, and population mixing. This allows appropriate HCR reference points to be suggested for varying degrees of stock structuring and productivity. From this we show the potential costs of ignoring stock structure in HCRs (in terms of long-term yield and probability of stock crash), but also highlight the potential gains of including good estimates of population mixing and productivity parameters in management plans.

Keywords: management, productivity, reference points, stochastic simulation, stock structure, subpopulations.

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**ICES CM 2012/N:09**

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**Modelling the responses of European anchovy growth and population dynamics to environmental fluctuations**

Heidi Pethybridge, David Roos, Véronique Loizeau, Laure Pecquerie, and Cédric Bacher

Understanding individual-level processes are important for fisheries management as they influence population and ecosystem dynamics and functioning. An individual-based bioenergetics and coupled population dynamics model (IBM) was implemented to examine the effects of food and temperature fluctuations on the population parameters of European anchovy, *Engraulis encrasicolus*, in the northwestern Mediterranean Sea. The model was developed within the framework of the Dynamic Energy Budget theory and parameterized using biological data collected from the Gulf of Lion, France. Model simulations successfully captured ontogenetic and seasonal growth patterns, including active growth in spring/summer, loss of mass in autumn/winter, and the timing and amplitude of multi-batch spawning events. An advantage of

the IBM is that interindividual variability in life-history characteristics is well represented, providing a powerful tool with which hypotheses concerning population responses to short- and long-term environmental and climatic variance can be tested. We would like to see future work that integrates larval drift and lower trophic models into our IBM framework, and incorporates the IBM into higher trophic (predator–prey and end-to-end ecosystem) models with the collective aim of better understanding system-level behaviours and processes. Our current working aim is to couple our anchovy bioenergetics model with a toxicokinetic model in which to examine mechanistically the assimilation and accumulation of polychlorinated biphenyls.

Keywords: Clupeidae, IBM, life-history traits, population dynamics, temporal variability.

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## ICES CM 2012/N:10

### Evidence of natal homing in Atlantic cod: combining migratory trajectories with genetics

H. Svedäng and C. André

Population structuring mechanisms in marine broadcast spawning species is still an open issue. While philopatric migration has been demonstrated for anadromous and coral reef fish, there are few documented cases of natal homing in temperate marine fish species. In this study, we present behavioural and genetic evidence for philopatric migration in Atlantic cod (*Gadus morhua*) in the Kattegat–Skagerrak–North Sea area. By combining individual migratory routes of adult cod derived from archival taggings with genetic profiles of individual fish, migratory behaviour was evaluated in relation to stock identity. The genetic assignment of individuals with a known migratory history to predefined spawning populations demonstrates that both migrating and resident groups of cod display philopatric behaviours. This finding closes the loop between spawning, larval drift, and adult return migrations to spawning areas, and underlines that behavioural key patterns in the adult phase is important for stock separation and integrity in marine fish like Atlantic cod.

Keywords: *Gadus morhua*, genetic assignment, marine connectivity, philopatric behaviour, population structure, stock.

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## ICES CM 2012/N:11

### Lumpfish, *Cyclopterus lumpus*, biological insights and management recommendations

Jacob M. Kasper, Sigurdur Thor Jonsson, Hoskuldur Bjornsson, and Leif Nottestad

Lumpfish, *Cyclopterus lumpus*, are economically important to Iceland, Norway, Greenland, and Canada. Icelandic exports of female roes in 2010 amounted to €24 000 000. Despite the economic importance of this sexually dimorphic species, there is little scientific information regarding stock size and basic biology. While no trawl surveys directly target lumpfish, surveys of other species contain valuable information. Landing data were used in combination with data from the March Iceland Groundfish Survey (IGFS) and the International Ecosystem Summer Survey in the Nordic Seas (IESSNS) to establish management indicators and to better define the species' behaviour. Female biomass index, male abundance index, and  $F_{\text{proxy}}$  estimation were established. Female lumpfish landings in 2010 were a 20-year high and in the following 2011 March IGFS biomass index was among the lowest in 27 years, thus emphasizing the importance of this type of analysis. Data from the spring and autumn IGFS further define the behaviour and migratory patterns of the species. Seasonally dependent diel vertical migration patterns, protandrous migratory patterns, and evidence of male lumpfish migration earlier in recent than in past years were observed. The IESSNS provides insight into the summer behavioural patterns and shows lumpfish increase in

length as they move further offshore. By combining multiple surveys, our understanding of lumpfish behaviour was expanded and new management strategies were established.

Keywords: Iceland, lumpfish, migration, trawl survey.

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## ICES CM 2012/N:12

### Highly variable life history of Atlantic cod in Norwegian coastal waters and its consequences for sustainable exploitation

Mikko Heino, Torild Johansen, Erik Berg, Asgeir Aglen, Terje Svåsand, Geir Dahle, and Knut Jørstad

Atlantic cod is common throughout the Norwegian coast, it is an important predator, and is among the primary targets in commercial and recreational coastal fisheries. Yet coastal cod in Norway is managed as just three units. Here we describe the life-history variability that exists between different local spawning components based on sampling from more than a hundred locations covering the whole Norwegian coast. The material reveals marked variability in growth and maturation that has consistent and significant north–south and inshore–offshore (or fjord–coast) components. Furthermore, we use the estimated life-history parameters to assess theoretical limits for exploitation of individual components. We show that life-history variability is associated with strong differences in productivity of individual spawning components, and consequently, in reference points that can be derived from yield-per-recruit models ( $F_{\max}$  and  $F_{0.1}$ ). This high variability is a challenge for rational, sustainable exploitation of Norwegian coastal cod.

Keywords: coastal cod, maximum sustainable yield, productivity, spatial population structure.

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## ICES CM 2012/N:13

### Evaluating population effects and management implications of mixing between eastern and western Atlantic bluefin tuna stocks

Lisa A. Kerr, Steven X. Cadrin, and David H. Secor

Atlantic bluefin tuna (*Thynnus thynnus*) is currently managed as two stocks (eastern and western) separated by the 45°W meridian. Tagging and otolith chemistry patterns indicate there is a high degree of natal homing within each stock, but there also appears to be a high level of mixing during non-spawning periods. Because the rebuilding capacity of stocks may be partly determined by connectivity between populations, failure to account for mixing of populations can jeopardize the realization of rebuilding expectations. We developed a simulation model for Atlantic bluefin tuna to explore the consequences of alternative hypotheses of stock structure and mixing on stock productivity and rebuilding goals. The operating model is composed of two spawning populations based on western and eastern Atlantic stocks, each with its own unique vital rates and independent recruitment dynamics. The model is stochastic, age-structured, seasonally, and spatially explicit, assuming overlap between stocks. Model structure was informed by synthesis of all data available and consensus of experts on bluefin mixing. Alternative movement rates among seven geographic zones were derived from a tag-integrated stock assessment model, as well as qualitative patterns of tagging, otolith chemistry, and demographic data. Model simulations projecting the time for each stock to recover to the biomass that can support maximum sustainable yield were sensitive to the assumptions of mixing between stocks. Results indicate that consideration of connectivity between populations is critical to understanding how populations will respond to management strategies designed to rebuild Atlantic bluefin tuna stocks.

Keywords: connectivity, population model, rebuilding, stock structure.

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**ICES CM 2012/N:14**

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**Predicting the spatial distribution and population structure of Pacific swordfish with the help of an ecosystem model and a statistical parameter estimation approach**

Inna Senina, Melanie Abecassis, and Patrick Lehodey

The swordfish (*Xiphias gladius*) is highly migratory species of billfish inhabiting vast areas of the world oceans and encountered in the Pacific Ocean from 50°S to 50°N. Swordfish has a high commercial value; the population is exploited by industrial and artisanal fisheries all over the world. Due to its migratory behaviour and large geographic extent of habitat, modelling and stock assessment of swordfish population is a challenge. Various stock assessment applications developed for swordfish consider only subareas of the ocean and hence assume zero connectivity between substocks. SEAPODYM is a spatial ecosystem and population dynamic model describing spatiotemporal dynamics of fish populations under the influence of environment and fishing in a Eulerian framework. The maximum likelihood estimation methodology incorporating catch and length frequencies data within the model allows significant improvement of the fit between observations and model predictions and hence enables the use of the model as a predictive and management application tool. The application to the Pacific swordfish population was developed on a 2 × 2 degree computational grid over the Pacific domain using environmental forcing provided by the NCEP-OPA-PISCES reanalysis. Thanks to the availability of major longline fleets data, covering the entire model domain, the parameter estimation approach yielded reasonable biological parameters and allowed the prediction of population structure, spatial distributions, and migration patterns, which are consistent with cpue and length frequency data. Although swordfish stock predicted by SEAPODYM is much larger than that estimated by an ensemble of stock assessment models, the predicted regional trends are in a good agreement.

Keywords: modelling, Pacific Ocean, spatial population dynamics, swordfish.

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**ICES CM 2012/N:15**

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**Partial migration in the northern Gulf of St. Lawrence Atlantic cod population**

Arnault Le Bris, Alain Fréchet, and Joseph S. Wroblewski

The coexistence of resident and migratory individuals within a population is termed “partial migration”. Using data storage tags that record depth and temperature, we investigated the migratory behaviour of adult Atlantic cod in the northern Gulf of St. Lawrence. The geolocation problem was solved using the hidden Markov model based on daily maximum depths and bottom temperature. Reconstructed migration routes revealed undocumented partial migration in the panmictic population. Migratory individuals overwintered in relatively deep (300–500 m) and warm (5°C) waters. In the spring, these migratory fish displayed extensive diel vertical movements that were interpreted as spawning behaviour and that were localized within a closed fishing area. Resident individuals displayed a prolonged period of dormancy in shallow (<50 m) and near freezing (–1.5°C) coastal waters during the winter and the spring. This dormancy period was followed by short range movements in western Newfoundland coastal waters. Limited ability of scientific survey to sample resident cod in shallow coastal waters may induce bias in the population abundance estimations.

Keywords: Atlantic cod, data-storage tags, northern Gulf of St. Lawrence, partial migration.

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**ICES CM 2012/N:16**


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**Insight on the consequences of metapopulation structure in herring from a spatially explicit simulation model of Atlantic herring, *Clupea harengus***

Clémentine Harma, Lisa Kerr, Steve Cadrin, Maurice Clarke, and Deirdre Brophy

Knowledge of the underlying structure of fish stocks is fundamental to understanding their population dynamics and the management implications for fisheries operating on mixed stocks. Atlantic herring exhibit highly complex population structure, which a number of conflicting theories have attempted to explain. Herring structure and dynamics are now thought to be best described by the metapopulation concept. However, the current approach to assessment and management of herring stocks does not account for this complex structure. Using simulation modelling we investigated the consequences of connectivity between four populations of herring (based loosely on assessment and management delineated herring stocks around Ireland: ICES areas VIaN, VIaS–VIIb, VIIaN, and the Celtic Sea) on productivity, stability, yield, and persistence at the population and metapopulation level. The model was stochastic, age-structured, and spatially explicit. Different hypotheses regarding the type (i.e. straying and entrainment) and level (low ~5% to high ~30%) of connectivity between populations were examined. Increased straying rate reduced productivity of numerically dominant stocks but increased productivity of subordinate stocks. In contrast, increased entrainment rate impaired productivity and sustainability of minor populations. Subordinate stocks were generally sensitive (in terms of their stability and resilience) to high levels of connectivity with dominant stocks. Results confirm the currently held view of metapopulation structure of herring stocks around Ireland, but indicated that connectivity must occur at low levels to ensure population persistence. Consideration of connectivity in management appears crucial to preserve the ecologically important, yet numerically lesser, populations of herring within a metapopulation system.

Keywords: Atlantic herring, Ireland, metapopulation model, stock structure.

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**ICES CM 2012/N:17**


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**Connecting the oceanic population ecology of two transboundary anadromous alosines**

Jamie M. Cournane, Teresa A'mar, and Christopher Glass

The recent 2012 stock assessment by the US Atlantic States Marine Fisheries Commission revealed that alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) populations are depleted coast-wide. The stocks appear to be faring better in the northern rather than southern portion of their range. Both species are transboundary anadromous alosines, with alewife ranging from Newfoundland (Canada) in the north to North Carolina (US) in the south, while blueback herring extend as far south as Florida (US). The assessment, however, ignores the northernmost extent of these species by leaving out Canadian information. Furthermore, the National Oceanic and Atmospheric Administration is investigating whether to list these species under the Endangered Species Act. Inclusion of Canadian data could provide insight on the overall stock status and population stock structure of alewife and blueback herring. This work bridges US and Canadian information to improve understanding of the oceanic population ecology of the two alosines. Using information from seasonal inshore and offshore US and Canadian trawl surveys, this work constructs expected oceanic distribution models and estimates oceanic population sizes for alewife and blueback herring. This information is combined with published literature on hypothesized alewife and blueback oceanic population substock structure to estimate spatial and seasonal changes in potential stock components. Population estimates are compared with published ecosystem indicators, directed fishery catch, and oceanic bycatch in a discussion of trade-offs of population, ecosystem, and economic needs. Outcomes of the analysis provide recommendations on how to improve transboundary management of marine species.

Keywords: anadromous fish, herring, New England, trans-boundary management.

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**ICES CM 2012/N:18      Poster**

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**Life history and genetic implications of overexploitation in Eurasian perch. *Perca fluviatilis*, from the Matsalu Bay, northeastern Baltic Sea**

Leili Järv, Lilian Pukk, Anna Kuperinen, Tiit Raid, and Anti Vasemägi

Despite of ample evidence that overfishing can lead to changes in life-history traits such as age at maturation and growth rate, only a few studies have documented the evolutionary effect of fishery at both phenotypic and molecular level. In the present study, we evaluated the effect of fishing-induced effect on life-history traits, genetic diversity, and population genetic structure of Eurasian perch (*Perca fluviatilis*) local population in the northeastern Baltic Sea over three decades. The results reveal a major reduction in population mean age, length, and age at maturation among males after the population collapse in the mid-1990s. Using seven microsatellite loci, we observed a drastic change in population genetic composition over just 24 years expressed as sharp increase in genetic differentiation between pre- and post-collapse samples and deviations from Hardy–Weinberg equilibrium and linkage disequilibrium in post-collapse cohorts. Analysis of temporal variation in genetic diversity and Bayesian clustering analysis indicated that this change is probably not caused by a genetic bottleneck but instead, is the result of influx of novel genotypes to the area and subsequent mixing of previously distinct populations. This study is among the first cases where a drastic change in population genetic composition rather than fisheries-induced evolution (FIE) might be responsible for the observed phenotypic changes. These findings also suggest that local small fish populations are extremely vulnerable to high exploitation rates and replacement of native populations can go unnoticed without population genetic monitoring.

Keywords: Baltic Sea, genetic diversity, overfishing, perch, population genetic structure, stock collapse.

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**ICES CM 2012/N:19      Withdrawn**

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**ICES CM 2012/N:20      Withdrawn**

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**ICES CM 2012/N:21**

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**Downstream to upstream gradient along rivers in muscle fat contents in composite samples of European eels may be explained by gradient in sex ratio**

Stijn M. Bierman, S. Glorius, M. de Graaf, J. M. H. Schobben, N. Tien, and M. J. J. Kotterman

A long-term decrease in muscle fat contents in composite samples of European eels (25 eels per sample, mostly between 30 and 40 cm in length) from water bodies in the Netherlands has been reported. The causes underlying this trend are unknown, but if it indicates a decrease in fat reserves of migrating eels this may limit their reproductive potential since eels need sufficient fat reserves for their long-distance migration to spawning grounds. We show that fat contents were stable in lower reaches of the main rivers, whereas evidence of decreases over time exists only for locations further upstream where population densities are likely to be lowest. Data collected on individual eels show that males between 30 and 40 cm have higher expected fat contents than females with the same body length, and that sex ratios and length compositions may have a large impact on fat contents in composite samples. We hypothesized that the observed spatiotemporal

trend in fat contents reflected a trend in length composition and/or sex ratio of eels from lower to upper reaches, as had been reported for other river systems. Trends in body lengths in composite samples did not correlate with the trends in fat contents in these samples. We therefore propose that an increasing relative dominance of females in upper reaches of the main rivers in the Netherlands may explain the trends in fat contents in composite samples. We discuss possible causes of the contrasting spatial trends in the context of the falling recruitment of eel over the past decades.

**Keywords:** *Anguilla anguilla*, dioxin, maturation, spatial structure, spawning migration.

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## Theme Session O

### How does renewable energy production affect aquatic life?

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#### ICES CM 2012/O:01

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##### **Unravelling the life cycle of Atlantic cod (*Gadus morhua*) and pouting (*Trisopterus luscus*) at offshore windfarms**

Jan Reubens, Steven Degraer, and Magda Vincx

The substantial expansion of offshore windfarms in North Atlantic waters induces a growing interest in the possible effects of these artificial habitats on the marine environment. Fish aggregations are particularly vulnerable to fishing pressure and overexploitation, for example, so it is important to understand how offshore windfarms relate to the attraction and productivity of hard substrate-dwelling fish. We therefore investigated the trophic ecology, community structure, and distribution of Atlantic cod (*Gadus morhua*) and pouting (*Trisopterus luscus*) at a Belgian offshore windfarm since 2009. A wide range of sampling techniques was used, ranging from line fishing and stomach analysis to acoustic telemetry. High densities of Atlantic cod and pouting were present in the vicinity of the windfarms in summer and autumn: both species arrive in spring, stay throughout summer and autumn, and leave the area in wintertime. The diet of both species was dominated by hard substrate epifouling organisms, illustrating a direct trophic relationship between the artificial hard substrates and both species. We also demonstrated a high site fidelity and residency near the windmills, indicative of a true selection of habitat. We conclude offshore windfarms to be highly attractive to Atlantic cod and pouting and plea for continued research focused on the potential for sustainable fisheries within these windfarms.

Keywords: acoustic telemetry, Belgian part of the North Sea, cpue, demersal fish, windmill artificial reefs.

