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# Theme session Report

## Oceanography and ecosystems in the North Atlantic: science and operational services

Conveners: Tomasz Dabrowski (Ireland), Caroline Cusack (Ireland), Marcos Llope (Spain)

Special thanks (in alphabetical order) to Trish Clay (USA), Sofia Ferreira (Denmark), Jessica Fuller (Norway), William Hunter (N. Ireland), Jed Kempf (Ireland), Glenn Nolan (Ireland), Lidia Yebra (Spain) for their contributions and help organising the session panels.

**Sharing Knowledge**

The "sharing knowledge" discussion started off with a poll around participation in expert groups. Results showed 41 % of participants were already involved in ICES expert groups. A good deal of the participants collaborate with other expert groups outside ICES.

A lack of funding (for those working at universities, for instance) is perceived as a barrier to participation in ICES expert groups. One solution could be to budget expert group attendance in research project proposals and justify it in the impact section.

In terms of data, ICES needs to get better at promoting its databases, identifying end-users and expert group integration. For instance, it is unclear where oceanography fits into the aquaculture expert groups. Sharing methodologies was put forward as a solution as, for instance, fisheries scientists don't always understand the nuances of oceanographic data. While ICES has numerous data guidelines, they do not seem to work well.

Scientific articles and reports are not enough for effective uptake. In-person connections work well, in particular workshops (rather the working groups) have proven to be more effective when it comes to knowledge sharing. To this end, it is important that clear objectives / next steps exist so that connections have a true purpose and end up in tangible results.

**Data Integration**

Many scientists attending the ICES ASC are already integrating datasets, however, file formats (e.g., netCDF, GIS layer, etc) still present a challenge. In addition, duplication of data in multiple databases with different data identifiers and database structure is unhelpful, e.g., it is time consuming to remove duplicates. It is also evident that a mismatch on tools used between biologists (e.g. "R") and oceanographers/modellers (e.g. MatLab, Phyton) exists.

Access, funding, collaboration (including connecting to the human element) were the main barriers identified. For example, "ecologists are interested in the number of fish, economists in their value, anthropologists in communities…". While you might have a scientific model that gives you biomass, economists want information in terms of market cost (inflation adjusted). Even with variables as simple as sea surface temperature, it is quite confusing to know what dataset(s) to use. This is why access to knowledge and competent scientists who specialise in different fields is often more important than access to data. Communication (using the same language between oceanographers, biologists, economists and fishermen etc.) and good partnerships (to help with the different parts) are critical to transfer information. Conceptual modelling of the system can help you find what connections are needed. Indicators can help connect the ecological and social elements, but useful indicators need development. For instance, storm surge and sea level rise impact fishing communities, while ocean temperatures and ocean acidification affect ocean biota and therefore

fishing which in turn affects fishing communities. Sometimes we need to take a step back to understand how we can connect different types of information and datasets.

**What data products to use?**

The discussion on what data products was initiated due to the fact that there is a plethora of data sources and deciding on what data product to use is most often a challenge.

The panellists commented on the many barriers that exist, starting from data formats (e.g. NetCDF) and volume through to understanding what information the specific data product contains, how the indices were derived, how to understand their meaning and how to obtain information on the data quality. The experience gained in ICES WGOOFE teaches us that the collaboration with the fisheries and ecosystem assessments WGs needs to start from the provision of basic oceanographic data before moving to more complex (e.g. indices) and work through the process. It is also easy to get lost in translation, as terminologies used by different groups may differ.

Answers to the poll questions indeed indicate that the participants in the session mostly used basic oceanographic variables in their work, with good numbers using model outputs sourced from well-established international databases, mostly recommended to them by a colleague or an expert. Approximately half of the responders were able to process data themselves, whereas the other half asked a colleague for help.

Further discussion revealed that there is a strong need for long term time series. An example provided by one of the panellists prompted for a high degree of caution when dealing with long time series, as discontinuities in the datasets may be present. This calls for a need to have clear, simple and transparent information on the quality and uncertainties in the data provided by the oceanographers to other groups.

**Conclusion**

In summary, the session audience were actively involved in the discussion and attentive to the focus topics. A clear message arising from the conversations is that there is a great need to address existing bottlenecks that are inhibiting the use of oceanographic data and products.

Some example questions from the audience in this session included

(a) Should ICES revisit the needs of the many users of ocean data (LINK)?
(b) Is there a need for practical workshops to develop skills, or signpost resources for people to learn?
(c) Is there a need for more direct involvement of oceanographers in ICES WGs, i.e. should the oceanographic datasets required by ICES WGs be tailor-made, supplied and rubber-stamped by dedicated oceanographic ICES WGs?

# Contents

# CM 26: Non-linearity in interspecific interactions between Barents Sea cod and haddock in response to climate change

Joël M. Durant

Climate change is affecting many fish populations globally. For instance, sea temperature warming has been shown to affect distribution, population growth and trophic interactions in marine systems. This is particularly true in high-latitude marine ecosystems where the sea warming effect is projected to be strongest. In the cold Barents Sea, increase of sea temperature is beneficial for the productivity of many commercially important fish species, such as the haddock *Melanogrammus aeglefinus* and the Atlantic cod *Gadus morhua*. These sympatric fish compete for food at younger stages and thereafter the former is preyed by the latter but Climate change might affect the interaction and coexistence of these two species. We used 33-year long time series of haddock and cod abundances estimates from two data sources (acoustic and trawl survey) to analyse the dynamic effect of climate on the coexistence of these two sympatric species in the Arcto-Boreal Barents Sea. Using a Bayesian state-space threshold model, we demonstrated that long-term climate variation, as expressed by changes of sea temperature, affected species demography through different influences on density-independent processes. The interaction between cod and haddock has shifted in the last two decades due to an increase in sea temperature, altering the equilibrium abundances and the dynamics of the system. During warm years (sea temperature over ca 4°C), the increase of the cod abundance negatively affected haddock abundance while it did not during cold years. This change in interactions therefore changed the equilibrium population size with a higher population size during warm years. Our analyses show that long-term climate change in the Arcto-boreal system can generate differences in the equilibrium conditions of species assemblages.