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#### ICES CM 2012/O:02

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##### **Effects of river regulations on fjord dynamics and retention of coastal cod eggs**

Mari S. Myksvoll, Anne D. Sandvik, Lars Asplin, and Svein Sundby

High annual precipitation and steep mountains make Norway especially suited for the extraction of potential energy from waterfalls, and it is the country with the largest production of hydroelectric power in Europe. Power production can change both the position of river outlets and the seasonal cycle of fresh-water discharge. To study the impact of river regulation on fjord dynamics and transport of cod eggs, a numerical model is applied for the year 2009. We investigated two cases: the first case with only the natural seasonal cycle of fresh-water discharge while the second case includes all river regulations in the fjord system. The results show stronger surface outflow in the main part of the fjord when applying river regulations compared to natural run-off. The transport of cod eggs out of the fjord system increased with regulated run-off compared to the natural run-off, which correspondingly caused reduced local retention of eggs within the various fjord branches. Changes in the seasonal cycle of fresh-water discharge due to hydroelectric power production cannot be neglected as a contributing factor to the observed decline in coastal and fjord cod subpopulations.

Keywords: coastal cod, fjord circulation, river regulation.

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#### ICES CM 2012/O:03      **Withdrawn**

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**ICES CM 2012/O:04**


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**The added value of “small-scale” monitoring of the soft-sediment endobenthos around offshore windfarms in the Belgian part of the North Sea**

Delphine Coates, Jan Vanaverbeke, and Magda Vincx

From 2005 onwards, a baseline monitoring programme was carried out to assess whether the construction of offshore windfarms induced changes in the soft-sediment endobenthos in the Belgian Part of the North Sea. The natural, temporal variability of the endobenthos was detected without any apparent effects from windfarms. To understand underlying processes and detect future effects, a targeted (small-scale) sampling strategy was initiated in 2010, alongside the baseline monitoring activities. The sandy offshore sediments near one gravity-based foundation (GBF) may be altered due to (i) previously created pits, (ii) changing hydrodynamics, (iii) organic enrichment, and (iv) prohibition of beam trawl fisheries. Benthic samples were therefore taken at 1, 7, 15, 25, 50, 100, and 200 m from the scour protection system and along four gradients, in order to stress the importance of currents around the GBF. In 2010, high mean total densities and macrobenthic biomass were detected at 1 and 7 m from the GBF. The natural occurring *Nephtys cirrosa* community shifted to a community dominated by *Monocorophium acherusicum*, *Lanice conchilega*, and *Spiophanes bombyx*. One year later, higher macrofaunal densities were also observed at 15 and 25 m from the GBF and this primarily on the southwest gradient. Furthermore, a decline in median grain size was observed between 2010 and 2011, suggesting changing hydrodynamics around the GBF. These results illustrate the importance of dedicated small-scale and short-term investigations in national monitoring strategies for offshore windfarms as they permit a better understanding of the large-scale observations.

Keywords: benthos, North Sea, benthos, spatial and temporal patterns.

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**ICES CM 2012/O:05**


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**Monitoring the effects of the Belgian windmill parks on the epibenthos and demersal fish fauna of soft-bottom sediments**

Jozefien Derweduwen, Sofie Vandendriessche, and Kris Hostens

A BACI (before–after control impact) design is used to evaluate two possible effects of offshore windmill parks in the Belgian part of the North Sea on soft-bottom epibenthos and demersal fish, namely the effect of the presence of turbines (hard substrate) and border (fringe) effects due to changing fisheries activities at the concession borders. For the Thorntonbank windfarm (27 km offshore, 18–24 m water depth, six gravity-based foundations), a lower number and slightly larger individuals of swimming crab (*Liocarcinus holsatus*) and brown shrimp (*Crangon crangon*) and higher autumn densities of whiting (*Merlangius merlangus*) inside the park were noted in 2010 compared to the reference area. VMS (vessel monitoring system) data showed an increased fishing intensity in the neighbourhood of the concession. The absence of the smallest size classes of sole (*Solea solea*) at the “fringe” stations might indicate an increased indirect fishing mortality (discards) or changes in the local benthic community. For the Bligh Bank windmill park (40 km offshore, 18–40 m water depth, 55 monopiles), clear differences were noted at species level. For example, the green sea urchin (*Psammechinus miliaris*) was found at higher densities in the impact area, both on the sandbank top and in the gullies. Also, some larger flatfish individuals (plaice (*Pleuronectes platessa*) and turbot (*Psetta maxima*)) were encountered inside the concession area. The results suggest fringe, refugium, and reef effects on soft-bottom epibenthos and demersal fish, related to the presence of the windmill parks.

Keywords: Belgian part of the North Sea, epibenthos and demersal fish, soft bottom, windmill parks.

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**ICES CM 2012/O:06**

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**Biofouling and fish at offshore wind power foundation—German Bight**

Roland Krone, Alexander Schröder, and Lars Gutow

The ecological consequences of the large-scale introduction of wind turbine foundations into the marine environment are still poorly understood. The FINO 1 research platform provided the first opportunity to investigate the local effects of a single foundation on the macro- and megafauna inside the German Bight. The fouling assemblages on the structure were sampled by scientific diving during three seasons from the 3rd to the 5th year after construction. A biomass accumulation of up to 6000 kg was attached to the entire underwater construction. Blue mussels (*Mytilus edulis*) contributed the largest part to the biomass (75%) but only down to about 5 m below the sea level, while deeper sections were dominated by the amphipod *Jassa* spp. (>200 000 ind. m<sup>-2</sup>). To obtain a complete picture of the reef biocenosis, the fish and crab fauna of FINO 1 was quantified as well and compared to five shipwrecks and the natural soft-bottom fauna. In general, the composition of the reef fauna of the wrecks and the FINO 1 foundation was similar, but abundances at wrecks were up to 5 times higher. Some species, such as the bull rout (*Taurulus bubali*), occurred only at the artificial structures. The abundances of some species such as hermit (*Pagurus bernhardus*) and edible crabs (*Cancer pagurus*) were 90% and >99.9%, respectively, higher at the foundation than on the sandy soft bottom. The investigation revealed the function of offshore wind turbines and wrecks as hotspots for benthic megafauna and biofouling in the North Sea.

Keywords: benthos, crabs, demersal fish, offshore wind power, reef effect, ship wrecks.

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**ICES CM 2012/O:07**

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**A call for hypotheses-based benthos research in offshore windfarm environmental impact studies**

Jennifer Dannheim, Steven Degraer, Lars Gutow, Silvana Birchenough, Arjen Boon, Thomas Brey, Delphine Coates, Jean-Claude Dauvin, Gwenola de Roton, Jozefien Derweduwen, Andrew B. Gill, Urszula Janas, Francis Kerckhof, Roland Krone, Sophie Lozach, Georg Martin, Christian Mohn, Katharina Reichert, Jan Reubens, Mike Robertson, Liis Rostin, Henning Steen, and Dan Wilhelmsson

Offshore windfarms are expected to affect substantially the structure and functioning of marine ecosystems. Collision risks for migrating birds and noise impact on marine mammals and fish are issues of major public concern. Less charismatic organisms, however, from marine algae through to benthic invertebrates and demersal fish receive far less attention. We contend that the benthos deserves much greater attention owing to the numerous ecosystem goods and services, such as marine biodiversity and long-term carbon storage and natural resources (e.g. for fish, birds, mammals, and finally humans), that are intimately linked to the benthic system. The installation and operation of extensive offshore windfarms in shallow shelf seas will initiate processes which are expected to affect benthic communities over various spatial and temporal scales. Extensive baseline monitoring programmes allow observations of structural changes to benthic communities, but this is a post-hoc approach. To gain a mechanistic understanding of these processes that enables us to explain the observed changes, specific target monitoring and well-designed experimental studies are required. In this conceptual talk we will discuss specific cause–effect relationships in the marine benthos arising from the anthropogenic activities associated with offshore windfarms. The identification of cause–effect relationships is the prerequisite for an efficient, hypothesis-driven approach towards the disentanglement of the various effects of offshore windfarms on the marine benthos as well as on the whole ecosystem.

Keywords: benthos, cause–effect relationships, demersal fish, impact assessment, offshore windfarm.

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**ICES ASC 2012/O:08**

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**Turbine height as a management tool for collision risk to birds at offshore windfarms**

Ian Davies and Bill Band

An important element of the environmental impact assessments for offshore windfarms is the potential for interactions with seabirds, particularly through collision of birds in flight with rotating blades. In many cases, these birds are protected through Natura regulations, and Appropriate Assessments are required of the responsible authorities. Traditional models of collision (the “Band model”) make use of the numbers or density of birds flying at turbine height (i.e. within the swept area of the turbine blades). In the UK, the minimum clearance of the blades above the water is normally 22 m above HWS. Recent compilations of flight height information indicate that, for some species, most birds at risk of collision are flying in the lower part of the swept area. For such species, increasing the clearance above the water surface can significantly reduce the number of flights exposed to collision risk. Modelled distributions of flight heights for a range of species have been used to estimate the reduction in collision risk achieved by increasing clearance of turbine blades above the water. While it is recognized that there will be additional engineering and cost considerations involved in adopting greater clearance heights, increasing the clearance in areas of importance to seabirds may reduce the constraints on windfarm development arising from concerns over potential collisions with birds in flight. The ability to manage collision risk in this way adds a new dimension to the expressions of risk available to marine planners, and could lead to new formulations of development strategies.

Keywords: collision risk, Scotland, seabirds, windfarms.

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**ICES CM 2012: O:09**

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**Offshore windfarms and their impact on fish abundance and community structure**

C. Stenberg, G. E. Dinesen, M. van Deurs, C. W. Berg, H. Mosegaard, S. Leonhard, T. Groome, and J. Støttrup

Deployment of offshore windfarms (OWF) is rapidly expanding. A before–after control impact (BACI) approach was used to study the impact of one of the world’s largest offshore windfarms (Horns Rev Offshore Windfarm) on fish assemblages and species diversity. Fish were generally more abundant in the control than the impact area before the establishment of the OWF. Eight years later fish abundance was similar in both the impact and control area but the abundance of one of the most frequently occurring species, whiting, was much lower compared to 2001. However, the changes in whiting reflected the general trend of the whiting population in the North Sea. The introduction of hard bottom resulted in higher species diversity close to each turbine with a clear spatial (horizontal) distribution. New reef fish such as goldsinny wrasse (*Ctenolabrus rupestris*), viviparous eelpout (*Zoarces viviparous*), and lumpsucker (*Cyclopterus lumpus*), established themselves on the introduced reef area. In contrast very few gobies were caught near or at the OWF, presumably owing to the highly turbulent hydrographical conditions in the OWF. We suggest that the lack of this common prey fish is the main reason for the absence of larger predatory fish species.

Keywords: artificial reef effect, BACI, pisces, spatial distribution.

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**ICES CM 2012/O:10**

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**Monitoring high-energy littoral environments: photographic and image analysis methodologies for quantifying species and biotope coverage**

Andrew Want, Jonathan Side, and Michael C. Bell

Across Europe, governments are setting ambitious targets for delivering energy from renewable sources in attempts to stimulate economic development, promote energy security, and mitigate environmental concerns associated with other energy sources. In the UK, and other maritime nations, wave and tidal energy is playing an increasing role in fulfilling these targets. The west mainland shoreline of Orkney, with a westerly fetch of over 3000 km, is at the forefront in the development of wave energy extraction devices. While exposure to wave energy plays a dominant role in both shaping this landscape and determining the ecological community, little is known of the consequences of removing energy from this environment. We have begun an extensive long-term monitoring programme to assess the impacts of altering wave energy exposure on these rocky shores alongside responses to other systemic forcing agents such as climate change. Within this programme are several photographic surveys, including quadrat and fixed viewpoint techniques used to study individual species and biotopes. We have developed software for efficiently analysing these images and producing quantitative data on species and biotope coverage. In addition, extensive surveys along this shoreline have provided detailed image records and helped to identify areas of environmental sensitivity. Collectively, these data are providing a comprehensive "pre-impact" baseline along this important coastline.

Keywords: climate change, ecological monitoring, photographic image analysis, wave energy.

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**ICES CM 2012/O:11**

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**Small-scale distribution of fish in offshore windfarms**

K. S. Hansen, C. Stenberg, and P. R. Møller

Knowledge about small-scale distribution of fish around turbines in offshore windfarms (OWF) remains relatively scarce. In the present study we used underwater video camera installations to access abundance of fish at 0, 25, and 50 m around the turbine foundations in Middelgrund and Lillgrund OWFs in Øresund between Denmark and Sweden in the period August–November 2011. Fish fauna in both localities were dominated in terms of numbers by two-spotted gobies (*Gobiusculus flavescens*). Average number of fish observed per hour was a factor 100 higher at Lillgrund and a factor of 2 higher at Middelgrund at 0 m from the turbine compared to 25 and 50 m away. At Lillgrund sediment was dominated by bare sand while Middelgrund had more heterogeneous sediment types with sand, boulder, pebbles, and dense eelgrass areas. This suggests that OWFs in areas with homogeneous sand sediment have a higher impact on fish fauna compared to OWFs in areas with heterogeneous sediment. Furthermore, the effect of OWFs on fish appears to be of a much smaller scale than previously thought.

Keywords: distribution, fish, offshore windfarm, Øresund.

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**ICES CM 2012/O:12**

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**Quantifying harbour porpoise disturbance by offshore windfarm piling activities**

Jan Haelters, Laurence Vigin, and Steven Degraer

The impact of pile driving on marine mammals is one of the major environmental concerns in offshore windfarm construction. We assessed the impact of pile driving on the spatiotemporal distribution of harbour porpoises during the season of maximum abundance in Belgian waters. We combined data collected by a small number of passive acoustic monitoring (PAM) devices, moored

inside and outside the project area, and five standardized aerial surveys, covering the Belgian part of the North Sea ( $\pm 3600 \text{ km}^2$ ). The combination and integration of both techniques proved very useful as PAM results in low spatial but high temporal resolution data, while aerial surveys have a complementary low temporal but high spatial resolution. Just before construction activities started, aerial surveys yielded an estimate of 2.5 harbour porpoises per  $\text{km}^2$ , while after the start of the construction (piling) activities density estimates had decreased to 1.3 animals per  $\text{km}^2$ . Although a decreasing density towards the end of April in Belgian waters should be considered as normal (cf. seasonal migration), an obvious shift in spatial distribution between pre- and post-piling already suggested harbour porpoise disturbance. This pattern was further explored with PAM, which indeed showed a clear fine-scale match between PAM harbour porpoise detections and piling activities. PAM demonstrated that immediately upon the start of piling activities harbour porpoise detections fell to virtually zero, and that it took hours to days before new detections were made after the cessation of piling. Aerial surveys allowed us to quantify an impact radius of more than 20 km.

Keywords: Belgian part of the North Sea, harbour porpoise, offshore windfarms, pile driving.

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### ICES CM 2012/O:13

#### **Sensitivity of marine species and biotopes to hydrodynamic changes induced by extraction of wave and tidal energy**

Michael C. Bell, Michael T. Burrows, Jon C. Side, Andrew Want, and Susana Baston

Hydrodynamic energy is an important determinant of species distribution and assemblage composition in both littoral and sublittoral marine environments. Modelling studies indicate that commercial-scale extraction of energy by wave and tidal energy devices has the potential to affect tidal current velocities, circulation patterns, and wave climates at scales ranging from metres to tens of kilometres. We use data on marine species and biotope distribution in Scottish waters to determine probabilities of occurrence in relation to tidal current stress and wave exposure and examine the extent to which changes in hydrodynamics owing to energy extraction are likely to cause long-term changes in distribution. Canonical variates analysis is used to describe the ecological niche space occupied by species and biotopes in relation to hydrodynamics and other environmental variables, providing the basis for predictions about responses to environmental change. We discuss the extent to which barriers to dispersal and responses to concurrent environmental trends (e.g. climate change) might affect the scale and nature of responses to energy extraction and the capacity of marine ecosystems to absorb potential impacts.

Keywords: impacts, marine biotopes, marine renewable energy, Scotland.

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### ICES CM 2012/O:14

#### **The development of benthic communities on hard substrates within OWEZ, the first Dutch offshore windfarm**

Sietse Bouma and Wouter Lengkeek

This study documents the development of a benthic reef community on the foundations of the first Dutch offshore windfarm in the first years after construction. The windfarm was built in 2006 and has been in operation since January 2007. The turbine monopile foundations and the rocks around the foundations that serve as scour protection form a new hard-substrate habitat in an environment previously dominated by soft, sandy substrates. Five years after commissioning of the windfarm a total of 55 different taxa (including several non-indigenous species) were identified using video

footage and samples collected by divers. The intertidal zone was characterized by a band of green algae, different species of barnacles, oysters, and small blue mussels. In the subtidal zone, a patchy but generally thick layer of blue mussels was present to about 10–12 m depth with associated species such as starfish, crabs, and various polychaetes. At greater depth, benthic communities were dominated by small crustaceans, anemones, and ringed tubularia. The most dominant species on the scour protection were plumose anemones, small crustaceans, and the encrusting sea mat. Total densities of hard substrate species increased over the study period to circa 28 000 individuals per m<sup>2</sup> on the monopiles and circa 2500 individuals per m<sup>2</sup> on the scour protection layers. Total biomasses varied between circa 450 and 1400 g AFDW per m<sup>2</sup>. The new hard-substrate communities can form a valuable food source for fish and bird species. This study was commissioned by NoordzeeWind (a joint venture of NUON and Shell Wind Energy).

Keywords: benthic reef communities, Dutch offshore windfarm, hard substrate.

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## ICES CM 2012/O:15

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### Cod and sole behaviour in an offshore windfarm

H. V. Winter, G. Aarts and O. A. van Keeken

Offshore wind power is a rapidly expanding sector of renewable energy industry. Potential impacts of wind production on marine environments can be adverse, indifferent, or, in the case of impacted ecosystems, even positive (e.g. by banning fisheries or acting as artificial reefs). In 2007, the first offshore windfarm (OWEZ) along the Dutch North Sea coast became operational with 36 monopile wind turbines. We studied sole (*Solea vulgaris*) and cod (*Gadus morhua*) behaviour within OWEZ with telemetry and tagging experiments. We compared return rates of sole caught, tagged, and released within OWEZ to a reference area and used an array of 16 Vemco detection stations, each covering one monopile, to study the behaviour of 40 sole and 47 cod with implanted acoustic transmitters during 2008–2009. For tagged sole, there was no significant difference in return rate between OWEZ and reference area. The tagging and telemetry results for sole indicate that the majority of movements take place at larger spatial scales than the windfarm area and that sole appears indifferent to wind turbines. For cod, telemetry showed large variation in individual behaviour, with 30% detected for a few days, 55% for several weeks to months, and 15% detected for the entire nine months duration of the experiment. Typically, cod stayed near monopiles for prolonged periods and sometimes switched to a different monopile and showed diurnal patterns changing throughout the seasons. For cod, OWEZ, where fisheries are banned, may act as a refuge for at least part of the cod population.

Keywords: behaviour, demersal fish, offshore windfarm, telemetry.

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## ICES CM 2012/O:16

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### Ecosystem impacts from offshore windfarms: cross-border overview of lessons learnt from UK and Belgium

S. N. R. Birchenough and S. Degraer

The marine system is known for its complexity, especially when compared with other ecosystems. A combination of physical, chemical, and biological components is known to influence the integrity of marine systems. The successful study and management of marine systems requires information from all its ecological levels. Current monitoring programmes of offshore windfarms (OWFs) collect information on the physical (e.g. hydro-geomorphology and underwater noise), biological (i.e. hard substratum epifauna, hard substratum fish, soft substratum macrobenthos, soft substratum epibenthos and fish, seabirds and marine mammals) and socio-economical (i.e.

seascape perception, and offshore renewable appreciation) aspects of the marine environment. The majority of the current OWFs installations concentrate on monitoring a series of ecological receptors. This information can be used to support current monitoring programmes for advancing current knowledge on the effects of OWFs. The need to produce energy from renewable sources has prompted countries such as the UK and Belgium to build a series of OWFs. While these OWFs are operational, there is a demand to continue with new installations, which will require more turbines over larger areas. The operational and future of OWFs will need to be supported by robust monitoring programmes for evaluation and auditing the environmental impacts of offshore windfarms. This work presents a review of commonalities and dissimilarities of ecological baseline and monitoring assessments of offshore windfarms in UK and Belgium waters. It will provide valuable information for future monitoring assessments as well as for fostering cross-border links for scientific collaborations in support of cost-effective OWF monitoring programmes.

Keywords: benthos, ecosystems, monitoring, offshore windfarms.

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## ICES CM 2012/O:17

### **Impacts of tidal power in the UK: fish and turbines – one and strike and you're out!**

Adrian E. Williams

Global and European policy is increasingly focused towards the reduction of CO<sub>2</sub> emissions and the use of renewable energy sources. At the same time, the security of energy sources, whether via foreign import or development of nuclear power, is increasingly of public concern. Tidal barrages are a proven technology, which have been successfully developed in other countries while tidal stream and lagoon technologies are rapidly advancing. As a potential long-term (>100 years) source of reliable, renewable, low-carbon energy, the harnessing of tidal power from several estuaries in the UK offers an approach that could tackle key current issues of climate change and energy security. Environmental legislation and public perception of the value of natural habitats and conservation species, however, has also developed apace, which combined with the unique nature of many estuaries, produces a clear requirement for the balance between energy production and environmental protection to be rigorously maintained. There is an obvious need to determine whether the energy benefits outweigh any negative environmental impact aspects. The potential risks to migratory, estuarine and marine fish species from the development of tidal power is set to be a key determinant in the successful consenting of such schemes throughout UK waters. This presentation will discuss the potential impacts upon fish from tidal power, impact assessment techniques, possible optimization measures and the identification of "feasible" mitigation and compensation measures. Experience developed through assessments of the Severn and Mersey Tidal Power schemes will be used throughout as case studies.

Keywords: none

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## ICES CM 2012/O:18

### **Aerial survey techniques for assessing offshore windfarms – session "How does renewable energy production affect aquatic life?"**

Stuart C. Clough, David Campbell, and Mark M. Rehfisch

The offshore wind industry has grown rapidly, mirrored by an expansion and evolution of environmental survey techniques. Observer-based techniques have been supplemented, and sometimes superseded, by technology-based tools, each with strengths and weaknesses. It is imperative that developers choose the most appropriate survey tools, fully understanding the best methods for answering the relevant questions. Similarly, regulatory decisions must be informed by



full comprehension of surrounding issues. Differences in bias and precision between survey methods and platforms make calibrations complicated, and are best avoided if clear and far-sighted survey strategies are identified from the outset. Historically, bird and marine mammal surveys have relied upon observer-based visual transect methods. As technology has evolved, developers and regulators requiring new levels of scientific verification in their data have welcomed digital data acquisition. In this transition period, attempts have been made to splice data from different collection methods into an effective and usable form. This has led to desk-based and field-based comparisons between different methods, and an assessment of the ability of different methods to estimate populations with precision. Based on the experience gained over the last decade, we discuss the relative merits of the main survey techniques, and explore the challenges posed by inter-method calibration. We discuss recent developments in data collection and analysis methods, and present a vision of likely future developments. This will allow regulators and developers to make informed cost-benefit decisions based on specific requirements, and take advantage of current experience in this rapidly evolving field.

Keywords: aerial survey, bird population, monitoring, offshore, windfarm.

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**ICES CM 2012/O:19      Poster**

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**The impact of underwater noise on the early life stages of fish**

Elisabeth Debusschere, Alain Norro, Sofie Vandendriessche, Kris Hostens, Magda Vincx, Dick Botteldooren, and Steven Degraer

“Anthropogenic underwater noise is at levels that do not adversely affect the marine environment” is the 11th descriptor to maintain a Good Environmental Status (GES) as defined by the Marine Strategy Framework Directive. Both construction and exploitation of offshore windfarms generate underwater noise in the Belgian part of the North Sea. Sound measurements have been conducted to determine the reference noise level, and the pile-driving and operational noise in BELWIND at the Bligh Bank. Based on the sound pressure level (SPL) peaks, pile-driving caused a 16-fold amplification of the background acoustic pressure at 550 m, and a threefold amplification during the operational phase. SPL peaks are seen at frequencies ranging from 100 to 1000 Hz for both pile-driving and exploitation, covering the optimum hearing frequency range of fish. Fish eggs and larvae are dependent on currents for their transport and consequently cannot avoid underwater noise. Vulnerability to noise could influence their recruitment and have a substantial effect on population levels. Hence, a research project has been initiated to unravel the acute and chronic effects of the intense impulse piling sound and the long-term continuous operational sound on eggs, larvae, and juveniles of commercial fish such as European seabass (*Dicentrarchus labrax*), sole (*Solea solea*), and cod (*Gadus morhua*). Cage experiments at sea and playback experiments in the lab are planned. Effects on behaviour, physiology, morphology, and survival will be monitored and linked to sound parameters. The results of this research will assist in the process of establishing GES noise boundaries.

Keywords: Belgian Part of the North Sea, early life stages, fish, underwater noise.

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**ICES CM 2012/O:20                      Poster**

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**Case study on effect of construction of offshore windpark on benthic communities in the northeast Baltic Sea**

Liis Rostin and Georg Martin

Negative effects of offshore windpark construction are usually attributed to soft-bottom communities. There are very few studies covering sessile communities on hard substrates. In Estonia, wind energy is one of the most credible alternatives to solve the problems associated with

the depletion of fossil fuels and their negative impact on the environment, and thus pressure on suitable marine habitats is likely to increase in the near future. Our study was designed to evaluate the possible effect of construction of offshore windfarms on benthic communities and included a set of experiments on colonization experiments of artificial substrate and recolonization experiments of natural hard substrate after mechanical destruction of sessile communities. Material for the current study was collected during investigations carried out during an environmental impact assessment of Neugrund offshore windpark project in the Gulf of Finland, northeast Baltic Sea. During one field season (April–October 2008), benthic disturbance experiments were carried out at three different depth intervals in the area of planned construction. Benthic communities of limestone rock were disturbed in three treatments during the vegetation season and then recolonization of disturbed sites was followed monthly. The possible effect of construction activity was then estimated based on data from quantitative mapping of the benthic communities in the project area. Results show that at certain depth intervals, near the depth limit of the photic zone, construction activities could have significant long-term effects on the condition of the benthic community, which could be followed through several vegetation periods.

Keywords: artificial substrate, Baltic Sea, benthic communities, offshore wind park.

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#### ICES CM 2012/O:21 Poster

### Offshore intertidal hard substrata: a new habitat promoting non-indigenous species in the southern North Sea

Francis Kerckhof, Steven Degraer, Alain Norro, and Bob Rumes

Expansion of non-indigenous species alters local biodiversity and can cause competition with native species, some of which are of commercial interest. This is especially the case in shallow coastal waters, subject to a multitude of human activities, including the increasing construction of artificial hard substrata. We took the opportunity of the construction of two windfarms off the Belgian coast to study the colonization of non-indigenous species on these new artificial structures. We monitored the fouling communities of the windfarms on a regular basis from the beginning of their installation. We demonstrated that the new artificial hard substrata of the wind mills offer new opportunities for non-indigenous species (introduced and southern Northeast Atlantic range-expanding species) to enter the southern North Sea, or, if already present, to expand their population size and hence strengthen their strategic position in the southern North Sea. This is particularly important for the obligate intertidal hard substrata species, for which other offshore habitats are rare to non-existent.

Keywords: artificial substrata, non-indigenous species, offshore windfarm, southern North Sea.

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#### ICES CM 2012/O:22 Poster

### Target monitoring in offshore windfarms—the need to understand cause–effect relationships in the marine benthos

Steven Degraer, Jennifer Dannheim, Lars Gutow, Silvana Birchenough, Arjen Boon, Thomas Brey, Delphine Coates, Jean-Claude Dauvin, Gwenola de Roton, Jozefien Derweduwen, Andrew B. Gill, Urszula Janas, Francis Kerckhof, Roland Krone, Sophie Lozach, Georg Martin, Christian Mohn, Katharina Reichert, Jan Reubens, Mike Robertson, Liis Rostin, Henning Steen, and Dan Wilhelmsson

In many European countries offshore windfarm projects are accompanied by obligatory environmental impact assessments, including baseline monitoring of the marine benthos and demersal fish. The effects of offshore windfarm developments on the benthic system are complex.

However, legal baseline monitoring merely allows for net effect descriptions but not for identifying and understanding the underlying processes. Instead, key processes should be identified and become subject to hypotheses-based target monitoring and/or experimental studies in order to make environmental impact assessments more efficient and reduce duplication internationally. We compiled an overview over the anthropogenic activities associated with the construction and operation of offshore windfarms and identified cause–effect relationship to facilitate the development of specific hypotheses. We expect offshore windfarming activities to modify the geomorphological and hydrodynamic environment at different temporal and spatial scales. The environmental effects will have consequences for the behaviour and physiology of benthic organisms, including demersal fish, restructuring natural local populations and communities. Major effects on biological production, biogeochemical processes, as well as on structure and function related to biodiversity, are expected from the massive colonization of the artificial underwater constructions by a specific hard-bottom fauna which is naturally missing in soft sedimentary habitats. Understanding the mechanisms behind these changes is a priority for assessing and predicting the ecological implications for the benthic system. Such predictions may help to develop science-based mitigation actions.

Keywords: benthos, cause–effect relationships, demersal fish, offshore windfarm, target monitoring.

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**ICES CM 2012/O:23    Poster**

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**Environmental monitoring of offshore renewable energy installations: a plea for timely knowledge sharing**

Steven Degraer, Robin Brabant, and Bob Rumes

New offshore renewable energy installations are being constructed at high speed. At present, environmental monitoring is ongoing in various countries throughout the North Atlantic. A timely knowledge-sharing with regard to their environmental impacts is needed to ensure proper incorporation of new findings into the design of new installations. Unfortunately, the monitoring programmes are very much dealt with on a case-by-case basis, and scientific reports are produced only irregularly and most often in a non-integrated manner. In the worst case, scientific findings cannot be shared at all because of confidentiality. An integrated approach of reporting would not only lead to readily and widely available state-of-the-art knowledge, it would also ensure a continued audit of the ongoing monitoring (cf. adaptive monitoring programmes) and would further strengthen the communication and interaction with the offshore renewable energy sector at large. As an example, the Belgian offshore windfarm environmental monitoring has been summarized yearly in an integrated report since 2009. From a research point of view, these reports have facilitated a swift transition from observational, baseline monitoring to understanding-oriented process monitoring and research. Through their wide distribution, both as hard copies and via the web ([www.mumm.ac.be](http://www.mumm.ac.be)), we further promoted our monitoring programme, increasing the visibility of our research both to the scientific community and the offshore wind energy sector. The integrated reports further ensure a close interaction with the sector. This paper should be considered a plea for integrated reporting at the country level and for scoping for coordinated and integrated scientific reporting at the international level.

Keywords: knowledge sharing, North Atlantic, offshore windfarm.

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**ICES CM 2012/O:24     Poster**


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**Effects of Dutch offshore Windfarm OWEZ on birds**

Sietse Bouma, Wouter Lengkeek, Karen Krijgsveld, Ruben Fijn, and Martin Poot

We studied the flight patterns of birds in the Dutch Offshore Windfarm Egmond aan Zee and subsequently used the results to estimate cumulative effects of all windfarms planned in the Dutch North Sea on bird populations. We carried out visual and continuous radar observations between 2007 and 2010, to assess fluxes, flight altitudes, and deflection of flight paths around the wind turbines, and thus gain insight into barrier effects and collision risks. Pelagic seabirds (e.g. gannets) and migrating geese, in particular, avoided the windfarm, while gulls and cormorants did not. The majority of movements in the area were from gulls flying at turbine height during daytime. In the migratory seasons, nocturnal migratory birds (e.g. small passerines, thrushes, waders) passed through the area in high numbers but at altitudes mostly well above turbine height. To assess the potential impacts of further windfarms on bird populations, a two-step modelling approach was applied. Step one involved constructing matrix-based population models for bird species occurring within the Dutch North Sea (seabirds, coastal species, and key passage migrants). This was done for Dutch national populations as well as for international populations on a large regional scale. Step two involved assessing the ability of the populations to sustain changes in increased mortality. Various windfarm scenarios were modelled in order to provide a range of estimates of increased bird mortality due to collisions. This study was commissioned by NoordzeeWind (a joint venture of Nuon and Shell Wind Energy).

Keywords: barrier effects, bird collision victims, cumulative effects, offshore windfarms.

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**ICES CM 2012/O:25     Withdrawn**


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**ICES CM 2012/O:26     Poster**


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**Dams, fishways, and successful fish passage: win–win or death by half-way technologies?**

Jed Brown, Karin Limburg, John Waldman, Kurt Stephenson, Ed Glenn, Francis Juanez, and Adrian Jordaan

With more than 45 000 large dams (>15 m) worldwide and more on the way, solutions to allow the survival of migratory animals in rivers have focused on fish passage in many designs. We document here that fishways on the main stems of large rivers in the US East Coast area have largely failed in their intended tasks of moving diadromous fish past dams to their spawning grounds. Passage efficiencies for American shad to their spawning grounds from the sea are less than 5% and have been declining in recent years, falling well under targets. River herring (alewife and blueback herring) as well as American eel have all but collapsed in these systems. Rather than promoting healthy fish communities, these and other fishways represent “half-way technologies” that persist as socioeconomic conveniences.

Keywords: Eastern US, fish passage failure, main stem dams.

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## Theme Session P

### Genetic impact of aquaculture on wild populations

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#### ICES CM 2012/P:01

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##### Interbreeding between farmed escapees and wild cod

Jon Egil Skjæraasen, Justin J Meager, and Anders Fernö

Global declines of commercially exploited fish have resulted in new aquaculture targets. One such species is the Atlantic cod (*Gadus morhua*). As farming leads to genetic divergence from wild stocks, one potential adverse effect of fish farming is fitness depression in wild populations because of interbreeding between escaped farmed fish and wild fish. To assess this risk, we used a combined laboratory and field approach. We first examined morphological and physiological traits known to affect reproductive success in cod. We then examined the behaviour and reproductive success of farmed and wild cod breeding “naturally” in large mesocosm experiments. Finally, we used telemetry and mark–recapture to investigate spatial dynamics of wild and farmed cod on a natural spawning ground in the spawning period immediately following a simulated escape and for the next two years. Escaped farmed fish attempted to join spawning shoals post escape, but did not appear to develop the same long-term fidelity to spawning grounds as wild cod. We find that hybridization between farmed and wild cod is likely in the short term, and farmed females the most likely vector for genetic introgression.

Keywords: cod, farmed escapees, fitness, hybridization.

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#### ICES CM 2012/P:02

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##### Reproduction trials between wild and farmed salmon in Newfoundland (Canada)

D. Hamoutene, J. Perez-Casanova, L. Lynn, K. Burt, N. Camarillo-Sepulveda, S. Kenny, P. Goulet, R. Hinks, and C. Collier

A better understanding of the effect of river conditions (water pH, temperature, etc.) on farmed–wild salmon crosses is necessary to predict the potential reproductive impact of salmon escapees from local farms on wild spawners in their natural environment. Crosses between wild and farmed salmon were completed and held in a small hatchery in river water conditions. Fertilization rates, growth, and survival of larvae up to 45 days post hatch is being completed. Our results indicate that the fertilization success of crosses between farmed Atlantic salmon and their wild counterparts is not significantly different when compared to crosses of wild–wild or farmed–farmed salmon. A comparison of sperm and egg quality of wild and farmed Atlantic salmon is also being completed as part of this study. We measured cell counts, energy levels (ATP), as well as the activities of enzymes of the aerobic (citrate synthase, CS), glycolytic metabolism (lactate dehydrogenase, LDH), lipid catabolism (lipase, LIP) as well as oxidative phosphorylation (creatine kinase, CK) in sperm samples from farmed salmon and wild salmon (mature and precocious parr). Results indicate that despite higher cell counts in farmed salmon, sperm cells of wild males show statistically higher levels of energy and CK than farmed fish. Similarly, a trend (non-significant differences) can also be seen in CS, LIP, and LDH, with higher activities in wild salmon than in farmed salmon. Gamete quality, as well as survival of hybrid crosses and reproductive success of farmed and wild salmon, will be discussed after completion of all analyses.

Keywords: aquaculture, eastern Canada, escapees, reproduction, salmon.