**Keywords**: cod, haddock, trophic interaction, sea temperature

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# CM 48: The role of large spawners for population productivity in Northeast Arctic cod

Øystein Langangen, Leif Chr. Stige

This work aims to improve our understanding of the role of old and large spawners as a driver for productivity and potentially on the population dynamics of fish. In particular, we aim improve the mechanistic understanding of the lacking statistical relationship between wide egg distribution in cod and later recruitment.

The role of large spawners on the population dynamics of fish has been debated in the scientific literature for decades. In a recent study on the Northeast Arctic stock of Atlantic cod (*Gadus morhua*) the effects of parental age and size on offspring abundance and distribution were investigated. The analysis indicated that an old and large spawning population were associated with higher egg abundance and a wide egg distribution. However, little support has been found for a wide egg distribution acting as a buffer against environmental influences by leading to higher mean or less variable recruitment. The lacking relation between egg distribution and recruitment can be due to data limitation or alternatively that wide egg distributions may be of limited relevance for survival in later stages. To investigate these two alternatives, we analysed the output from a mechanistic coupled physical–biological drift model that projected the abundance of juvenile cod on the nursing grounds in the Barents Sea from empirically estimated egg distributions. The projections were performed with initial egg distributions reflecting the expected distributions at high and low mean weight of the spawners. We found that the extended distribution at the fringes only marginally contributed to recruitment, as a large proportion of the extra eggs at high mean age and size of spawners did not reach suitable nursing areas or failed to grow to a suitable size by the end of the season. Moreover, we present recent results indicating that despite the limited role of wide egg distribution on recruitment, old and large fish tend to increase the recruitment in this stock.

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# CM 84: Resilience for whom and according to what criteria? An examination of adaptations to changes in the Bay of Biscay anchovy fishery

Jennifer Beckensteiner [1], Sebastian Villasante[2], Anthony Charles[3], Christelle Legrand[4], Olivier Thébaud[4]

We investigate the empirical application of resilience analysis, considering how fishing communities, on the one hand, and fishery management institutions, on the other, have responded and adapted to largescale changes in the Bay of Biscay anchovy fishery. The system has undergone important transformations in the last two decades, with a closure of the fishery from 2005 to 2010. This has had negative repercussions due to displacement of fishing effort increasing pressure on other species and loss of market for the French operators. Spanish fishing industries on the other hand seem to have been more robust to changes. While the anchovy stock has recovered, the fishery socio-ecological system has not returned to its pre-collapse status. Through a multidisciplinary and systemic approach combining quantitative methods (time series analyses of fisheries and market data) and qualitative methods (interviews with key stakeholders), we 1) analyze adaptive responses of fishing communities and industries as well as fisheries management, 2) examine potential opportunities or barriers to adaptation in France and in Spain, and 3) identify governance mechanisms that support adaptation towards more resilient and sustainable fishery systems. We highlight the difficulties in answering the question “was the anchovy fishery socio-ecological system resilient to the collapse of the resource?”; We find the response depends on whom is asked, as well as on the management objectives and their application scales. This retrospective analysis can serve as a basis for a more comprehensive assessment and understanding of the long-term responses at the sectoral, coastal community and institutional levels in this and other fisheries systems, in the face of possible future shocks.

**Keywords:** Fisheries social-ecological systems, global changes, adaptation, resilience, Bay of Biscay, small pelagic

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# CM 85: Impacts of the match-mismatch hypothesis across three trophic levels – a case study in the North Sea

A. Sofia A. Ferreira[*1,2], Anna B. Neuheimer[2], Joël M. Durant[1]

Sustainable fishery practices require accurate predictions of fish recruitment – the abundance of the earliest age of fish entering a fishery. A key driver of recruitment is linked to understanding the impact of predator-prey dynamics fish early life stages has on their survival at later stages, as in the MatchMismatch Hypothesis (MMH). MMH states that predator survival depends on the match (or mismatch) between the timings of predator feeding and prey availability.

The main objective of this study is to understand how the predator-prey spatio-temporal overlap at different levels of the food chain explain the variation in pelagic fish populations. Here we focus on three questions:

1) can MMH explain recruitment variability in other regions not previously studied?

2) does the performance of MMH vary with trophic levels?

3) what predictions can MMH make for future recruitment?

We calculate the predator-prey overlap between each pair of three trophic levels in the North Sea: we use data from the International Bottom Trawl Survey from ICES.org for the herring (*Clupea harengus*) larvae; and the Continous Plankton Recorder from Marine Biological Association for zooplankton (*Temora longicornis, Oithona sp., Pseudocalanus spp, and Acartia spp*) and the phytoplankton colour index from 1982 to 2017. We assessed whether the predator-prey overlap explains herring recruitment, there is a spatial pattern in the predator-prey overlap, and there is a spatial pattern in the relationship between the overlap and recruitment.

We demonstrate the applicability of the predator-prey overlap metric across the trophic chain and region tested, and, more importantly, its predictive power of 18 % with the possibility of predicting recruitment 3 years ahead of spawning, thereby substantially increasing the forecast horizon for identifying major recruitment variations.

**Keywords:** phenology, seasonal cycles, plankton dynamics, fish recruitment

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# CM 88: Temporal dynamics and climatic forcing of dissolved inorganic nutrient chemistry in the western Irish Sea: evidence from a long-term oceanographic observatory

William R. Hunter, Steven Beggs, Jay Calvert, Claire Smyth, Adam Mellor.