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**ICES CM 2012/P:03**

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**Farmed escaped salmon and genetic interactions with wild conspecifics: What do we know, and just as important—what don't we know?**

Kevin A. Glover, Øystein Skaala, Vidar Wennevik, and Terje Svåsand

Each year, hundreds of thousands of farmed salmon escape into the wild. Although many escapees simply “disappear” once they have escaped, some enter fresh water and attempt to spawn with wild conspecifics. In some Norwegian rivers, over half of the spawning population has consisted of farmed escapees for many years. It has been documented experimentally that farmed escaped salmon display reducing spawning success in comparison with wild fish. Nevertheless, with such consistently high numbers of escapees being observed on the spawning grounds, the potential for widespread and extensive genetic introgression in wild populations exists. A range of studies have investigated the fitness of farmed salmon in the wild and investigated the genetic basis of differences between wild and farmed salmon. They report findings such as strongly increased growth rates in farmed fish, reduced antipredation responses in farmed fish, and reduced survival of farmed fish in the wild. Furthermore, studies have also reported changes in allele frequencies in wild populations as a result of introgression from escapees. Nevertheless, there are still large and significant gaps in current knowledge. For example, how much introgression has occurred in general, and how much introgression can a native population “tolerate” before genetic changes in fitness-related traits are evident in the recipient population. In addition, to our knowledge, no study has unequivocally documented quantitative genetic changes in a native population as a result of introgression with farmed fish—thus far. This talk summarizes “what we know” and, not least, “what we don't know”.

Keywords: current knowledge, farmed escapee, genetic interactions, Norway, sustainability.

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**ICES CM 2012/P:04      Withdrawn**

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**ICES CM 2012/P:05**

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**Genetic tagging of farmed Atlantic Cod (*Gadus morhua*) and detection of escapement from a commercial cod farm**

K. E. Jørstad, O. I. van der Meeren, Paulsen, G. T. Bakke, H. Otterå, G. Dahle, and T. Svåsand

Farmed fish are escaping from the aquaculture industry and this is considered a risk for negative genetic impacts on native gene pools. A genetic tagged Atlantic cod (*Gadus morhua*) strain, homozygote for a rare allele in the GPI-1 locus, was developed to identify escapees from commercial cod farms. Two year classes (2007; 2008) of this strain, each consisting of 500 000 juveniles, were raised in a commercial cod farm and a monitoring programme was established. The first farmed cod escapees, identified to the 2007 year class through the genetic tag, were found in the wild near the farming site in November 2008. The second escapement of the same year class was detected during the natural spawning season in early April 2009. The escapees were spreading in the whole fjord system, including local spawning sites for wild cod, and screening of larvae during late spring 2009 detected offspring possessing the genetic tag, thus documenting successful reproduction in the wild. A third escapement, identified to the 2008 year class, was detected in November 2009. The farmed closed down in autumn 2009, but escapees were identified in the area the years after, thus demonstrating survival, growth, and spreading in the wild environment.

Keywords: escapees identification, escapement farmed cod, genetic tagging.

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**ICES CM 2012/P:06**

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**A study of growth reaction norms of farmed, wild, and hybrid Atlantic salmon (*Salmo salar*) families exposed to different levels of stress**

Monica Favnebøe Solberg, Øystein Skaala, Frank Nilsen, and Kevin Alan Glover

In Norway, the domestication of Atlantic salmon has been ongoing for 40 years, and has resulted in farmed salmon deviating from wild salmon in multiple traits. One of the most important traits linked with the successful domestication of animals is reducing their sensitivity to environmental stressors in the human-controlled environment. While farmed salmon have not been directly selected for reduced stress responsiveness, we investigated whether genetic changes in this trait have occurred, potentially as an indirect consequence of selection for growth. Mixing 29 families together, we studied growth reaction norms of juvenile wild, hybrid, and farmed Atlantic salmon under hatchery conditions (control) and in the presence of a chronic stressor, for a 14-week period. Here we report the results of this study, containing more than 2000 juvenile individuals.

Keywords: farmed escapees, genetic interaction, Norway, reaction norms.

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**ICES CM 2012/P:07**

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**Global genetic divergence among worldwide distributed stocks of *M. galloprovincialis***

Yassine Ouagajjou and Pablo Presa

Blue mussels of genus *Mytilus* distributed in the northern hemisphere are historically differentiated, though they appear to have a recent history of interspecific gene flow. This introgressive scenario is facilitated by long-distance larval dispersion and weak reproductive barriers between these species. Their proper aquaculture management requires the development of molecular tools aimed at uncovering the genetic constitution of each gene pool. Three main *Mytilus* species have been studied with microsatellite markers aiming at depicting how divergent the genomes of the main cultured species are from each other and how much the genome of *Mytilus galloprovincialis* has diverged from its original source in remote areas. Genetic differentiation was large between the four species considered (*M. galloprovincialis* vs. various, *M. trossulus*, *M. chilensis*, and *M. edulis*;  $Dest \pm SD = 0.635 \pm 0.047$ ,  $0.495 \pm 0.073$ , and  $0.436 \pm 0.098$ , respectively) while differentiation within *M. galloprovincialis* was much less ( $Dest \pm SD = 0.284 \pm 0.092$ ). Individuals' membership showed that *M. galloprovincialis* samples were highly genetically pure, except the Australian population (MgCk). Although *M. galloprovincialis* formed a highly compact group with low intraspecific differentiation, its regional populations were clearly separated into five well-supported gene pools. The present genetic data may be useful for the genetic management of wild populations and cultured stocks as well as for the conservation and molecular traceability of commercial stocks.

Keywords: gene pools, microsatellites, mussel aquaculture, *Mytilus* stocks.

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**ICES CM 2012/P:08**

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**“AquaTrace” The development of tools for tracing and evaluating the genetic impact of fish from aquaculture**

Einar Eg Nielsen, Dorte Bekkevold, Terje Svåsand, Luca Bargelloni, Paulino Martinez, Filip Volckaert, Rob Ogden, Jann Martinsohn, Gary Carvalho, Louis Bernatchez, Hervé Chavanne, Kevin Glover, Gregory Maes, Martin Taylor, Lucy Webster, and the AquaTrace consortium

Aquaculture represents a key solution to meet the escalating demand for fish. Accordingly, development of appropriate legislation within the European Union aquaculture sector

underpinned by cutting-edge research and technology is required. This necessitates implementation of breeding programmes and farming technologies which are economically viable, environmentally friendly, and perceived as socially acceptable. Here we present the objectives, implementation, and potential impact of a new EU FP7 project. The rationale behind AquaTrace is development of reliable and cost-effective molecular tools to identify of the genetic origin of both wild and farmed fish (assignment and genetic traceability), as well as for the detection of interbreeding genetic introgression between farmed and wild stocks. This work will be carried out on three marine fish of economic significance: the European sea bass (*Dicentrarchus labrax*), gilthead sea bream (*Sparus aurata*), and turbot (*Scophthalmus maximus*). To address quantitative effects of farm introgression, the rationale is to examine links between key fitness and life-history traits and specific functional genetic variation between wild and farmed fish, using Atlantic salmon and brown trout as model species. Thus, the scientific objectives of AquaTrace are to address and assess the genetic impact of aquaculture escapees introducing genes to wild populations that have been undergoing adaptation to farmed conditions through breeding and domestication selection. Nonetheless, the methods and aims also have implications for our general knowledge of local adaptation in wild populations, and thus also apply in a restocking context (e.g. when locally depleted wild populations are stocked with non-native strains that are potentially maladapted to local conditions).

Keywords: adaptation, aquaculture, introgression, population assignment, population genetics/genomics.

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## ICES CM 2012/P:09

### Assessing and mitigating risk from a diversifying aquaculture industry: the potential for interaction between escapee and wild Atlantic cod

Edward A. Trippel, Craig F. Purchase, Olivia A. Puckrin, Emily Zimmermann, Brendan F. Wringe, John Bratney, and Ian A. Fleming

Aquaculture is growing rapidly and outpaces all other animal food-producing sectors. This has led to concerns about its economic and environmental sustainability, including issues surrounding escapes. This presentation summarizes research findings of a Canadian federally funded project to evaluate the risk and mitigation of cod escapes. The project has five key elements: (i) determination of the likelihood of inbreeding of cod within cages, and the subsequent quality of embryos released into the environment; (ii) examination of factors which may reduce the motivation of cod to escape from cages; (iii) acoustic telemetry and tagging studies to determine the fate of escaped fish and whether they can be easily recaptured; (iv) mating experiments to determine the potential for interbreeding between farmed and native wild cod; and (v) laboratory experiments to determine if hybrids potentially produced from native cod and escaped fish from a different population will have lower growth and survival than native fish. Results to date showed no difference in the incidence of deformities between inbred and non-inbred F1 progeny. Hungry cod in unenriched cages (i.e. no behavioural distractive devices) were more motivated to bite at netting, suggesting that nutrition and cage enrichment could be used to reduce cod escapes. Following an experimental release of cod at a cage site, farmed cod showed a similar and rapid dispersal pattern to locally caught wild cod. Differences in fitness between hybrid and non-hybrid eggs and larvae will be discussed as it relates to competition between escape/native hybrid and native larvae.

Keywords: cod, distractive behaviour, escape, inbreeding, interstock hybrid, mating, telemetry.

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**ICES CM 2012/P:10**

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**Can the frequency of escaped salmon in the spawning stocks of Atlantic salmon the previous 20 years explain the reduction in catch?**

Mikko Heino, Terje Svåsand, Ole T. Skilbrei, and Vidar Wennevik

Atlantic salmon stocks are in decline throughout their range. This decline has a complex background comprising both biotic and abiotic factors. In Norway, sea lice and interaction with escaped farmed fish are regarded as key threats to wild salmon. In this work we have used the available data on escapees in the period 1989–2009 and related this to the development of the annual catches in the same rivers (“Salmon register” at the Norwegian Directorate for Nature Management). A 20-year mean frequency of Atlantic salmon escapees among returning salmon (summer and autumn data) was available for 99 rivers. For most of these rivers also annual catch data were available. We hypothesized that high frequencies of escapees would negatively affect catch trends. Thus, we estimated the logarithmic catch trend in 1989–2005 (a period without major changes in catch regulations), and regressed this against the frequency of escapees, estimated size of the stock, and geographic area. The analysis showed high variability in catch trends between the rivers, but none of the explanatory variables could consistently explain the variability. However, in the rivers with very high frequencies of escapees (>50%), catch trends tended to be negative. The analysis suggests that the frequency of escapees has no major impact on catch trends, but that possibility of a negative impact at very high frequencies of escapees cannot be dismissed.

Keywords: Atlantic salmon, aquaculture–wild fish interactions, catch trend, escapees, introgression.

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**ICES CM 2012/P:11**

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**Offspring from farmed cod (*Gadus morhua*) spawning in net pens: documentation of larval survival, recruitment to spawning stock, and successful reproduction**

T. van der Meeren, K. E. Jørstad, O. I. Paulsen, and G. Dahle

Marine fish in culture, such as Atlantic cod, mature in seawater cage farms and thereby spawn and spread fertilized eggs into the surrounding water. The present study investigates the fate of such eggs originating from coastal Atlantic cod kept in net pens during the spawning season in the small fjord system, Heimarkspollen in Austevoll on the west coast of Norway. The fjord is known to be a spawning ground for wild cod. Use of a genetically marked cod strain made it possible to identify the origin of collected cod larvae, juveniles, and adults in the wild environment. Eggs were released from 2006 to 2008 in Heimarkspollen, and a sampling programme was initiated to monitor the occurrence of genetic marked cod at various life stages. Cod larger than 30 cm were tagged by T-Floy after sampling and released back to the fjord. Substantial fractions of genetically marked cod larvae (6–36%) were collected in Heimarkspollen during the three spawning seasons. However, recovery of genetically marked juvenile cod within the expected size ranges was low (0.4–5.8% of catches). The largest genetically marked cod caught from Heimarkspollen in 2011 was 62 cm, which is well into the size of mature coastal cod. In 2011, genetically marked cod larvae (2.4%) were again found, documenting recruitment to the spawning population in the area and successful reproduction. Interbreeding between cod of farmed origin and wild cod has so far not been indicated.

Keywords: Atlantic cod, genetic interactions, spawning stock recruitment, successful reproduction.

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**ICES CM 2012/P:12****Poster**

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**Not to be cited**

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**Recapture and spread of escaped farmed Atlantic salmon depends on the life stage at escape and farm location**

Ove T. Skilbrei and Terje Svåsand

To improve assessments of the environmental risks of aquaculture, we performed a series of simulated escapes of farmed Atlantic salmon from cages in seawater. From 2005 to 2010 individually tagged smolts, post smolts, and adult salmon have been released from different locations at different times of the year. Smolts and post smolts that escaped during their first summer were capable of rapid migration towards open sea. Some (0.4%) returned to spawn and were recaptured after 1–3 years at sea in nearby, but also in remote rivers hundred of kilometres from the release site. Thirteen per cent of the post smolts that escaped during autumn were targeted in nearby fisheries the following months, partly because they had grown large enough to be caught in the gillnets used, but more importantly because the migratory behaviour declined with time. The mean recapture rates of adult salmon were high after releases in fjords (32%), lower after coastal releases (4–7%), and zero at the outer coast. However, the majority of these recaptures were immature fish that were recaptured in sea relatively close to the release site during the first months post release (0.2% in rivers), and adult escapees very rarely survived one year in the wild. The risk that an escaped salmon reaches maturity and enters a river to spawn appears to be highest if it escapes as a smolt or post smolt during the first summer in sea, or if it has already started maturation at the time it escapes as an adult.

Keywords: environmental risks, escapes, farmed Atlantic salmon, fish farms.

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**ICES CM 2012/P:13****No genetic changes detected in the wild population in a long-term (20-year) study of lobster (*Homarus gammarus*) enhancement in Norway**

K. E. Jørstad, E. Farestveit, and A.-L. Agnalt

The lobster fishery in Norway dates back to the sixteenth century and has been an important resource in many coastal areas. A decrease in catches has led to the development of extensive lobster investigations and large-scale hatchery operations were established in the mid-1980s to produce juveniles for release into the wild. From 1990 to 1994 about 130 000 hatchery-produced juveniles were mechanically tagged and released at the Kvitsøy Island in western Norway. Genetic aspects were incorporated into the overall research programme, and samples for genetic analyses were collected during the hatchery production as well as during the extensive fishing monitoring period after the releases. The samples from the local fishery have been collected in cooperation with local fishers from 1990 to 2010. Initially, the genetic analyses were based on protein variation (allozymes), and no genetic changes were detected during the hatchery operations. The development of microsatellite DNA methods, however, have opened the way for more detailed analyses over time, focusing on potential genetic changes in the wild population in the area. In this case we compared allele frequencies for eight microsatellite loci in wild lobster samples collected in the period from 1991 to 2010. No significant genetic variation or genetic changes were detected during the investigation period.

Keywords: allozymes, genetic changes, lobster enhancement, long-term study, microsatellites.

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**ICES CM 2012/P:14**

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**Factors affecting farmed to wild gene flow in Atlantic salmon populations**

Ola H. Diserud, Peder Fiske, Kjetil Hindar, and Sten Karlsson

Throughout their range, wild salmon populations represent a genetic and ecological diversity reflecting adaptations to different rivers. We have previously developed a model for how escaped farmed salmon may affect a wild population, based on estimated proportions of escaped farm salmon in the spawning population, the reproductive success of escaped farm salmon, and estimated survival rates for wild salmon juveniles, farmed offspring, and hybrids in controlled natural and semi-natural settings. As a result of the biggest monitoring programme for escaped farm salmon worldwide, estimates of proportions of escaped farmed salmon in wild populations exist for around 100 Norwegian salmon rivers from 1989 to the present. There are large differences between rivers with respect to magnitude and trend in proportion of escapees, and the effect the escaped farm salmon may have had on the wild populations. Besides the escapee proportions, we want to evaluate river-specific environmental and population characteristics that may influence to what extent escaped farmed salmon, and their offspring, pass on their genes to wild Atlantic salmon populations. Environmental and population factors controlling the gene flow could include water flow regime, migratory complexity and obstacles, spawning population density, phylogeographic history, and possible differences in spawning time and body size between farmed and wild salmon.

Keywords: genetic introgression, life cycle model, Norwegian salmon rivers.

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**ICES CM 2012/P:15**

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**Risk assessment of escaped Atlantic salmon – assessing the impact of escaped farmed salmon on the genetic integrity of wild salmon populations**

Geir Lasse Taranger, Kevin A. Glover, Ove T. Skilbrei, Øystein Skaala, Vidar Wennevik, and Terje Svåsand

The proportion of escaped salmon is currently being monitored in around 40 Norwegian salmon rivers through analysis of growth pattern in scales, revealing around 13% escaped farmed salmon at the spawning sites on average. The Institute of Marine Research conducted an initial risk analysis in 2011 based on these data, and suggested that the likelihood of permanent genetic changes would be low if the proportion of escaped salmon on the spawning grounds was < 5%, moderate in the range 5–20%, and high if the proportion was >20%. However, more precise methods to assess genetic introgression of escaped farmed salmon are needed. To this end, the temporal stability in genetic profiles was assessed in 21 Norwegian salmon rivers, by comparing historical and current samples using selected microsatellite and SNP markers. The microsatellites reveal significant genetic temporal changes in a minimum of six rivers, and that these changes are to a large extent due to introgression of farmed escaped salmon. On the other hand, some resilience in the genetic structure was noted in some rivers despite high proportions of escaped salmon during the last 20 years. When comparing several indices of genetic stability from the microsatellite markers and the proportion of escaped salmon over the last 20 years in these rivers, no strong correlation was observed. This suggests that genetic markers should be used to monitor the genetic integrity of the native populations. Analysis of the SNP markers is still ongoing, and will be incorporated in the analysis.

Keywords: escaped salmon, genetic impact, genetic markers, risk assessment.

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**ICES CM 2012/P:16**

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**Consequences of interbreeding with farmed escapees on adaptive phenotypic plasticity in Atlantic salmon**

Jeffrey A. Hutchings

The conservation consequences to wild populations resulting from interbreeding with farmed escapees depend primarily on the probability of spawning between groups, the level of genetic differentiation between farmed and wild individuals, and the abundance of wild populations relative to conservation targets. The present work pertains to the second of these factors. In addition to the divergence that breeding designs and domestication selection can generate, genetic dissimilarities will also depend on the magnitude and type of genetic differentiation that exists among populations in the wild. Here, I describe the results of several common-garden experiments that examined the consequences of farmed:wild interbreeding for reaction norms and adaptive phenotypic plasticity in Atlantic salmon. The reaction norms studied include those pertaining to gene transcription, growth, survival, and development time. I find that interbreeding significantly alters the elevation and slope of reaction norms likely to be associated with fitness. Although the conservation consequences to wild populations associated with disruptions to reaction norms cannot always be readily quantified, the most credible scientific conclusion is that interbreeding with farmed escapees negatively affects individual fitness and population persistence in wild Atlantic salmon.

Keywords: common-garden experiment, farmed–wild interbreeding, phenotypic plasticity, reaction norms.

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**ICES CM 2012/P:17**

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**Effects of wild salmon origin and environment on the outcome of competition with farmed salmon**

L. Sundt-Hansen, G. Robertsen, and K. Hindar

Escaped farmed salmon may pose a threat to wild Atlantic salmon populations through interbreeding, competition, and transmission of disease agents. Even though lifetime success has been shown to be higher for wild than farmed offspring, wild juveniles may be competitively inferior to the faster growing and more aggressive farmed juveniles at certain life stages. Since density-dependent mortality is high during the period immediately after juvenile emergence from the gravel, wild offspring may be particularly sensitive to competition with farmed offspring at this life stage. The competitive interactions between wild and farmed juveniles are likely to depend on environmental conditions that vary among streams, such as local levels of juvenile density. Furthermore, the outcome of competitive interactions between wild and farmed offspring may depend on traits that may vary among local populations of wild Atlantic salmon (e.g. growth rate and maturation rate). To assess the effect of both environmental conditions and population origin on the outcome of competition between offspring of farmed and wild salmon juveniles, we performed a set of experiments under semi-natural and/or hatchery conditions. We used a substitutive design, where yolk sac fry were planted out a week prior to emergence and wild fry were either in allopatry or sympatry with the farmed strain. We tested for the effect of high- and low-population densities on the relative competitive ability of wild (River Imsa population) and farmed fry (Aqua Gen breeding strain) by measuring survival and growth. Then, the effect of wild population origin was tested using two wild populations (River Imsa and River Namsen) and one farmed strain (Aqua Gen). In the latter study, the growth potential of the different strains was tested in hatchery tanks where the juveniles were fed *ad libitum*. Mechanisms that influence the competitive ability of farmed offspring on wild offspring are still poorly known. Our results indicate that at the earliest life stages, farmed offspring may have a competitive advantage over wild fry, which results in a reduced survival of wild fry. At the present stage, we cannot exclude

the possibility that offspring of escaped farmed salmon may have a profound negative influence on natural populations of wild salmon.

Keywords: Atlantic salmon, competition, escaped farmed salmon, interference, juvenile.

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**ICES CM 2012/P:18      Poster**

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**Evaluating genetic interactions between domesticated and wild fish**

Gloria Blanco and José Antonio Sánchez

The hybridization between domesticated and wild populations constitutes a potential threat to the integrity of the genetic pool of the natural populations. In this study, genetic interactions among cultivated and wild populations have been evaluated using brown trout (*Salmo trutta*) as model. Brown trout populations of Duero Basin (Spain) present a unique gene pool, but this basin has been restocked using different hatchery stocks. In this study eight wild samples (four unstocked and four stocked areas) and two hatchery stocks were analysed using 25 allozyme, 6 microsatellite loci and the sequence of a 707-bp fragment of the mtDNA D-loop region. Stocked samples showed high levels of genetic variability and lower levels of genetic differentiation than unstocked. The percentages of genetic introgression in the stocked samples showed differences between samples (5–90%) and between markers, showing higher nuclear loci values (38–48%) than those obtained with mitochondrial DNA (34%). The success of hatchery specimens not only to survive but also to mate with natural ones implies that the replacement of indigenous gene pools is a real factor that should be avoided, suggesting the necessity of changing the stocking activities in order to protect the unique and valuable resource that Duero River populations represent.

Keywords: brown trout, introgression, genetic impacts, genetic markers.

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**ICES CM 2012/P:19      Poster**

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**Incidence of farmed Atlantic salmon in the sea fishery along the northern Norwegian coast line**

M.-A. Svenning, M. Falkegård, V. Wennevik, J.-P. Vähä, R. D. Fernandez, M. Ozerov, S. Prusov, E. Samoylova, T. Kalske, B. Christiansen, and E. Niemelä

A multistock Atlantic salmon (*Salmo salar*) sea fishery operates off the northern Norwegian coast, with average annual landings around 250–300 tonnes in the last two decades, constituting close to 50% of the total catch of Atlantic salmon in Norway. This fishery has been under intense debate, because of the complexities involved in the potential mixed stocks harvesting, especially since Russian salmon may also be harvested during their homeward spawning migration. Between early May and late August (2008–2011), more than 15 000 salmon caught (hook net and bag net) by local northern Norwegian sea fishers were sampled. All fish were recorded for their date of capture, size, sex, maturity, and supposed wild/farm origin. River and sea ages were determined for each fish from scale samples, as well as verified for its wild or farm origin. From 2008 to 2011, the average proportion of escaped farmed salmon in the catches increased by threefold, constituting 27, 15, and 10% in Nordland, Troms, and Finnmark, respectively, in 2011. The proportion of farmed salmon increased from early spring to late autumn, amounting to 60% of the catches in Nordland in August. The proportion was higher in outer coastal areas than within fjords. The fishers, although very well experienced, detected less than 40% of the farmed fish. The results are discussed in relation to geographical distribution of catch sites, distances to salmon farming sites, seasonality in salmon migration patterns, sea temperatures, and the potential effects on the northernmost wild salmon populations from aquaculture activities.

**Keywords:** incidence of farmed salmon, northern Norway, salmon sea fishery.

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## Theme Session Q

### Joint ICES/PICES Session—Sustainability of aquaculture

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#### ICES CM 2012/Q:01

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##### **Assessing control options for the invasive tunicate *Didemnum vexillum* in shellfish aquaculture: towards sustainability**

Thomas W. Therriault, Soleil E. Switzer, Anya Dunham, Katherine Rolheiser, and Christopher M. Pearce

Globally, invasive tunicates continue to plague shellfish aquaculture operations by fouling both cultured bivalves and cultivation gear and in some areas have threatened industry sustainability. Recently, in British Columbia, Canada, the colonial tunicate *Didemnum vexillum* has become established at various Pacific oyster (*Crassostrea gigas*) aquaculture sites and at some locations it is the dominant fouling species. In the present study we examined potential chemical (4% hydrated lime), mechanical (removal via scrubbing), and biological (green sea urchins, *Strongylocentrotus droebachiensis*) treatments to control *D. vexillum* fouling oysters. Both chemical and mechanical treatments reduced *D. vexillum* fouling on oysters by 85–96%, while urchins did not reduce fouling substantially. Our results suggest that both lime and mechanical treatments may be viable options for controlling *D. vexillum* fouling Pacific oysters, although a decrease in per cent survival was observed for lime-treated oysters, suggesting that the concentration and duration of exposure should be investigated further. In a subsequent experiment we explored the efficacy of lime treatments relative to freshwater, brine, and acetic acid (vinegar) treatments by manipulating chemical concentrations and dip durations in an effort to identify the most appropriate combination to utilize on fouled oysters. We found that lime (3–4% for 5 min) was the most effective treatment at reducing *D. vexillum* fouling while minimizing oyster mortality. Interestingly, the reduction in *D. vexillum* fouling created free space that allowed invasive botryllid tunicates to increase, suggesting a holistic management plan will be required to mitigate invasive tunicate impacts on shellfish aquaculture operations to ensure sustainability.

Keywords: Canada, control options, *Didemnum vexillum*, invasive tunicates, mitigation, shellfish aquaculture.

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#### ICES CM 2012/Q:02

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##### **Spatial planning of aquaculture, Finnish Archipelago Sea as a case**

Timo Mäkinen, Jari Setälä, Markus Kankainen, Pekka Salmi, Ville Tarkki, and Timo Halonen

The consumption of fresh salmon fish has been steadily growing in Finland in recent decades. Since the 1980s, the supply of farmed rainbow trout has complemented the declining fish supply from the capture fisheries. However, the rigid environmental permit system and increased summer dwelling in the Archipelago Sea have contributed to a decline of Finnish aquaculture production. At the same time import of Norwegian salmon has grown, substituting the domestic fish products on the market, and the self-sufficiency of fish has collapsed in Finland. In this situation the fishery authorities, backed by the EU's Common Fisheries Policy (CFP) have tried to find new ways to stimulate new growth in the livelihood. Spatial planning has been launched as a tool to find a way round the practical moratorium on developing new fishfarms and to find new areas for the production in the Finnish coastal area of the Baltic Sea. The process of balancing the environmental target with economic and cultural dimensions of sustainability is described and the outlook for success is discussed. The vested interests of stakeholders manifested in the permission procedures,

in the practices of planning groups, and in selections made during the organization and realizing of their tasks, are discussed. Recent developments in other Baltic countries is mentioned to discuss the differences in weightings of the goals in similar regions in neighbouring countries.

Keywords: Baltic Sea, rainbow trout farming, spatial planning, sustainability.

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### ICES CM 2012/Q:03

#### Life cycle environmental impacts of different fish farming alternatives in the Baltic Sea

Juha Grönroos, Frans Silvenius, Markus Kankainen, Kimmo Silvo, and Timo Mäkinen

Life cycle assessment method (LCA) was used to evaluate climate and eutrophication impacts as well as primary energy consumption of the total product system of rainbow trout farmed in the Baltic Sea Archipelago Sea area. The results are expressed as per 1000 kg of ungutted rainbow trout at the landing site. The product system studied included all relevant life cycle phases which are needed in farmed fish production. Besides the farming activity itself, the fish feed manufacturing, fish feed raw materials production and production of inputs needed, electricity generation as well as all transportations related to fish, fish feed, and feed raw materials were included. The emissions and energy consumption data in each phase were collected. Based on the inventory data, impacts on climate change and eutrophication were assessed, and total primary energy consumption was estimated. First we assessed the environmental consequences of the current production model (i.e. the present average net cage fish farming of rainbow trout). After that, the same was performed for the following three alternative options: (i) net loading option, where low-valued fish are caught from the Baltic Sea for nutrient removal to compensate nutrient emissions from fish farming; (ii) nutrient recirculation, where fish meal and oil used as fish feed raw materials are produced from fish originating from the Baltic Sea instead of fish caught from oceans; and (iii) a rationalized fish farm location plan (spatial planning) option, where fish farming is based on fewer and bigger farms, located in more offshore areas.

Keywords: Baltic Sea, fish farming, life cycle assessment, rainbow trout, spatial planning.

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### ICES CM 2012/Q:04

#### The effects of fallow zones on the distribution and risks of salmon lice infection in wild salmonids in an intensively farmed Norwegian fjord system

Pål Arne Bjørn, Ingrid Askeland Johnsen, Rune Nilsen, Rosa Maria Serra Llinnares, Peter Andreas Heuch, Bengt Finstad, Karin Boxaspen, Lars Asplin, Alf Harbitz, and Ulf Lindstrøm

A critical factor determining the risk of salmon lice infection in an area is the density of farmed salmon. The Hardangerfjord system on the western coast of Norway is intensively farmed, and has experienced severely increased salmon lice infection pressure on wild salmonids for almost two decades. The Norwegian Food Safety Authority has therefore implemented a special Hardangerfjord regulation. This regulation instructs fish farmers to perform synchronized fallowing of geographically restricted production zones after a previously decided plan. They have also commissioned an evaluation of this regulation, especially with regard to the distribution and risks of salmon lice infection in wild salmonids. The regulations have been preliminarily evaluated by a before–after control impact approach combining infection levels in wild sea trout and sentinel caged salmon smolts with a farmed salmon–salmon lice database and a three-dimensional salmon lice growth and advection model. Preliminary results show that the spatiotemporal infection risk on wild sea trout and in sentinel cages clearly has shifted from high risk in outer fjord areas before fallowing (2010) to low risk after fallowing (2011). Concurrently, local biomass densities of farmed



salmonids, as well as farm levels of salmon lice, have increased drastically in middle fjord areas from 2010 to 2011; and so has the salmon lice infection level in wild sea trout and in sentinel cages.

Keywords: fallowing, salmon farming, salmon lice.

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## ICES CM 2012/Q:05

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### Suitability mapping for European aquaculture

Narangerel Davaasuren, Bas Bolman, Robbert Jak, and Sonia Corso

The European aquaculture sector needs to be sustainably developed using the concept of ecosystem-based management. The challenge is to find an optimal balance between investments in European aquaculture and marine resource management. Therefore, it is necessary to create a tool for identifying and mapping suitable locations for European aquaculture. The suitability maps integrate physical characteristics of marine ecosystems with suitable thresholds of aquaculture species. Examples of physical characteristics are temperature, salinity, and chlorophyll *a*. Included aquaculture species are, among others, salmon (*Salmo salar*), blue mussel (*Mytilus edulis*), and European flat oyster (*Ostrea edulis*). For each aquaculture species a map will be produced identifying suitable and not suitable locations in Europe. Because of the complexity of data analysis GIS techniques are used. The GIS analysis is based on logical aggregation of data on physical characteristics of the ecosystem and species.

Keywords: aquaculture, GIS, suitability mapping.

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## ICES CM 2012/Q:06

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### Indicators of production capacity for bivalve shellfish in Dutch coastal waters

Pauline Kamermans, Sven Inken, Jacco Kromkamp, Sairah Malkin, Roel Riegman, Tim Schellekens, Marnix van Stralen, and Aad Smaal

In the Netherlands, mussels (*Mytilus edulis*) are farmed on bottom plots in two coastal areas: the Wadden Sea and the Oosterschelde. For this, small mussels (seed) are fished from natural beds. The farmers are in a transition process from fishing seed to harvesting seed with pelagic collectors. This is a response to pressure from society to reduce bottom dredging and the desire to safeguard a steady supply of seed mussels. A seed collector consists of nets or ropes that are placed in the water column when larvae are present. The shift from fishing to using collectors results in a higher mussel biomass, because natural beds are no longer fished and spat survival is enhanced on the collectors. Competition for food (phytoplankton) between the extra mussel biomass and natural shellfish populations may result in overgrazing and possibly affect the production capacity. This can have consequences for the yields of cultured shellfish and for organisms that depend on shellfish stocks for their food such as birds. Different indicators for assessment of changes in production capacity for bivalve shellfish were investigated for the Wadden Sea and the Oosterschelde. Meat content and growth rates of shellfish can show if the shellfish are food limited. In addition, studies have shown that the percentage of picoplankton (that cannot be filtered by bivalves) increases as grazing pressure increases. Relationships between meat content or growth of shellfish and total bivalve stock will be presented. Furthermore, the use of the percentage of picoplankton will be discussed.

Keywords: bivalve shellfish, indicators, mussel culture, production capacity.

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**ICES CM 2012/Q:07**


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**Modelling the seasonal production and bioremediation potential of the kelp *Saccharina latissima* in integrated multitrophic aquaculture (IMTA)**

Ole Jacob Broch, Ingrid H. Ellingsen, Silje Forbord, Aleksander Handå, Xinxin Wang, Morten O. Alver, Zsolt Volent, Yngvar Olsen, Dag Slagstad, Kjell Inge Reitan, and Jorunn Skjeremo

Norway is the main aquaculture producer of salmonic species worldwide (mainly Atlantic salmon, *Salmo salar*). Mass balance models indicate that about 40% of the considerable nitrogen effluent from this industry to the Norwegian coastal waters is in the form of  $\text{NH}_4$ . There are concerns that these effluents may impact negatively on the marine ecosystem. One may try to abate the potentially negative effects of salmon farming by cultivating, for example, kelp alongside the salmon, so-called integrated multitrophic aquaculture (IMTA). The actual efficiency of IMTA systems in Norway is still unknown, however, and only a few successful small-scale trials have been carried out. In this talk we will describe a dynamic model system being used to study the bioremediation potential of kelp (*Saccharina latissima*) in an IMTA setting. A previously published model for growth and composition (carbon and nitrogen content) of *S. latissima* has been coupled with the 3D hydrodynamic–ecological model system SINMOD, which includes states for phytoplankton concentration,  $\text{NH}_4$  and  $\text{NO}_3$ . Effluents of  $\text{NH}_4$  from fish cages may be realistically simulated in the model, as well as the N uptake by *S. latissima*. In the first part of the talk we describe the model system and show how it describes the growth of kelp in an actual field experiment, thus validating the model in this setting. In the second part we use the model to study the full-scale production and bioremediation potential of *S. latissima* in IMTA.

Keywords: bioenergy, bioremediation, environmental interactions, high-resolution ecological model, integrated multitrophic aquaculture, marine biomass, mathematical model, *Saccharina latissima*, salmon farming.

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**ICES CM 2012/Q:08**


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***Mytilus trossulus*: managing impact on sustainable mussel production in Scotland**

M. J. Gubbins, D. McLennan, D. Pendrey, M. Snow, I. M. Davies, J. Dias, D. Fraser, and G. Hermann

Loch Etive is a large, fjordic, low-salinity sea loch on the west coast of Scotland that has historically supported a large production tonnage of mussels from suspended aquaculture using rafts and longlines over approximately ten farming sites. The presence of thin-shelled, poor-meat-yield *Mytilus trossulus* was first recorded in 2005 and has since dominated the mussel communities on aquaculture facilities in surface waters of the loch to such an extent that mussel farming is currently unviable in the area. Diving surveys of the area have shown that *M. trossulus* (identified by species-specific real-time PCR) is predominantly present on artificial structures in low-salinity surface waters of the loch and that on deeper natural substrates it is either absent or a very small proportion of the mussel community. Consequently, removal of adult spawning stock from aquaculture facilities and artificial structures is likely to remove the majority of *M. trossulus* from the loch. In January 2010 growers in the area signed a management agreement to remove all mussels from on-growing equipment. A Marine Licence (under the Marine Scotland Act, 2010) was obtained to deposit the mussels from equipment onto the seabed, where rapid predation and mortality is anticipated. Marine Scotland Science has monitored the survival of mussels, the local water quality following deposition of mussels and the proportion of *M. trossulus* alleles in the plankton to determine the efficacy and effects of this eradication attempt. These results are presented alongside a draft Code of Practice for the shellfish industry to manage any potential for spread of *M. trossulus* from affected areas and so minimize any future impacts.