Anthropogenic climate change is causing changes in ocean physico-chemistry, including ocean warming, thermal stratification and the recycling and retention of dissolved nutrients in surface waters. This has huge potential to impact the marine food-web, altering the phenology of organisms from phytoplankton to fish. The western Irish Sea basin is characterised by the formation of a thermally stratified cyclonic gyre in the spring and summer. This gyre forms when warming near the sea surface isolates a cold dome of bottom water which overlies an area of muddy sediment that supports the Irish Sea's main Norway lobster (*Nephrops norvegicus*) fishery in addition to fin-fish fisheries including haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*) and cod (*Gadus morhua*). The Agri-Food and Bioscience Institute, Northern Ireland, have maintained an instrumented long-term oceanographic observatory within the western Irish Sea gyre since the mid 1990's. This observatory provides a unique dataset for investigating temporal changes in the onset and duration of thermal stratification, and the consequences for dissolved inorganic nutrient (nitrates, ammonia, phosphates and silica) concentrations and their stoichiometric ratios. Here we present a time-series analysis and investigate temporal changes in the dissolved inorganic nutrient concentrations within the western Irish Sea gyre, and how these are influenced by changes in the onset and duration of thermal stratification and extreme events such as marine heat waves.

**Keywords:** Climatic forcing, Dissolved nutrients, Gyre, Irish Sea, Oceanographic Observatory, Stratification, Time-series

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# CM 141: Remote sensing for quantitative mapping of kelp (*Laminaria hyberborea*)

K.H. Kartveit*, H. Steen, L. Christensen, K.M. Norderhaug

Kelp forests are among the most productive marine ecosystems. A better understanding of the distribution and quantity of these forests is vital in order to increase our comprehension of marine ecosystems, the ecological drivers of change, and how to harvest resources along our coasts in a sustainable way. In order to secure sustainable management of kelp resources, accommodate other ecosystem services and avoid overexploitation and assess impacts from global change including warming efficient monitoring tools are needed. Traditional surveying methods include physical sampling and camera investigations. While the established methods are reliable, the use of such tools are sensitive to water and weather conditions and are time consuming.

In this study we test a novel method for estimating kelp biomass by utilising a scientific echosounder mounted on a fishing vessel. The acoustic data were collected using both the 38kHz and 120kHz transducers on a Simrad EK60 echosounder. The datasets were interpreted with the Large Scale Survey System (LSSS) and processed in the KORONA pre-processing software. The echo strength of the kelp forests was investigated using the 120kHz channel due to the superior cleanliness of the echograms when compared to the 38kHz channel. The 38kHz channel was however included to aid the seabed detection algorithm. The less backscatter noise in the 120kHz data helps us to define the presence and height of the kelp forests on echograms in concordance with existing literature.

Through careful processing of raw data, interpretation of echograms and echo integration, a relationship between the area backscatter coefficient (SA) and the estimated biomass density, based on extensive diver observations, physical sampling and video analysis, has been established. A total of 319 locations along the coast were surveyed using echosounder, of which 291 were judged to comprise data of satisfactory quality. The results demonstrate a linear relationship between SA-values and kelp biomass estimates from video analysis at the same sites. This relationship facilitates for efficient and reliable mapping and monitoring of kelp resources by using the echo strength as a proxy for biomass. The established SA-biomass relationship will be validated by independent and randomly selected data sampled during fieldwork in the spring of 2022, when we plan to compare the acoustic biomass model with conventional biomass estimates relying on physical sampling and video analysis.

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# CM 142: An ecological approach characterizing factors influencing the yellowtail flounder population within Closed Area II Access Area, Georges Bank

Patricia J. Perez, Kevin D.E. Stokesbury

The Georges Bank yellowtail flounder (*Limanda ferruginea*) fishery was once vibrant in the 1960s and 1970s with landings reaching 15,000 MT, but has since collapsed to only 6 MT landed in 2020. Despite reductions in the total allowable catch, biomass estimates from federal fisheries independent trawl surveys are at historical lows, suggesting biotic and abiotic factors are influencing abundance. The stock has become concentrated in Closed Area II Access Area; an area closed in 1994 to protect groundfish but is rotationally opened to the Atlantic sea scallop fishery, resulting in bycatch of yellowtail flounder. Working collaboratively with fishermen, we conducted a seasonal video trawl survey from 2013 to 2021 to better estimate yellowtail flounder population size within the Access Area. Using our trawl survey data, drop camera scallop survey data and FVCOM temperature data, we characterized the yellowtail flounder population and physical and biological variability within Closed Area II Access Area. This yellowtail flounder aggregation has continued to decline and sustained low numbers over our time series, while the Access Area has experienced changes in substrate composition, fluctuating seasonal temperatures, and strong increases in skate and dogfish density across the time series. These variable physical and biological processes could affect yellowtail recruitment success and the rebuilding capacity of this stock, in turn affecting how we manage bycatch of yellowtail flounder in the sea scallop fishery.

**Keywords**: yellowtail flounder, closed areas, environmental variability, optical survey

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# CM 177: Does climate-integrated stock assessment improve management? An American plaice example

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Climate impacts on marine species are widely acknowledged, but are rarely incorporated directly into management advice. Climate-integrated stock assessment models may reduce this disconnect by linking broad climate and oceanographic drivers to population dynamics. However, the proposed benefits of this approach have not always been realized. We implemented a two-step process to evaluate the impact of physical-biological linkages on fisheries management, using American plaice as a case study because this species has demonstrated changes in productivity and distribution in response to climate change. First, Generalized Additive Models (GAMs) were used to assess the strength of relationships between population dynamics (recruitment and catchability) and environmental covariates identified through a literature review (e.g. temperature, North Atlantic Oscillation). Second, the Woods Hole Assessment Model (WHAM) was used to develop stock assessments with and without these environmental covariates influencing aspects of stock dynamics and we tested their performance using Management Strategy Evaluation. The strength of oceanographic drivers on recruitment and catchability were varied across simulations to identify possible thresholds for oceanographic change, past which climate-integrated assessment models are more likely to result in differential management advice. Our results explore methods to incorporate physical-biological links in single-species stock assessments and explore the long-term consequences for management under climate change.