Keywords: Loch Etive, mussel farming, *Mytilus trossulus*, real-time PCR.

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**ICES CM 2012/Q:09**

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**Environmental impacts of salmon farming in a Norwegian fjord: the importance of water currents**

R. J. Bannister, T. B. Valdemarsen, P. K. Hansen, M. Holmer, and A. Ervik

Salmonid production using floating net cages in Norway has increased substantially over the past decade, with an annual production exceeding one million tonnes in 2009. This increase in production is raising concerns on the environmental impacts and long-term sustainability of a rapidly growing industry. To reduce environmental impacts of caged salmon farming, fish farms are being relocated to deeper and more dynamic locations. It has been suggested that this will improve cultivation conditions by alleviating potential benthic impacts through increased dispersal of waste products released from caged cultivation. However, few studies have investigated such impacts. The main aim of this study was to quantify benthic responses of deep soft-sediment ecosystems to aquaculture-induced stress at contrasting fish-farming sites based on water current velocities. This was achieved through detailed investigations of benthic fluxes, biogeochemical responses and in-faunal community composition across a production cycle at two commercial fish-farming facilities. The results of this study provide some of the first detailed sediment biogeochemical and benthic flux measurements undertaken within deep-fjord soft-sediment habitats heavily impacted by organic material derived from the waste of caged salmon farms. Sediment metabolism, mineralization rates of carbon and nitrogen, sulfate reduction rates, biogeochemical profiles of sediments, and infauna communities varied dramatically both within and between farming locations over the production cycles of the two different farming locations. The results to be presented here reinforce the importance of current velocity in the distribution of organic waste from fish farming in reducing localized benthic environmental responses.

Keywords: benthic faunal responses, benthic fluxes, sedimentation, sulfate reduction.

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**ICES CM 2012/Q:10**

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**AkvaVis—decision support system for aquaculture management**

Øivind Strand, Arne Ervik, Anne A. Hageberg, Inge Døskeland, Rune Rosland, Marianne Alunno-Bruscia, Lars Asplin, Sonal Patel, Henrik Hareide, and Stein Mortensen

Planning and management of coastal areas is becoming more complex with new stakeholders and various environmental and social interactions. To meet these challenges and as part of a new framework, the decision support system (DSS) AkvaVis is presently under development to manage a broader scale of environmental effects and area allocation in Norwegian aquaculture. Software demonstrators for locating Atlantic salmon and blue mussels are available for demonstration at [www.akvavis.no](http://www.akvavis.no). In AkvaVis the user communicates dynamically with an integrated system of data compilation, simulations, coastal zone development plans, regulatory frameworks analysis, and assessments. It applies GIS, georeferenced information, objects containing quantitative information on environmental parameters, and regulations on the allocation of area set by society. The user can insert into the map a “virtual farm object” that communicates dynamically with the system, providing suitability indicators for the site or area chosen. The AkvaVis concept is generic and can in principal be applied for all species and siting parameters, provided sufficient information and adequate simulation models are available. Disease control is the governing concern in Norwegian aquaculture management and thus regional disease transfer and prevention is currently being prioritized. Parameters where simulation models exist and are under implementation are water quality in the net pens, benthic carrying capacity, exposure to waves, risk of eutrophication on a regional scale, and risk of oxygen depletion in the deeper parts of fjord basins. Siting parameters for mussel farming are growth indices for individuals, production capacity for farm, water depth, current conditions, and distances to conflicting sources.

Keywords: GIS, Norway, site selection, spatial planning.

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## ICES CM 2012/Q:11

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### Achieving sustainable use of wrasses as cleanerfish on salmon farms

B. Skiftesvik, S. Mortensen, T. Jørgensen, S. Løkkeborg, K. Nedreaas, C. M. F. Durif, A.-L. Agnalt, and R. M. Bjelland

Wrasses are used as cleaner fish in salmonid aquaculture. The demand for wrasses has recently increased as a result of the need for an efficient and environmentally friendly method of delousing salmon and trout and because the effectiveness of chemical delousing treatments has declined dramatically. To meet this demand, millions of ballan wrasse, corkwing wrasse, rock cook, goldsinny wrasse, and cuckoo wrasse are fished and transported to fish farms. Concern about the long-term sustainability of this intense fishing pressure has motivated research into wild wrasse populations along the Norwegian coast and into the health and welfare of the fish used on salmon farms. We report the results of population censusing by mark–recapture methods undertaken to assess demographics: age and size at which wrasses recruit to the spawning population and which part of the population is affected by the fishery in different locations along the coast. The objective is to provide the scientific basis for a sustainable fishery. In addition, research on trap design is being conducted to minimize bycatch and to allow undersized wrasse to escape. The epidemiology of diseases in these wrasses is also being investigated to assess the potential for diseases to be spread along the coast when wrasses collected at one location are transported to a farm elsewhere. Finally, research into the status of wrasse after introduction into sea cages has also begun to improve their health and welfare.

Keywords: aquaculture, cleaner fish, salmon, salmon lice, sustainable fishery, wrasse.

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## ICES CM 2012/Q:12

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### Fate of organic waste from Norwegian fish farming in deep areas

P. K. Hansen, S. Aa. Olsen, R. Bannister, T. Kutti, O. B. Samuelsen, and A. Ervik

Norwegian fish farming produces over a million metric tonnes annually and releases large amounts of organic particles to the fjords and along the coast. The initial fate of the waste is primarily dependent on the hydrography of the area through dispersion and on depth. There is a temporal dynamic to the emissions, since the discharge is low at the beginning but gradually increases tenfold or more towards the end of a production cycle and then stops entirely during a three months fallowing period. Most of the organic waste particles will settle on the seabed, and be consumed by benthic fauna or decomposed by bacteria in the sediment. Eventually the organic waste may be channelled into the wider foodweb and potentially increase production of commercial species. A number of investigations at deep fish-farm sites (>150 m depth) performed at the Institute of Marine Research have shown large variations in sedimentation rates, benthic impact, and effects on other parts of the foodweb. For fish farms located in more dynamic areas the waste is dispersed and may be detected up to a kilometre away and traced in the foodweb. In deep areas with low current regimes and with medium to high sedimentation rates and stimulation of the benthic fauna, the flux of carbon from the benthos and into the wider foodweb may be restricted.

Keywords: deep sites, Norway, organic waste, tracing.

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**ICES CM 2012/Q:13**

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**Influence of waves and current speed on resuspension of fish-farm waste: case study in Funningsfjørður, Faroe Islands**

Gunnvør á Norði and Øystein Patursson

The Faroe Islands are a small group of islands situated in the North Atlantic Ocean. One of the major industries is farming of salmonids. The farms are mostly located in bays and fjords that are sheltered from strong currents. The small distance between the fjords and the open ocean implies that many Faroese fjords are periodically exposed to ocean swells, especially during winter. Ocean swells are generally long-period waves with motion reaching deep into the water column. When the swells are large enough they can add to the cleaning of fish-farming sites by resuspension of the bottom sediments. In the present study the influence of swells on the bottom sediment in Funningsfjørður is investigated. By means of wave and current measurements, combined with turbidity and sedimentation trap measurements, we found that wave action induced major resuspension events. Events with significant wave height above 2 m and peak period of around 13 s caused sediment at bottom depths of 54 m to be in suspension at <14 m depth in the water column. However, current speeds of 15–20 cm s<sup>-1</sup> near the seabed did not induce noteworthy resuspension of fish-farm wastes. Sediment inventory combined with mineralization measurements of organic carbon indicated that the influence of waves contributed to the removal of fish-farm wastes from the seabed below the fish farm.

Keywords: Faroe Islands, fish farm wastes, resuspension, waves.

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**ICES CM 2012/Q:14**

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**Biodeposition from farmed mussels on the benthic environment: *in situ* mesocosms to evaluate dose–response effects**

Andrea M. Weise and Christopher W. McKindsey

Many studies have examined the impacts of biodeposition from farmed bivalves on the environment. However, little effort has been directed at determining the dose-dependent effects of biodeposition on the benthic environment. This study evaluated the dose-dependent response of benthic communities to varying levels of biodeposition using benthic mesocosms in the Magdalen Islands, eastern Canada. A series of 40 benthic mesocosms (60 cm diameter) was placed on a muddy sand sea bottom 500 m distant from an existing mussel farm and received biodeposits from known densities of mussels (0, 25, 50, 100, 200, 300, 400, and 500 mussels mesocosm<sup>-1</sup>). Mussel biodeposition rates (e.g. total solids deposited, percentage organic matter) were measured using sediment traps placed below a series of treatments. Sediment cores were collected from each mesocosm and controls following 75 days incubation to examine benthic infaunal communities and various sediment biogeochemical parameters (oxygen, redox potentials, sulfide concentrations, percentage organic matter, and percentage organic carbon). There were clear visual effects from biodeposition and all parameters responded dramatically past a certain level of biodeposition. Results are discussed in the context of sustainable bivalve aquaculture.

Keywords: aquaculture, benthic communities, biodeposition, biogeochemical, dose–response, mussels.

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**ICES CM 2012/Q:15**

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**Weather conditions may induce mortalities of oysters cultivated on the bottom: example in the bay of Quiberon (56, France)**

Jean-Yves Stanisiere, Joseph Mazurie, Franck Dumas, Guillaume Charria, Jean-Francois Bouget, Aimé Langlade, Francis Gohin, Michael Retho, and Raoul Gabellec

Weather conditions undoubtedly affect the production of commercial shellfish. At the end of 2006, the shellfish farmers from the bay of Quiberon declared a sudden mortality of oysters, *Crassostrea gigas*, cultivated subtidally, on the bottom, specially in the deepest zone where the sediment is muddy. In order to verify the farmers' suspicion of a "bottom effect", especially during the 2006 summer, an extensive collection of physico-chemical vertical profiles (between 2000 and 2012) was analysed: many cases of thermal stratification were observed, capable of isolating a layer of under-oxygenated water near the bottom. Then, the past series of meteorological conditions were compared, which revealed an abnormally warm and calm summer in 2006. Finally, a 3D hydrodynamic model was developed, confirming a high frequency and intensity of thermal stratifications during the hot season, in 2006. As a consequence, a majority of oyster farmers ceased to exploit their concessions since 2007, specially in the deeper zone, interrupting regular maintenance to control predators. This is probably why our field survey, conducted in 2010, revealed an impressive predatory pressure from oyster drills, starfish, and sea breams. Moreover, a direct influence of the weather on predators may also be questioned (for example, starfish tend to proliferate along the shore when river outflows diminish). It may be concluded from our study that extreme meteorological conditions have the capacity to modify physico-chemical parameters in coastal zones with possible consequences on the biotopes of oysters and their predators: farm yields of commercial species may be severely affected.

Keywords: climate, *Crassostrea gigas*, mortality, stratification, weather.

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**ICES CM 2012/Q:16      Poster**

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**Nutrient management for sustainable nori (*Pyropia yezoensis*) aquaculture in the Seto Inland Sea, Japan**

Katsuyuki Abo, Kenji Tarutani, Kazuhiro Harada, and Kazutaka Miyahara

Nori (*Pyropia yezoensis*) is an important mariculture product in Japan. However, in recent years, the production has declined because of the bleaching of nori caused by nutrient deficiency in the seawater. In the Seto Inland Sea of Japan, eutrophication occurred rapidly during the period of rapid economic growth of Japan around 1970. After that, however, effective anti-eutrophication measures reduced the eutrophication in the seawater and it became oligotrophic in this decade. These oligotrophic conditions resulted in the depletion of inorganic nitrogen and decreased productivity. For the sustainable production of nori, measures have been taken to maintain appropriate inorganic nitrogen levels for nori aquaculture, such as the application of nitrogenous fertilizer, additional discharge of dam water, and moderate operation of sewage treatment plants (STPs). The moderate operation of STPs increases inorganic nitrogen discharge by inhibiting nitrification and denitrification in the sewage treatment process. In this paper, we evaluated the effect of moderate operation of STPs on the nutrient environment of a nori aquaculture field in the Kako River estuary in the Seto Inland Sea. In this aquaculture field, nori production is sustained by nutrient discharge from STPs and industrial effluents during the winter season. A numerical simulation demonstrated the increase of inorganic nitrogen flux in the aquaculture field and estimated the effective area of the moderate operation. It is suggested that the moderate operation of STPs is a practical measure that could be used to increase inorganic nitrogen in nori aquaculture fields.

Keywords: nutrient, seaweed, Seto Inland Sea, water discharge.

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**ICES CM 2012/Q:17      Poster**

**Developing land-based multitrophic recirculating aquaculture concepts**

Stephanie Borchardt, Lars Christiansen, and Ronny Marquardt

Recent studies have indicated that integrated multitrophic aquaculture (IMTA) concepts can be suitable alternatives to conventional indoor land-based recirculating aquaculture systems (RAS). Main advantages are improvement of waste water management, optimal exploitation of feed input and minimization of water and energy resources, while still providing constant and suitable rearing conditions for the cultured organisms. Two experimental marine temperate land-based aquaculture systems were set up, both with the same fish starting biomass. While in the RAS solids and other nutrients were treated by a complex biofilter system, in the IMTA particulate solids were removed by oysters and dissolved solids by red algae. First results are presented regarding the mass balance of nutrients, solids, and abiotic water parameters as well as carrying capacity of the system, biomass production, and condition of reared organisms for IMTA versus RAS. Final conclusions will be used to adapt the IMTA design to industrial scales, optimize nutrients flows and feeding output, test new species, as well as create new products and technologies for land-based recirculating aquaculture systems.

Keywords: integrated multitrophic aquaculture, land-based, mass balance, recirculating aquaculture.

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**ICES CM 2012/Q:18                      Withdrawn**

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**ICES CM 2012/Q20                      Withdrawn**

**ICES CM 2012/Q:21      Poster**

**Management strategies: impact on health in aquaculture**

David W. Verner-Jeffreys, Nick G.H. Taylor, Lars Asplin, Øivind Bergh, João G. Ferreira, Edmund Peeler, Anne D. Sandvik, Camille Saurel, Katrine Soma, and Arie van Duijn

By definition, aquaculture implies rearing large numbers of animals of the same species in limited space. This, in principle, favours the establishment and proliferation of pathogens (i.e. viruses, bacteria and parasites capable of exploiting the reared animals as hosts). Pathogens may be spread by wild organisms, escapees from aquaculture, transport of cultured organisms, transport of equipment or people, ballast water from ships, or water currents. Diseases can be spread from wild to farmed animals and vice versa. There is a risk for proliferation and enhancement of virulence of the pathogens in farmed populations, thereby in turn increasing the challenge pressure towards the wild animals. COEXIST is a broad, multidisciplinary EU FP7 project, tasked with evaluating competing activities and interactions in European coastal areas. As part of COEXIST, we are investigating how disease interactions particularly affect the aquaculture activities in two

contrasting case study regions: the Hardangerfjord region in Norway and the Ria Formosa in the Algarve region of Portugal. Models are being used to help assess the threat and evaluate countermeasures. Outputs of the project will include a series of management recommendations to reduce the impact and spread of different pathogens in the study regions, and facilitate their control and eradication should they be introduced to a coastal zone. More generally, recommendations will be made as to how disease interaction assessments should be factored into the marine spatial planning process in Europe, particularly for aquaculture activities.

Keywords: COEXIST project, disease spreading epidemiology, marine spatial planning.

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## ICES CM 2012/Q:22      Poster

### Towards sustainable coexistence of aquaculture and fisheries in the coastal zone

Øivind Bergh, Emma Bello Gomez, Knut Yngve Børsheim, Bas Bolman, Suzanne Bricker, Gavin Burnell, Miguel Caetano, Arie van Duijn, Gianna Fabi, João G. Ferreira, Jeremy Gault, Fabio Grati, Juha Grönroos, Olivier Guayder, Robbert Jak, Timo Mäkinen, Vicki O'Donnel, Anne Marie O'Hagan, Hans van Oostenbrugge, Merete Vik Ottesen, Jorge Ramos, Camille Saurel, Torsten Schultze, Anne Sell, Katrine Soma, Claus Stenberg, Vanessa Stelzenmüller, Carlos Vale, and David Verner-Jeffreys

Globally, coastal areas are subject to an increase in competing activities. Coastal fisheries and aquaculture are highly dependent on availability and accessibility of appropriate sites. Aquaculture production is increasing, whereas fisheries are at best stagnant. Coastal activities also include activities such as recreation, tourism, facilities for renewable energy production, all of which are expected to increase in importance. There is also increasing focus on Marine Protected Areas (MPAs). Thus, competition for available sites will probably increase, emphasizing the need for Marine Spatial Planning (MSP) and improved management tools supporting policies for space allocation along the entire European coastline.

Successful MSP is not likely to be achieved without a certain level of conflict, and without iterative adaptations in management actions. MSP is viewed as an essential part of advancing ecosystem-based management as demanded by the Marine Strategy Directive. The biological interconnectedness of fisheries and aquaculture is strong, with factors such as competition for space, disease transmission, genetic impact from escapees, availability of food for cultured finfish, and organic and inorganic waste management. Furthermore, the public perception of aquaculture in Europe and North America may be characterized by the view of aquaculture being a “new” and “unnatural” activity, whereas fisheries are viewed as “traditional” and “natural”. However, in an ecosystem-based management context, both industries represent human activities strongly influencing, and influenced by, the environment. Management of aquaculture and fisheries, as well as other uses of the coastal zone, should be considered integral parts with local variations in their respective importance.