**Keywords:** Stock assessment, Management Strategy Evaluation, climate driver

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# CM 188: Automatic Detection of *Nephrops norvegicus* Burrows from Underwater Surveys

Atif Naseer, Yolanda Vila, Jennifer Doyle, Enrique Nava

Research in underwater image analysis is gaining popularity in many applications of marine sciences. Underwater image analysis requires a set of image processing tasks including underwater object detection, classification, visual content recognition, and image annotation of large-scale marine species. Certain challenges like turbidity, color variations, illumination changes make the underwater environment very difficult for the models to detect and classify the objects automatically. The Norway lobster, *Nephrops norvegicus*, is one of the main commercial crustacean fisheries in Europe. This species can be found in sandy-muddy sediments from 90 to 800 m depth in the Atlantic NE waters and the Mediterranean Sea, where the sediment is suitable for constructing their burrows. *Nephrops* spend most of the time inside the burrows, and their emergence behavior is influenced by several factors: time of year, light intensity, tidal strength. These burrows can be detected through optimal lighting set-up during video recordings of the seabed. The abundance of *Nephrops norvegicus* stocks is assessed based on identifying and counting the burrows where they live from underwater videos collected by camera systems mounted on sledges. The Spanish Oceanographic Institute (IEO-CSIC) and Marine Institute Ireland (MI-Ireland) conduct annual underwater television surveys (UWTV) to estimate the total abundance of *Nephrops* within specified areas, with a coefficient of variation (CV) or relative standard error of less than 20%. Currently, the identification and counting of the *Nephrops* burrows are carried out manually by marine experts. We proposed an automated framework to detect, classify, and count the *Nephrops* burrows. The proposed architecture uses four steps in the methodology. The first step is data preparation in which we process two data sets collected by the Marine Institute Ireland and Spanish Oceanographic Institute during the UWTV survey. The second step of our framework is to train the models using state-of-the-art deep learning models. We develop multiple models that use the current Faster RCNN models Inceptionv2, MobileNetv2, ResNet50, ResNet101 for detecting the *Nephrops* burrows. To train the models, we used transfer learning to fine-tune the Faster R-CNN models on our datasets. The 3$^{rd}$ step is to test the models. We tested our models against some unseen images from the datasets and evaluated the model's performance. The last step of our proposed framework is to evaluate the performance of the models quantitatively and qualitatively. From the results, we observe a higher precision and recall rate, while visually the accuracy of burrows detection is more than 85%.

**Keywords:** *Nephrops norvegicus* stock assessment, underwater videos classification, deep neural network, Faster RCNN

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# CM 213: Developing a short-term harmful jellyfish forecast model for the salmon aquaculture industry

Hannah Brownlow[1*], Robin Raine[2] Damien Haberlin[1,3], Thomas K. Doyle[1,3]

The occurrence of harmful jellyfish blooms (aggregations/swarms) are a regular feature in the Northeast Atlantic. The movement of these blooms into coastal areas can have major negative economic impacts on finfish aquaculture. For example, in 2009 a jellyfish bloom killed 250,000 salmon (valued at £1 million) in a Northern Ireland farm, and since then there have been similar events in Ireland, Scotland, Norway, Australia and Chile. An accurate forecast of harmful blooms is essential to protect finfish aquaculture from large economic losses. Here we present a predictive jellyfish model based on a successful HAB (Harmful Algal Bloom) model currently used in Ireland in shellfish aquaculture. This HAB model is based on wind driven flows that characterise water exchange events between the bay and the coastal waters outside the bay when the water is thermally stratified. These events, called flip flops, can be identified by deviations in the prevailing wind patterns that are axially aligned to southwest facing bays in southwest Ireland and by temperature signatures in the water column. The aim of this jellyfish model is to develop a short range (3-4 days) forecasting tool that uses bi-weekly zooplankton count data and metrological data to alert farm managers of a potential rapid increase in harmful jellyfish (*Muggiaea atlantica*). To test the model in real-time, high resolution quantitative zooplankton sampling and CTD profiles were conducted at a salmon farm in Bantry Bay, southwest coastal Ireland from July 2020 to November 2022. The model successfully identified three flip flop events in 2020 which corresponded with an increase in densities of *Muggiaea atlantica.* Once operational this model could provide farm managers with an early warning system that could help them to implement other mitigation measures if necessary to reduce the harm caused to farmed salmon and reduce mortalities.

**Keywords:** prediction, modelling, fish farming, circulation

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# CM 238: Trends in the abundance of Celtic Sea demersal fish: identifying the relative importance of fishing and environmental drivers

Jed Kempf[1,2], Patricia Breen[2], Emer Rogan[1], David G. Reid[2]

The Celtic Sea is a productive fishing ground, therefore identifying the relative importance of fishing and environmental factors on fish stock dynamics is crucial for developing our understanding of sustainable yields and to operationalize Ecosystem Based Fisheries Management (EBFM). We investigated the effect of environmental variables and fishing on the relative abundance inferred from catch-per-unit-effort (CPUE), of twelve demersal stocks (i.e., cod, haddock, whiting, anglerfish, hake, megrim, plaice, sole, lesser-spotted dogfish, spurdog, *Trisopterus* spp., skates and rays) in the Celtic Sea from 1997 to 2019 (23 years). Annualized time series (1997-2019) of net primary production, bottom temperature, copepod abundance (*Calanus finmarchicus* and *Calanus helgolandicus*) and North Atlantic Oscillation index were used to characterize key environmental variables. Fishing exploitation rates ($F/F_{MSY}$) were used to represent fishing pressure and CPUE trends derived from an International Bottom Trawl Survey (IBTS) were used to infer abundance. We used redundancy analysis to identify key explanatory variables and then dynamic factor analysis to assess their relationships with the CPUE series and identify underlying patterns in the unexplained temporal variation. Our results show that for the majority of demersal fish species, the CPUE trends were strongly influenced by fishing exploitation rates. The gradual reduction in exploitation rates observed throughout the study period most likely led to the partial recovery of cod, spurdog, hake, megrim, plaice, whiting, *Trisopterus* spp., and the skates and rays. In addition, exploitation patterns on one stock influenced CPUE trends of other demersal stocks (e.g., hake, megrim, plaice, lesser-spotted dogfish, sole). We also observed that the CPUE of whiting, hake and plaice increased when *C. finmarchicus* were abundant in the plankton. We infer from our findings in the investigated time series that the recovery of cod, spurdog, hake, megrim, plaice, whiting, *Trisopterus* spp., and the skates and rays in the Celtic Sea remains dependent on controlling fishing mortality, and this would not, at least for now, be confounded by the environmental conditions.

**Keywords:** Dynamic factor analysis, ecosystem assessment, ecosystem-based fisheries management, Calanus finmarchicus, international bottom trawl survey

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# CM 251: Lower river outflows or decreasing phosphorus concentration as possible causes of the decline of chlorophyll-a in the coastal waters of the eastern English Channel over the period 1998-2019?

Antoine Huguet (Ifremer), Francis Gohin (Ifremer), Laurent Barillé (University of Nantes), Domnique Soudant (Ifremer)

It has been established from previous studies that the phytoplankton biomass, as derived from the chlorophyll-a concentration, has been declining over the period 1998-2017 in the eastern English Channel. Considering that the phytoplankton production is limited by phosphorus and nitrogen after the major spring bloom, the evolutions of the riverine nutrient inputs are likely to be at the origin of this relative improvement in the water quality. The phosphorus concentration has been steadily decreasing in the rivers throughout the period but lower riverine outflows in the coastal waters during the second part of the period were also identified as a possible cause in the decline of chlorophyll-a. In our study, the outflows of the two main rivers of the area, the Seine and the Somme, have been compared to time-series of *insitu* data and satellite-derived chlorophyll-a from mid-April to the end of October, a season where the limitation by nutrients is the highest, particularly compared to the limitation by light. The time-series were modelled using dynamic linear models, which allows the identification of trends over the two decades with a seasonal adjustment. The spatial distribution of these trends have been mapped at the English Channel level. The results clearly showed that despite an increase in the river flows at the end of the period 1998-2019, chlorophyll-a levels stayed significantly lower than average. The time-series of the mean chlorophyll-a concentration appeared to be well related to the declining riverine fluxes of phosphorus whose concentration in the river halved in the period. Therefore, we can exclude a dominant effect of the climate variability, through the river flows alone, in the decline of the phytoplankton biomass in the area

**Keywords:** Eastern english channel, chlorophyll a, nutrients, climate variability, dynamic linear model, time series analysis, satellite, riverine fluxes

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# CM 252: Atlantis in the North Atlantic: An ecosystem approach to marine planning and decision making

Denise O'Sullivan, Andrew Conway, Michael Arrigan

Ecosystem models can help us understand how oceanographic processes influence ecosystem dynamics and predict how changes in environmental conditions could affect biological components. The increase in extreme climate events in the past few years is highlighting the need to understand how oceanographic processes respond to change and incorporate this information into management policies.

Atlantis is an end-to-end modelling framework that was developed to support management strategy evaluation and includes dynamic, integrated representations of the biophysical system, human use and adaptive management. It uses data from oceanographic products, such as ROMS (Regional Ocean Modelling System) output, to calculate water fluxes. Oceanographic model output can also be used to force temperature and salinity conditions. Incorporating the physical properties from oceanographic products into Atlantis can create a more accurate and consistent representation of the physical dynamics of the area.

Atlantis has proved to be a successful decision-making tool around the world, from Australia to the North Sea, as it can consider all components of marine ecosystems including economic and social aspects. This means not only can we gain an insight into ecosystem responses to climate change but also how these changes could affect human economic activity that supports coastal communities. Atlantis has particularly been focused on ecosystem-based fisheries management but has also been used to explore responses to climate change and oil spills. Through engaging with stakeholders a model can be tailored to a specific need by conducting scenario-analysis based on concerns of decision-makers, researchers and community representatives. This engagement makes the model more useful and relevant as model output can be incorporated into existing processes and can be more applicable to support policy decisions.

We propose a theoretical Atlantis model for the North Atlantic and will describe the various components of the model, including hydrographic, biological and economic sub-models. We will discuss it's potential to use oceanographic products to improve the predictive capability of ecosystem change and how this can support marine spatial planning and decision making in Ireland and potentially other parts of Europe.