Keywords: Coexist project, aquaculture, coastal fisheries, Marine Spatial Planning, coastal zone

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## Theme Session R

### Mapping and modelling of planktonic ecosystems for better monitoring and future projections of responses to global change

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#### ICES CM 2012/R:01

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##### Estimation from space of organic and inorganic production by phytoplankton in the ice-free Arctic Ocean

Dmitry Pozdnyakov, Dmitry Petrenko, Elizaveta Zabolotskikh, and Francois Counillon

Based on the collected vast database on shipborne measurements and employing the Behrenfeld and Falkowski algorithm (1997 both the annual primary productivity (PP) in the Arctic and the trend in PP over the time period 1998–2010 were determined. Our results indicate that PP in the Arctic has increased by 16.3% over 13 years (1998–2010) or ~14.6% over 12 years (1998–2009). This finding is at odds with the analogous numerical assessments of other workers: Pabi *et al.* (2008), Babin and Bélanger (2011), Arrigo *et al.* (2008), and Arrigo and van Dijken (2011). The absolute annual values of PP remotely quantified in the present study also differ substantially from their counterparts reported in the literature. These disagreements are thought to be due to differences in the applied methodologies of satellite data processing. To investigate the inorganic carbon (IC) production by *E. huxleyi* from ocean colour, a dedicated algorithm has been developed. Three major areas of *E. huxleyi* blooms have been identified: the Barents, Greenland, and northern Norwegian Seas, of which the Barents Sea prevails. MODIS-Aqua data indicate that, as opposed to PP, the IC production due to *E. huxleyi* in the Arctic over the time interval 2002–2010 has decreased by 61.4%. Investigation of the dynamics of variations in the factors controlling the IC production by *E. huxleyi* blooms shows that sea surface temperature, photosynthetic active radiation (PAR), and summertime North Atlantic oscillation (NAO) exhibited a tendency to decrease, thus supporting the results on C production decline over the above time period.

Keywords: Arctic Ocean, remote sensing, phytoplankton, production of organic and inorganic carbon.

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#### ICES CM 2012/R:02

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##### Mapping plankton biomass in the deep ocean: an ecological provinces approach

A. Bode, J. L. Acuña, J. Bueno, M. L. Fernández. de Puellas, J. I. González Gordillo, S. Hernández-León, X. Irigoien, C. Mompeán, and P. Olivar

The distribution of epipelagic plankton biomass by size-fractions was studied during the Malaspina-2010 expedition across the Indian, Pacific, and Atlantic Oceans. The objective was to characterize plankton biomass structure at large spatial scales in poorly explored areas of the ocean. Samples from 95 stations, representative of three major ocean biomes and 12 ecological provinces, were fractionated into five size-classes (40–5000  $\mu\text{m}$ ) and biomass determined as dry weight. Mean plankton biomass was similar for all oceans and major biomes but varied significantly between provinces, being particularly high in the North Pacific Equatorial Countercurrent and in the Caribbean provinces. The differences were mainly due to increases in medium-sized plankton, while for most provinces the biomass was uniformly distributed across logarithmic size-classes. Total and size-class plankton biomass was negatively and non-linearly correlated with the mixing layer depth and with the depth of the chlorophyll maximum across provinces. In contrast, only the biomass of the smaller plankton was positively and linearly correlated with sea surface temperature, while the biomass of other size-classes was positively

affected by the thermal stratification gradient in the upper layer. The obtained relationships will improve our ability to monitor and model the ocean response to global change.

Keywords: Atlantic, biomass, deep ocean, ecological provinces, Indian, Pacific, plankton, size-fractions.

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### ICES CM 2012/R:03

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#### How the Subpolar gyre strength influences phytoplankton blooms dynamics in the North Atlantic

S. A. Ferreira, M. R. Payne, B. R. MacKenzie, and A. W. Visser

Changes in the North Atlantic Subpolar gyre (NASPG) have been linked to the interannual variability of primary production. However, little is known about the mechanisms behind both environmental processes, and how the NASPG strength may extend its potential impacts to higher trophic levels, including early life stages of commercial fish species. We assess NASPG strength effect on North Atlantic phytoplankton bloom dynamics. We analyse time-series (from 1998 to 2010) of chlorophyll *a* (Chl *a*, from the Globcolour project) annual anomaly as a proxy of phytoplankton abundance, and of sea surface height (SSH, from the AVISO project) as a proxy of current strength. Three regions were strategically chosen to characterize positions relative to the NASPG, describing: region 1—the northern part of NASPG, including the Irminger Current (IC); region 2—the North Atlantic Current (NAC), its northwards drift, and the influence of the NASPG strength; and region 3—the within-NASPG dynamics. It is hypothesized that a strong NASPG index will be associated with a low-abundance, late phytoplankton bloom, possibly induced by higher heat losses, and thus lower temperatures. A correlation between the annual anomaly in chlorophyll concentrations and the gyre index was found for the southern region (region 3). Indications of a strong influence of NASPG index are related to areas within the gyre, which may have an impact in the ecosystem functioning. The results also suggest that physical forcing other than the strength of the NASPG influence the primary production of the more northerly regions east and west of Iceland.

Keywords: North Atlantic, phytoplankton blooms, Subpolar gyre.

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### ICES CM 2012/R:04

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#### Modelling interannual variability in the lower trophic levels in the North Atlantic

Annette Samuelsen, Ehouarn Simon, and Laurent Bertino

When projecting biogeochemical models into the future, being able to capture the interannual variability is as important as capturing the annual climatology. *In situ* and satellite measurements indicate that both timing and magnitude of phytoplankton blooms in the North Atlantic vary significantly between years. Model chlorophyll *a* and net primary production from a ten-year hindcast forced by an atmospheric reanalysis product has been compared to satellite-derived estimates of the same variables. The comparison revealed that the interannual variability is far weaker in the biogeochemical model results than in the observations. When the underlying assumptions behind these models is that the variability at the lower trophic levels are controlled by the variability in the climate system it is surprising that this variability is absent. To pinpoint the reason behind the lack of variability a series of model experiments are performed, perturbing both the forcing and the functional responses in the biogeochemical model. We also explore the possibility that interannual variability in the data may be a result of undersampling a system that has large spatial variability rather than actual year-to-year differences.

Keywords: interannual variability, modelling, North Atlantic, phytoplankton.

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**ICES 2012/R:05**

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**Modelling climate impacts on acidification in the North and Baltic Sea with ECOSMO II**

Ute Daewel, Corinna Schrum, and Dhanya Pushpadas

CO<sub>2</sub> increase in the atmosphere does not only potentially change the overall climate, but also increase the dissolved inorganic carbon (DIC) content in the ocean by ocean–atmosphere gas exchange, leading to a decrease in oceanic pH (acidification). Hence, it has both direct (via acidification) and indirect (via changes in atmospheric fields) implications for marine ecosystems and their productivity. On the other hand, changes in primary production would likewise impact the DIC content and could potentially alter the process of acidification on different temporal scales (seasonal, interannual, and decadal). Here, we extended the 3D coupled ecosystem model ECOSMO by formulations for carbon chemistry and applied the model system to the North and Baltic Seas in order to investigate ocean acidification in that specific region. We specifically aim to disentangle direct and indirect impacts of changes in atmospheric CO<sub>2</sub> on acidification. Therefore, we first present results from a long-term model hindcast (1948–2008) to validate the model and describe the dynamics in ocean acidification with respect to the different time-scales. Second, we apply downscaled products from general circulation models to project future climate impacts (2070–2100) on acidification. Third, we present results from cross-experiments, where we investigate the influence of future CO<sub>2</sub> increase under present-day atmospheric conditions and vice versa. These scenarios allow us to disentangle direct and indirect impacts on the process of acidification.

Keywords: acidification, climate change, ECOSMO, North and Baltic Sea.

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**ICES CM 2012/R:06**

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**Challenges in the integration of ecological indicators within a network of Atlantic Ocean observations**

Marie-Fanny Racault, Trevor Platt, Shubha Sathyendranath, Ertugrul Agirbas, Victor Martinez Vicente, and John Bruun

Plankton data have been sampled across the oceans for more than a century at diverse spatial resolutions and frequencies. Here, we examine a network of Atlantic Ocean observations in context of its relevance and practicality to retrieve ecological indicators. Indicators are essential metrics to monitor objectively, effectively, and comprehensively the responses of pelagic ecosystems to climate drivers. Two broad streams of ocean observations are identified: visible spectral radiometry and *in situ* measurements. Integration of ecological indicators with these streams of observations is illustrated by two original case studies: (i) long-term changes in phytoplankton phenology in the North Atlantic from *in situ* continuous plankton recorder surveys and visible spectral radiometry and (ii) temporal changes in phytoplankton biomass and size fractions across the Atlantic Ocean from *in situ* Atlantic Meridional Transect expeditions and visible spectral radiometry. Representativeness, comparativeness, potential for synergistic use, and complementarities of these streams of observations are assessed specifically in terms of coverage, resolution, cost-efficiency, availability to the scientific community, and range of variables measured. Practical, analytical, and numerical obstacles to the integration of ecological indicators are discussed. Based on the experience so far, minimum requirements in the data are outlined and recommendations for future observations are provided.

Keywords: earth observation, ecological indicators, climate change, phytoplankton.

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**ICES CM 2012/R:07**

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**Effects of climate change on the *Calanus* complex in the Nordic Seas from individual-based model simulations**

Geir Huse, Solfrid Hjøllø, Cecilie Broms, Morten D. Skogen, and Webjørn Melle

The copepods *Calanus finmarchicus* and *C. hyperboreus* are dominant species of herbivorous zooplankton in the Nordic seas. The species constitute an important link between the phytoplankton and the abundant fish resources that enter the area during summer feeding. Spatially explicit models are key tools for understanding the zooplankton dynamics of the heterogeneous area with warm Atlantic water masses to the south and east dominated by *C. finmarchicus* and cold Arctic water masses to the north and west dominated by *C. hyperboreus*. The two *Calanus* species differ in size and life history strategies. Here, we present individual-based models with emergent life history and behaviour for the species and investigate the importance of different predator abundances and climatic change on *Calanus* distribution and abundance. Simulations were performed over hundreds of years, which allowed the evolution of robust life history strategies. The results from the *C. finmarchicus* simulations show that the simulated population is able to remain viable within the Norwegian Sea basin for hundreds of years. In a simulation with interannual variation in forcing, individuals emerged earlier from diapause and dwelled deeper than in the basic run. In the simulation with increased predator density there was also an increased day depth compared to the simulation with lower mortality and no interannual variation in forcing. This kind of model is highly flexible and allows ready investigation of linkages between plankton traits and population and spatial dynamics.

Keywords: *Calanus finmarchicus*, *C. hyperboreus*, climate change, individual-based modeling, life history strategy, Nordic Seas.

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**ICES CM 2012/R:08      Withdrawn**

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**ICES CM 2012/R:09**

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**Impact of resolved scales on global marine biogeochemical models**

William McKiver, Marcello Vichi, and Tomas Lovato

As computer power improves so also does the trend towards using higher resolution in an effort to capture a greater proportion of the real world in models. In the framework of the EU-FP7 GreenSeas project we examine this approach by performing two simulations of the global marine biogeochemical system, one at 2-degree resolution (LOW-res), and the other at 1/4-degree resolution (HIGH-res) using the PELAGOS model, a coupling between NEMO and the BFM. Both the HIGH-res and LOW-res simulations are set up with the same initial conditions and forcings, allowing us to perform a direct intercomparison of the two, with a special focus on the Atlantic Ocean. We examine how resolving more of the physical features affects the biogeochemical system, in particular how differences in the resolved horizontal, vertical motions, and the mixed-layer depth are reflected in the plankton biomass, the nutrient availability, and community structure. These differences are particularly relevant at fronts and boundaries which are not well resolved in the LOW-res simulation. Overall, this approach gives us a means to identify which physical features need to be crucially resolved and quantified in terms of observations in order to best model the marine ecosystem and point to how we can improve the model for the future.

Keywords: Atlantic ocean, biogeochemical, models, resolution.

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**ICES CM 2012/R:10**

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**New methodologies to build an integrated global plankton database: the GreenSeas Analysis Framework**

John Bruun, Paul Somerfield, Icarus Allen, Marcello Vichi, William McKiver, Marie-Fanny Racault, Johnny Johannessen, Richard Bellerby, and Howard Waldron

In order to assess the current state of the marine planktonic ecosystem on an Atlantic basin scale it is necessary to provide a consistent framework through which historical data and knowledge can be used to benchmark the current state and function of the plankton ecosystem. This then provides the opportunity to enhance and improve current biogeochemical model predictions used for future assessments of climate change. We present a novel methodology that is applied in current GreenSeas analyses to carry out this type of climate assessment. Specifically, the GreenSeas Analysis Framework (GSAF) provides an integrated platform from which to create 30+ year time-series that combine knowledge from three types of marine observation: (i) biogeochemical numerical models (with a current focus on PELAGOS/BFM), (ii) remote sensing satellite observation, and (iii) from *in situ* sampling. The GSAF maps this combined knowledge onto the *in situ* transect sampling locations. This framework takes into account uncertainties caused by irregularly sampled time-series, and the potential for bias in the *in situ* sampling of plankton abundance because of small-scale spatial inhomogeneities in the plankton abundance. We also discuss the protocols required to ensure observations are mapped onto equivalent definitions of the metrics. This GSAF is currently combining knowledge across Arctic (1950+), Atlantic (1985+), and Southern Ocean (1992+) waters. In principle, this novel approach can also be extended and applied to other ocean studies and for wider biogeochemical numerical model types, and the potentials for carrying this out are discussed.

Keywords: Atlantic, integrated analysis, protocols.

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**ICES CM 2012/R:11**

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**Assessment of seasonal and decadal signals in the *in situ* Atlantic plankton data**

John Bruun, Andy Rees, John Stephens, Sandy Thomalla, Raissa Philibert, Howard Waldron, Paul Somerfield, Emil Jeansson, Richard Bellerby, and Denis Moiseev

Combining *in situ* plankton time-series datasets from different research cruises over an ocean Atlantic scale is particularly challenging. Specifically creating a knowledge base that enables statistical analysis of seasonal and the longer term structure and function of the planktonic presents two challenges: (i) subsampling—the underlying trends are not completely represented as not all measures are regularly sampled over time (months and years), and (ii) measurement protocols—scientific protocols for individual research expeditions need to be harmonized so that representative long-term time-series can be constructed. We present the current learning from combining *in situ* data across Arctic (1950+), Atlantic (1985+), and Southern Ocean (1992+) waters. To help address these challenges, this *in situ* data and the related knowledge is being combined with biogeochemical numerical models and remote sensing data in the GreenSeas Analysis Framework (GSAF). This novel framework will be briefly discussed to explain how the GSAF and its linkage with the *in situ* sampling design provide a systematic capability to construct longer term time-series. Ultimately, it enables analyses that help to improve the numerical models which are used to give future assessments of climate. We report here the current learning obtained from combining these *in situ* data, with a focus on phytoplankton abundance, primary production, and nutrient metrics. We discuss the seasonal and decadal trends in this data, and present (with relevant statistically simulated data) methods to distinguish seasonal and decadal variation from longer term trends that are typically present in these types of time-series.

Keywords: Atlantic, historical, *in situ*, longer term.

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**ICES CM 2012/R:12**

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**Satellite-derived phytoplankton functional group estimates in the northeast US continental shelf large marine ecosystem**

K. Hyde, A. Mannino, X. Pan, M. Mulholland, M. Fogarty, D. C. Melrose, and J. Hare

Historical measurements of size-fractionated chlorophyll *a* and primary production in the northeast US continental shelf Large Marine Ecosystem (LME) indicate that microplankton (>20 µm) accounted for ~30% of the total annual primary production during the late 1970s to early 1980s. Comparisons with contemporary data suggest that phytoplankton biomass has increased by more than 20% during the last decade, but diatom and dinoflagellates abundances measured by continuous plankton recorder (CPR) have decreased. A possible shift from larger to smaller phytoplankton species has important fisheries implications because it can impact the total amount of production in the system available to higher trophic levels and affect the fishery production potential. An ongoing research project, Climate Variability along the US East Coast (CliVEC), is collecting phytoplankton pigment and cell count data for validation with remotely sensed phytoplankton functional group/size class models. We are using satellite-derived estimates of phytoplankton pigment concentrations in a chemotaxonomic analysis (e.g. CHEMTAX) to quantify taxonomic groups based on pigment distributions. Preliminary results show good agreements with diatom-related pigments and capture seasonal variability in diatom abundance. By combining data from satellite models, *in situ* sampling, and CPR transects, we hope to improve our understanding of the phytoplankton composition and detect potential shifts in the size spectrum over time.

Keywords: diatoms, phytoplankton functional groups, ocean colour remote sensing, primary production.

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**Climate-driven changes in plankton trophic dynamics**

Stefano Ciavatta, Claudia Halsband, Claire Widdicombe, Tim Smyth, Elaine Fileman, Angus Atkinson, and J. Icarus Allen

Climate impact on the ocean can induce changes in the plankton community, with effects on ecosystem functioning and services (e.g. fisheries). Data from long-term plankton surveys can provide important insights into the above changes, if adequate analytical tools are applied. In this work, we investigated changes of the plankton trophic dynamics induced by fluctuations of essential climate variables (ECVs, e.g. wind velocity and sea surface temperature) in the western English Channel. Decadal time-series of phytoplankton and upper trophic taxa, sampled weekly by the Western Channel Observatory, were decomposed in their long-term and seasonal components, by using Dynamic Harmonic Regression (DHR) models and a Kalman filtering algorithm. The results show that the interannual fluctuations of the ECVs impacted the whole planktonic structure in the last decade, inducing significant changes in the biomass of phytoplankton taxa, microzooplankton and macrozooplankton abundance and production, with effects up to the level of fish larvae. Crucially, the correlation analysis among the long-term components of the time-series indicated that the changes in the ECVs also impacted the trophic relationships between primary and secondary producers. This work points out the relevance of plankton surveys and sound modelling to investigate the functioning and trends of planktonic ecosystems in the context of global changes.

Keywords: essential climate variables, plankton trophic dynamics, Western Channel Observatory.

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**ICES CM 2012/R:14**

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**Modelling the beginning and end of a planktonic life stage—the distribution of cod eggs and settled juveniles in the North Sea**

Hannes Höffle and Peter Munk

The North Sea cod stock is close to the southern limit of the species' range. Therefore, it might be vulnerable to future climate change. Direct as well as indirect effects of climate forcing may have the greatest effects on early life stages. Here we present a study on the distribution of cod (*Gadus morhua*) at the beginning and at the end of the planktonic life stage. The distribution of cod eggs was modelled with generalized additive models (GAMs) for the presence/absence and for the non-zero abundance, using environmental as well as spatial covariates. For comparison, we also examined the egg distribution of haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), and plaice (*Pleuronectes platessa*). Findings indicated that in the egg stage, the environment is more important for the probability of occurrence, while abundance is more under the control of spatial dependency. Modelling the potential habitat of newly settled 0-group cod based on presence/absence alone, identified temperature, salinity, bottom depth, and geographic position as the core descriptors of settlement distribution. The habitat models had good predictive power on the subdecadal scale, but were found lacking on a longer time-scale. The results showed that the effects of the predicted climate change may be complex and may, even within the same species, be beneficial for one life stage and detrimental for another.