**Keywords:** ecosystem models, physical-biological linkages, climate change, decision-making, management policy, Atlantis

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# CM 254: Satellite-derived marine environmental indices and their decadal patterns of variability in the Bay of Biscay

Marine Dorand, Antoine Huguet, Mathieu Doray, Pierre Petitgas

Operational oceanography provides since 20 years satellite-derived daily sea surface maps of temperature and chlorophyll a. In meteorology, similar data exist as atmospheric pressure fields. Their space-time analysis has allowed to identify characteristic and recurrent situations (spatial patterns) and provide amplitude indices for these patterns. The North Atlantic Oscillation index is a well-known index resulting from such analysis. We present here a similar approach for analysing the series of satellite-derived monthly sea surface maps of temperature and chlorophyll a, over the Bay of Biscay (43°N - 48°N, 0°W - 5°W) from 1999 to 2020. Empirical Orthogonal Functions were applied by month to the series of maps to extract spatial eigen vectors consistent in time and the time series of their amplitudes. The eigen vectors were further classified to identify consistent spatial patterns over years and months. An index by month and year for each spatial pattern is proposed. The analysis shows that sea surface temperature has increased from 1999 to 2020, emerging from seasonal variability in coastal waters and in winter. Chlorophyll a has decreased, especially in coastal waters and in autumn. The spatial patterns are discussed in light of the knowledge on hydrology and river plumes (Loire and Gironde) in the area. The series of indices correspond to new environmental time series that may statistically explain variations in higher trophic levels' abundance, condition or habitats.

**Keywords:** satellite, EOF, SST, Chlorophyll a, climate change, Biscay

# CM 280: Implementation of integrated ecosystem assessments in the International Council for the Exploration of the Sea – conceptualisations, practice and progress

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Management of marine social-ecological systems needs to embrace holistic approaches due to increasingly high stakes for all marine sectors. To meet this need, ICES promotes Ecosystem-Based Management (EBM) and Integrated Ecosystem Assessments (IEAs). ICES includes EBM and IEAs in its Science Priorities and tasks its IEA Working Groups (WGs) with IEAs for their ecoregions. But to what degree does IEA WG work accord with prescribed IEA practice? To understand the implementation of this approach within ICES, we first examined ICES documents and academic literature to establish a commonly accepted definition of an IEA and to understand the guidance that ICES has given with respect to IEAs. We then interviewed chairs of ten of the eleven ICES IEA working groups. All groups understand and acknowledge the holistic goals of the IEA and many have adopted the IEA model as laid out by Levin et al. (2009, 2014). However, we found significant variation in the degree to which the IEA groups have been able to apply the IEA ideal and in their level of ambition to do so. We identified two primary areas where WGs did not fully implement IEA: 1) integration of social and economic issues and 2) involvement of stakeholders. WGs diverged along North American-European lines and reflected differing historical development, even within Europe. We offer examples of how WGs have been making progress toward full IEAs and discuss how ICES can support this transition. We also reflect on barriers to achieving the IEA goal.

**Keywords:** ICES, integrated ecosystem assessment, ecosystem, multidisciplinary, interdisciplinary, transdisciplinary, marine management, ecosystem-based management, ICES ecoregions

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# CM 291: SPATIOTEMPORAL dynamics of the north-east ATLANTIC mackerel

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With almost 600,000 t landed in average these last ten years, the Atlantic Mackerel is one of the most exploited species in the North-East Atlantic.
The species is sensitive to the change of temperature, which perturbs its habitat. Therefore, huge migrations have been observed 15 years ago, leading to the “Mackerel war”.
For allowing a better management of its exploitation in the NEAtlantic it seems to be necessary to understand well the spatiotemporal dynamics of this species.
In the context of the H2020 Mission Atlantic we are calibrating the SEAPODYM numerical model based on the knowledge of catch, length frequency distribution, tags recaptured data, eggs and larvae density.
SEAPODYM describes the spatiotemporal dynamics of an age structure density. It allows to model well the pelagic fish taking into account environmental conditions such as temperature, oxygen, primary production, the oceanic currents and the density of preys.
The heart of the model is an age-structure advective-diffusive-reaction equation where the motion parameters are coupled to the habitat’s functions leading the density to its best habitats in space and time at different life stages (larva, juvenile, young, adult).
The model predicts both the space-time distribution and habitats of the species at different life stages. The model allows as well to estimate the influence that the fisheries have had on the biomass evolution so far.
After having calibrated the model, we plan to make projections up to 2070 using several scenarii from the IPCC to estimate the impact of climate change on the population.

**Keywords:** Atlantic Mackerel, dynamics, habitats, climate change, biomass distribution, fisheries

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# CM 300: Tracking integrated ecosystem assessments in the ICES network: a social network analysis of the ICES expert groups

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**Co-authors:** Strehlow, H.V., Schmidt, J.O., Dankel, D.J.

Under the framework of the ICES Integrated Ecosystem Assessment Steering Group (IEASG), twenty-two Expert Groups exist to develop quantitative and interdisciplinary evaluations and syntheses of biophysical and human social information to provide scientific advice on societal trade-offs between different policy options. Eleven of those Expert Groups focus specifically on integrated ecosystem assessments (IEAs), some of which have been established as early as 2007 (the Joint ICES/HELCOM Working Group on Integrated Assessment of the Baltic Sea – WGIAB), with the most recent coming into existence in 2021 (the Working Group on Integrated Ecosystem Assessment of the Northern Bering Sea-Chukchi Sea – WGIEANBS-CS).

As a long-established institution, ICES occupies a critical role demonstrating how impartial research and scientific advice across international borders can contribute to the co-management of shared species and transboundary ecosystems. Given the multi-institutional and intergovernmental nature of the organization, ICES offers a unique perspective on the functionality of international cooperation and collaboration in the pursuit of common goals. This unique perspective drives the key research framework for this study, which aims to understand where the IEA network is nested within the broader structure of ICES, and how the IEA network supports the development of IEA knowledge for ICES member countries. In pursuing this research, the scope of this study also includes how knowledge is fostered in the ICES network in general.

Social network analysis (SNA) offers a methodological approach to study how organizations like ICES are set up, how the different structures are connected to each other, and how interactions and relationships within the institution can be interpreted based on these connections. Such information can be used to support and steer interactions and coherence between different groups.

Our research objectives were to track the development of regional IEAs over time and to assess the role of workshops in the ICES network. To achieve these objectives, the degree of connections between ICES Expert Groups in the ICES network were compared over time and the network cohesion of workshops determined.

**Keywords:** social network analysis, integrated ecosystem assessments, ICES, expert groups, institutional management, science advice

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# CM 313: Migrant vs non-migrant deep scattering layers: A summary of recent advances on our understanding of their spatial and temporal dynamics

Marian Peña

Mesopelagic organisms are an essential component of the food web in oceanic waters and relevant actors in the biological carbon cycle through the active flux they perform with their daily vertical migration. They form deep scattering layers (DSL) that can be recorded and analysed with acoustic techniques. Traditionally, a single-frequency echosounder was employed to describe a unique DLS. However, several layers can be differentiated combining multiple frequencies thanks to their acoustic properties and behaviour. Vessel-borne echosounders are limited in range by signal loss with distance and thus lower frequencies (18 and 38 kHz) are most commonly employed to study deep layers. Due to their acoustic properties, mesopelagic fish with swimbladders are the organisms responsible for most of the scattering analysed at those frequencies, while weaker scatterers such as shrimps or euphausiids are acoustically registered only in cases of larger densities. Deep migrating scattering layers mainly include myctophidae with swimbladders (more visible at 18 kHz) while *Cyclothone braueri* is the main reflector for the 38 kHz non-migrating layer at 400-700 m depth. This presentation summarize the main findings of the spatial and seasonal variability of meso- and bathypelagic DSLs from different studies carried out in the North-Atlantic and the Mediterranean Sea during the last decade, focusing on the distinct traits that characterize migrating and non-migrating layers. Challenges encountered to apply acoustic techniques to meso- and bathypelagic species are discussed. Water masses characteristics, primary production, upwelling areas, canyon and seamounts proximity, eddies and fronts and main currents are considered. The first recording of a bathypelagic deep scattering layer that was detected in autumn (1300-1500 m) and winter (800-1200 m) in the Bay of Biscay is also described.

**Keywords:** deep scattering layers, acoustics, mesopelagic, bathypelagic, water masses, fronts, eddies, canyons, upwelling, currents, primary production

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# CM 318: Understanding the spatial dynamics of landings in the inshore Maine Lobster Fishery

Jaeheon Kim, Cameron Hodgdon, Keith S. Evans, Yong Chen

Continued warming of oceans has caused global shifts in marine species' distributions. This can result in changes in the spatial distribution of landings and have distributional impacts on marine resource-dependent communities. We evaluated the spatial dynamics of landings of American lobster (*Homarus americanus*) in coastal Maine, which supports the most valuable single species fishery in the U.S. We coupled a bioclimate envelope model and a generalized additive model to estimate spatial dynamics of lobster landings at a management level scale. This coupled modelling system was then used to forecast the future lobster habitat suitability based on IPCC RCP climate scenarios and predict distributions of fishery landings from projected lobster habitat suitability. Historical spatial distribution of fishery landings shows the highest proportional landings in Maine's Southern (southwest) regions. Current landings show higher proportional landings in Downeast (northeast) regions and the highest proportional landings in the Midcoast (middle) regions. Our results suggest that the distributions of fishery landings will remain in similar patterns for the next 30 years. However, proportional landings in Downeast regions will decrease in 50 to 70 years, while the Midcoast areas will continue to have high proportional landings. Total landings for the inshore Gulf of Maine are expected to fall in the far future. These findings have long-term implications for sustainable, localized management of the Maine lobster fishery in a changing climate. This study highlights the use of fine-scale, spatially explicit modeling to capture localized effects of climate change. This study develops an approach to directly link climate change effects to fishery landings and further highlights the importance of understanding climate-induced, ecological-fishery dynamics.

**Keywords:** American lobster, fishery landings, spatial distribution, climate change, habitat suitability, bioclimate envelope model, generalized additive model

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# CM 332: Investigating environmental drivers of cetacean occurrence in a cross-border region, the Malin Sea, using data collected during a transnational European fishery survey

Morgane Pommier, Cynthia Barile, Ciaran O'Donnell, Simon Berrow, Joanne O'Brien

Marine top predators tend to aggregate near topographic features (coastlines, sea mounts, shelf breaks, canyon systems, sandbanks), dynamic oceanographic systems (fronts, currents) or more ephemeral phenomena (seasonal upwelling, eddies, ice-edge) where prey concentration is relatively predictable. Irish and Scottish waters include a variety of these critical features and are amongst the most important habitats for cetaceans in Europe. In Ireland, Cetaceans on the Frontier and ObSERVE surveys have shed light on habitat drivers of several offshore species but remained spatially and temporally discrete. Moreover, due to their design, transect-line surveys tend to provide lower coverage near the limits of survey blocks, therefore leaving border regions marginally sampled when surveying only national waters. So far, few studies have focused on cetaceans distribution in the region of the Malin Sea, overlapping with the Irish EEZ, UK EEZ and International waters compared to the rest of Irish and Scottish waters. Despite an apparent rich species diversity, relative cetacean abundance over the Malin shelf seems rather low in comparison with hotspots documented further north off the Hebrides, and west and south of Ireland. As the environment appears suitable for many species based on their current range, it remains unclear whether this apparent low prevalence arises from a lack of published results, uneven survey coverage, or accurately portrays an ecological discontinuity between western Scotland and western Ireland habitats. Since 2016, the multi-disciplinary Western European Shelf Pelagic Acoustic Survey (WESPAS) has been extensively and systematically surveying the entire region of the Malin Shelf, monitoring marine megafauna, seabird, fish stocks and zooplankton distribution while collecting in-situ measurements of oceanographic conditions. It is to date the most comprehensive and longest on-going time series for visual observations of marine mammals in the area. Here, we use the WESPAS dataset to model i) cetacean (taxa), ii) common dolphin and iii) Minke whale occurrence against selected oceanographic and biological variables. Within a novel Bayesian Additive Regression Trees (BART) framework, we investigate cetacean distribution and habitat preferences in the Malin Sea, notably in relation with the occurrence of a dynamic tidal front, the Islay Front. Ultimately, results from this study should contribute towards informing strategic management and conservation decision making in this cross-border area. Information on species response to oceanographic conditions and prey distribution will provide baseline to further explore potential effects of climate change.