Keywords: cod, fish eggs, juvenile fish, North Sea.

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**ICES CM 2012/R:15     Poster**

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**Planktonic ecosystem response to climate warming signified by changes in abundance of krill and amphipods in Kongsfjorden, Svalbard**

Jon Rønning, Padmini Dalpadado, and Haakon Hop

Krill and amphipods were studied in Kongsfjorden (79°N) and adjacent waters, with few records from Isfjorden (78°N) and Rijpfjorden (80°N). Fjords have frequently been used as model systems because they carry typical features of adjacent seas, but retain characteristics for longer periods than the open sea. Fjords on West Spitsbergen are typically influenced by Atlantic water masses, whereas the inner parts are subjected to fresh-water run-off with sediment loads from glaciers and rivers. Different zooplankton species are associated with distinct water masses, and higher influx of Atlantic water increases the abundance of boreal species in the fjords. The Methot-Isaac-Kidd (MIK, 2 m diameter ring net) was used during April–July 2006–2010 to collect macrozooplankton. The abundance of krill was much higher in Kongsfjorden than in the other fjords and highest at the innermost stations (>1000 ind. m<sup>-2</sup>). The macrozooplankton composition changed from *T. inermis* and *Themisto libellula* in the inner part of the fjord, to *Thysanoessa longicaudata*/*Meganyctiphanes norvegica* and *Themisto abyssorum* in the outer parts. Krill showed varying abundances throughout the sampling period. The abundance of amphipod species increased in their respective areas during 2008–2010, with more *T. abyssorum* in the inner parts of the fjord. Increased abundance of *T. abyssorum* and krill in Kongsfjorden is likely a consequence of the warming period from 2006 to 2008, with increased influx of Atlantic water to Kongsfjorden during the winter and little ice. The fjord system then changed to more Atlantic, with reduced abundance of “true Arctic” species, such as the *T. libellula*.

Keywords: Arctic fjord systems, climate effects, Kongsfjord, macrozooplankton.

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**ICES CM 2012/R:16      Withdrawn**

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**ICES CM 2012/R:17      Poster**

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**Intercomparison of zooplankton (net) sampling systems used in mapping zooplankton**

Hein Rune Skjoldal, Peter H. Wiebe, Lutz Postel, Tor Knutsen, Stein Kaartvedt, and Doug Sameoto

An intercomparison and evaluation of methods for sampling and determination of zooplankton distribution and biomass was conducted in a fjord environment with the RV "A. v. Humboldt" and the RV "Johan Hjort". The intercomparisons included the MOCNESS, BIONESS, MultiNet, LHPR, OPC, CPR, Gulf-V, CalCOFI 1-m ring net, and WP-2 net. Net mesh size had a major influence on the biomass and species composition of the zooplankton community. There was a consistent relationship between escapement through the mesh and the width of the organisms; about 50% of the organisms escape through the mesh at a width equal to the mesh size. The effect of towing speed on the extrusion of smaller organisms through the net can be substantial and adds to the loss due to escapement. Active avoidance of the sampler is only important for the larger macrozooplankton and not a significant problem for the mesozooplankton. Different vertical, oblique, and multiple opening/closing net systems produced similar estimates of zooplankton when operated with comparable mesh-sized nets and a sufficiently high mesh open area to mouth opening ratio. This study corroborates the results of earlier studies and emphasizes the necessity to pay particular attention to the size of mesh and speed of tow as it relates to extrusion of smaller zooplankton through the mesh and avoidance of the sampler mouth by the larger ones. Replicate tow variability was also consistent with earlier studies. No single net is suitable to sample across the wide size range of zooplankton from small mesozooplankton to macrozooplankton.

Keywords: net intercomparison, plankton nets, towing speed, zooplankton.

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**ICES CM 2012/R:18      Poster**

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**Nitrogen regeneration and assimilation rates in the euphotic zone of the southern Benguela upwelling system**

Raissa Philibert, Howard Waldron, and Darren Clark

The rate of nitrification—the biologically mediated oxidation of ammonium to nitrate—in the euphotic zone has long been considered to be negligible. However, recent studies have shown that quantifying this process correctly is important to provide better estimates of carbon export. Furthermore, simultaneous determinations of nitrogen (ammonium, nitrite, and nitrate) regeneration and nitrogen assimilation rates can provide invaluable insight into nitrogen dynamics. In this study, a  $^{15}\text{N}$  tracer method was used. The samples were incubated *in situ* for 6–12 hours. N-assimilation rates were determined from the isotopic enrichment in particulate nitrogen while N-regeneration rates were obtained from isotopic dilution in the seawater samples. To measure the isotopic dilution, dyes (sudan-1 for nitrate/nitrite regeneration and indophenol for ammonium regeneration) are developed in the samples and extracted by solid-phase extraction (SPE) in the field. At the land-based laboratory, the samples are purified by HPLC and then quantified using GC-MS. In the present study, N-regeneration and N-assimilation in the euphotic zone of St Helena Bay, which is representative of the southern Benguela upwelling system, were measured during the course of field trips in November 2011 and March 2012. In November 2011, only daytime experiments were carried out, while in March, daytime and nighttime incubations were done. The rates of nitrification presented here represent the first obtained in the Benguela upwelling system. Results demonstrated simultaneous N-regeneration and assimilation in the euphotic zone. The implications for new production and carbon export are considered.

Keywords: nitrogen dynamics, nitrification, southern Benguela.



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**ICES CM 2012/R:19    Poster**

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**Towards a reanalysis of the North Atlantic and Arctic Ocean biology: a multiyear assimilation of satellite ocean colour data with the deterministic ensemble Kalman filter**

Ehouarn Simon, Annette Samuelsen, and Laurent Bertino

Ocean biogeochemistry models are sensitive to numerous and poorly known parameters. In addition, the strong non-linearity of the equations and the regional variations are challenging for classical optimization methods. This motivates the use and further development of ensemble data assimilation methods for combined state–parameter estimation in coupled physical–biogeochemical systems. For the purpose of the reanalysis of the biological component of the Arctic Ocean over the period 2007–2010, a combined state–parameter estimation experiment is conducted in a North Atlantic and Arctic configuration of the coupled physical–biogeochemical model HYCOM-NORWECOM. Analyses are performed every week with the deterministic ensemble Kalman filter in two steps. In the first step, satellite physical data (SST, track SLA, and ice concentration) are assimilated in the physical component (HYCOM). A vertical remapping of the biological tracers is introduced to guarantee the conservation of the amount of biological variables at each horizontal grid point. In the second step, surface chlorophyll concentrations data are assimilated in the biological component (NORWECOM) of the coupled model. Log-transformations are introduced to prevent issues arising from the positiveness of the biogeochemical variables, parameters, and observations. Preliminary results for the years 2007, 2008, and 2009 are presented and discussed. The error growth of the surface chlorophyll is relatively well controlled and improvements of the spatial distribution of this variable are observed. However, the assimilation leads to large corrections of biogeochemical parameters betraying the limits of current parameterizations, although that can suggest new ones.

Keywords: data assimilation, North Atlantic/Arctic Ocean, reanalysis.

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**ICES CM 2012/R:20    Poster**

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**Copepod monitoring in the southern Moroccan Atlantic Ocean: 21°N to 26°N**

Soukaina Zizah, Omar Ettahiri, Siham Salah, Ahmed Yahyaoui, and Mohammed Ramdani

The southern Moroccan Atlantic coasts are bathed with upwelled waters that are fresh and nutrient-rich. This is related to the flow of nutrients to the sea surface. Thanks to these nutrients productivity is developed. Particular attention is focused on the description of those interacting environmental factors that enable the maintenance and development of living plankton communities. Both the physical and chemical characteristics of the ecosystem and the species diversity of the plankton community foodwebs affect the development of different populations through time. An understanding of the relationships existing between these populations and the environment is necessary to clarify zooplankton community dynamics in the pelagic zone. Plankton samples were collected from the southern coastal pelagic ecosystem in the Moroccan Atlantic, between Cape Blanc (21°N) and Cape Boujdor (26°30'N). Sampling was carried out from the research vessel “Al Amir Moulay Abdallah”. Analysis of samples revealed a total of 85 identified species of copepod. The taxonomic composition of these showed a clear predominance of temperate zone taxa. Species from tropical waters were rare. The distribution of chlorophyll *a* concentrations showed an increasing gradient from north to south in all sampled stations. The area between Cintra Bay and Cape Blanc is characterized by rather diverse and dense populations of copepods in the upper water layers. This distribution corresponds to a zone of permanent front and cold water resurgence (upwelling) rich in nutrients.

Keywords: biomass, chlorophyll, copepods, pelagic ecosystem, south Moroccan Atlantic.

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**ICES CM 2012/R:21     Poster**

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**Planktonic ecosystem model in the Japan Sea based on an operational ocean forecast system**

T. Watanabe and K. Takayama

Based on an operational ocean forecast system with data assimilation the lower trophic ecosystem model called NEMURO was applied to improve our understanding of spatial and temporal variations of primary production and nutrients in the Japan Sea. Daily hydrodynamic data for the input of the ecosystem model, such as water temperature, current velocity, and vertical diffusion coefficient, were supplied from the operational ocean forecast system called JADE (Japan Sea Data Assimilation Experiment, <http://jade.dc.affrc.go.jp/jade/>). All of the Japan Sea was covered by the JADE with a resolution of 1/12 degrees horizontally and 36 levels vertically. As a result of data assimilations of satellite-derived SST, SSH, and CTD data, JADE can provide realistic hydrodynamic data which are good agreement with the other independent observation. Hence, the ecosystem model qualitatively reproduced the general characteristics of seasonal chlorophyll *a* and nutrient variations. The result of the ecosystem model suggested that in the northern part of the Japan Sea spatial and temporal variations of the spring bloom and the structure of the subsurface chlorophyll *a* maximum were controlled by the intensity of the vertical winter convection. On the other hand, in the southern part of the Japan Sea, horizontal advection of nutrients originating from an upwelling on the east coast of Korea was the main force for primary production.

Key words: Japan Sea, NEMURO, operational ocean forecast system.

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**ICES CM 2012/R:22     Poster**

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**Applications of Box Jenkins Transfer function methods to identify seasonal and longer term trends in marine time-series**

John Bruun, Paul Somerfield, and Icarus Allen

We present the uses of time-series methodologies to help identify and quantify dynamics, interactions, and longer term signals in ocean-scale biogeochemical marine ecosystems. In particular, we focus on the Box Jenkins Transfer Function (BJTF) model, which is a general statistical time-series approach based on an observation = system + noise representation. This model enables robust statistical identification of the underlying system using both time and frequency domain tools, using methods that utilize data and the knowledge of underlying dynamic structures effectively. In particular BJTF helps to measure: (i) seasonal and decadal variability and the structure of underlying trends, (ii) non-linear structure present in the system, (iii) the influence of multiple drivers on biological response, (iv) intrinsic memory that is present in the system, and (v) coherency of multiple series at different frequencies. This tool also provides a systematic statistical methodology to quantify the influence of interventions, extremely rare events and step changes such as a regime change. This methodology is being applied in current GreenSeas analyses. Specifically, the GreenSeas Analysis Framework (GSAF) provides a platform from which to create 30+ year time-series that combine knowledge from three types of marine measurement: (i) biogeochemical numerical models, (ii) remote sensing satellite observation, and (iii) from *in situ* sampling. The GSAF maps the combined knowledge onto the *in situ* transect sampling locations. We show examples of how the BJTF statistical tools can be utilized in environmental and marine systems with both simulated case studies and case studies from current GreenSeas Atlantic research.

Keywords: Atlantic, coherence, time-series analysis, transfer function.

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**Global plankton data and marine ecosystem modelling—GreenSeas**

The GreenSeas Consortium

The GreenSeas project (development of global plankton data base and model system for eco-climate early warning) combines observation data, numerical model simulations, and cross-disciplinary analysis at ocean basin scales to develop a global, high-quality, harmonized, and standardized plankton and plankton ecology data inventory and information service. GreenSeas delivers both contemporary and historical plankton data and information products, including error-quantified numerical simulations, to scientific users. New plankton data are collected in the Southern Ocean and a latitudinal transect from the Arctic to the Southern Ocean via the Atlantic Ocean. The goals are to: (i) assess the current state of the marine planktonic ecosystem by providing benchmarks of its present state for the future assessment of climate change; (ii) improve the knowledge base and understanding of the impacts of climatic and anthropogenic change on planktonic ecosystem structure and function, (iii) improve the ability to model and project future marine ecosystem states; and (iv) use an ecosystem approach to derive a suite of indicators which describe changes in ecosystem function. The results include observations and model simulations of the basin-scale distribution of plankton communities and their nutrient turnover and biogenic export in the context of hydrographical and biogeochemical provinces. The status and impact on planktonic marine ecosystem from natural variations will be assessed, including anthropogenically induced climate changes. A prototype downstream service is under development and demonstrated, by synthesizing plankton data, model outputs and satellite-based ocean colour fields to define a range of planktonic biological, environmental, and climatic indicators.

Keywords: environmental indicators, global, numerical models, plankton data.

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**ICES CM 2012/R:24    Poster**

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**Atlantic Zone Monitoring Program zooplankton atlas for the Northwest Atlantic**

Catherine L. Johnson, Pierre Pepin, Michel Harvey, and Benoit Casault

The Atlantic Zone Monitoring Program (AZMP), run by Fisheries and Oceans Canada, has sampled zooplankton at stations along 14 sections on the Northwest Atlantic continental shelf system, including the Labrador and Newfoundland shelves, Grand Bank, Gulf of Saint Lawrence, and Scotian Shelf twice annually since 1999. AZMP zooplankton samples are collected using 0.75 m diameter ring nets, equipped with 202 µm mesh and towed vertically from near-bottom or 1000 m to the surface. Here, we present maps of the climatological spatial distribution of dominant zooplankton species and groups throughout the Northwest Atlantic shelf system. Ocean circulation in this region is predominantly equatorward, and zooplankton distributions are influenced both by variability in along-shelf currents, in flow of slope water onto the shelf and the strong and variable cross-shelf gradients in environmental conditions. The zooplankton atlas will serve to provide a baseline of zooplankton spatial distributions that can be used in the future to identify biogeographic changes in the region.

Keywords: biogeography, Northwest Atlantic, spatial distribution, zooplankton.

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**ICES CM 2012/R:25      Poster**


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**Primary production in coastal waters off mid-Norway**

Ingrid H. Ellingsen, Ole Jacob Broch, Øyvind Knutsen, Johanne Arff, Thomas A. McClimans, and Dag Slagstad

We have used the coupled hydrodynamic–chemical–biological model system SINMOD to simulate primary production (PP) in the coastal waters off mid-Norway for the years 2009, 2010, and 2011. Model configurations with horizontal resolutions of 800 and 160 m have been used to study PP both on regional and local scales. Spatial and temporal variabilities in the productivity can be explained from changes in and interactions between the two dominating currents in the area: the Norwegian Coastal Current and the North Atlantic current. The simulations reveal several hot spots of production along the coast. In this talk we will use model results to explain the underlying physical processes. We will also address the importance of resolution and discuss the validity of the results.

Keywords: coupled models, primary production, upwelling.

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**ICES CM 2012/R:26      Poster**


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**Planktonic copepod structures and the impact of environmental parameters in the Northwest African upwelling area**

Siham Salah, Ahmed Errhif, Amina Berraho, Ahmed Makaoui, Tarik Baibai, and Omar Ettahiri

The species composition and structure of copepods were investigated in relation to hydrological characteristics in the Cape Ghir area (30°30'N–31°N, Northwest Atlantic Moroccan coast) during 2008 (December) and 2009 (February, April, June, and October). This study shows that the decrease of the temperature in the upwelling season (June) is accompanied by high copepod densities. The relation between the copepod species distribution and the environmental parameters shows that some species (*Paracalanus parvus*, *Oncaea venusta*, *Acartia clausi*, *Oithona nana*, *Euterpina acutifrons*) are mainly correlated with chlorophyll *a* and nutrients. However, other species (*Clausocalanus arcuicornis*, *Oithona plumifera*, *Oithona similis*), are correlated with the variation of temperature and salinity. The results showed that the temperature is not involved in the dominance of species but has more influence on the presence of the occasional species. In the case of *Corycaeus clausi* or *Oithona plumifera*, variation has a slight relation with the increase of temperature. The variation of the biological and physical parameters may explain the distribution of the zooplankton, with a dominant contribution from the hydrological factors.

Keywords: Cape Ghir filament, copepods, physico-chemical parameters and nutrients, seasonal variation.

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**ICES CM 2012/R:27      Poster**


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**The integrated ecosystems assessment initiative—enabling the assessment of impacts on large marine ecosystems: informatics to the forefront of science-based decision support**

Peter Fox, Andrew Maffei, Massimo DiStefano, Suzanne Lawrence, Stace Beaulieu, and Cynthia Chandler

What has been lacking, until recently, is a successful method to develop, implement, and sustain informatics solutions to modern application problems, such as environmental and climate assessments, that provide interoperability among diverse and heterogeneous data and information sources, as well as multidisciplinary organizations and people. This approach is directed toward an integrated ecosystem assessment for marine fisheries. The objective is to enable routine, integrated ecosystem assessments and forecasts, including impacts related to climate change and the capacity

to address vulnerability, risks, and resiliency, and to develop an outcome-based process that results in informed trade-offs and priority setting. The goal is to bring ocean informatics to the forefront as an essential tool for implementing this new national policy framework and advancing the capacity for science in support of ecosystem-based management, large marine ecosystems, as well as integrated ecosystem assessments. Existing data will be leveraged via semantic web technologies to capture knowledge. These technologies can leverage extant vocabularies and data repositories used by the stakeholders and define the meaning of that data by providing language constructs understood by computers that closely reflect how people think and pose questions of the data. Central to the success of this initiative is the commitment to train a new generation of scientists who will learn to interact effectively with this new integrated and interoperable ecosystem assessment capability.

Keywords: data science, escience, xinformatics.

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