**Keywords:** cetaceans, oceanography, habitat modelling, Malin Shelf, pelagic fisheries, surveys

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# CM 335: Sperm whale habitat use in Irish offshore waters using an innovative Bayesian modelling framework

Cynthia Barile, Simon Berrow, Joanne O'Brien

Species distribution models are increasingly used to understand species' environmental preferences and habitat use as a means to inform management decisions. To forecast changes in habitat suitability under future climate change scenarios, identify important areas and/or mitigate impacts of anthropogenic activities, an emphasis should be placed on computing accurate and representative models, from which reliable predictions can be derived. Most popular modelling techniques are limited by their capability to handle uncertainty, and conspicuously few studies in ecology exploited Bayesian frameworks. This study uses Bayesian Additive Regression Trees, an innovative alternative to traditional classification tree methods which inherently handles uncertainty by including a Bayesian component. In this study, we apply this promising framework to data collected over the course of six seasonal passive acoustic surveys (2015-2016) along the Irish continental shelf break to assess the habitat use of sperm whales, *Physeter macrocephalus*. Sperm whales are known to migrate through the area to move between southern breeding grounds and more northern feeding areas. However, recent studies have confirmed that Irish Atlantic offshore waters, particularly along and beyond the shelf edge, do not act as a simple migration corridor but also provide important feeding habitats, which explains the year-round presence of the species in significant numbers. Hence, sperm whales' movements throughout the area result from interactions between migrations and access to patchy prey resources. The scale-dependent nature of those processes further complexifies the quantification of relationships between underlying environmental variables and the distribution of the species. For this reason, we use a multiscale framework to investigate the influence of a set of topographic features and oceanographic processes acting as proxies for prey availability on sperm whale presence. Animals were found to associate with slope gradient and aspect, topographic position index, temperature, distance to nearest major front and sea level anomaly. Those variables were retained on different scales, which confirmed the importance of adopting multiscale approaches. The complexity of the relationships between those variables and the presence of sperm whales highlighted that the mechanisms at the origin of those relationships and the underlying environmental processes remain unclear. This study shed light on the complex interactions between sperm whales and their habitat and showed the potential of Bayesian frameworks for modelling cetacean habitat use.

**Keywords:** sperm whale, habitat use, modelling, Bayesian statistics, passive acoustics

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# CM 338: Deriving metrics from remote sensing and modeled data to relate oceanographic conditions to availability for the Northern shortfin squid fishery

Sarah L. Salois, Kimberly J. W. Hyde, Adrienne M. Silver, Avijit Gangopadhyay, Glen Gawarkiewicz, Anna Mercer, Brooke Lowman, John Manderson

Oceanographic satellite data provide a powerful tool for assessing dynamic marine systems in a changing world. Remotely sensed data are well suited for environmental analysis and ecological forecasting as they provide long-term synoptic, near real-time coverage of oceanographic conditions at high spatial (1-4 km) and temporal (daily) resolutions. This study utilizes these long term time series, as well as global ocean reanalysis physical data, to generate high resolution metrics to serve as indicators for understanding the distribution of the commercially important Northern shortfin squid, *Illex illecebrosus*. *Illex* are a fairly data poor species due to their sub annual lifespan and offshore migrations. Recent years have seen above average availability to the U.S. fishery, yet the drivers associated with the high abundance years are unknown. It is thought that the variable population dynamics exhibited by *Illex* in the U.S. Mid-Atlantic fishery are largely influenced by oceanographic conditions of the Northwest Atlantic, which have documented significant changes over the past decade. Using multivariate generalized additive models, we have identified a suite of oceanographic processes that correlate with fishery dependent catch data throughout the fishery footprint. In particular, we have identified relationships between the spatiotemporal distribution of *Illex* catch and specific properties of oceanographic features (e.g.: mesoscale eddies, fronts) with implications for understanding the mechanistic processes influencing the productivity and availability of this species. The general framework and indicators created for this study have potential to be useful for the management and assessment of a broad range of marine species and the dynamics of their associated ecosystems.

**Keywords**: generalized additive models, oceanographic conditions, mesoscale process, northern shortfin squid, remote sensing, stock assessments

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# CM 372: Spatio-temporal variability of the zooplankton community in the SW Mediterranean 1992-2020: linkages with environmental drivers

Lidia Yebra, Marta Puerto, Nerea Valcárcel-Pérez, Sébastien Putzeys, Francisco Gómez-Jakobsen, Candela García-Gómez, Jesús M. Mercado

Variability in the spatial and temporal distribution of the mesozooplankton abundance in the N Alboran Sea (SW Mediterranean) was assessed intermittently from 2010 to 2020, and compared with 1992-2000 historical time series data. Total abundance of mesozooplankton was significantly higher in the coast than in the shelf and slope waters. There were significant differences in mesozooplankton abundance between 1992-2000 and 2010-2020 at the three zones. Copepods dominated the mesozooplankton during winter and spring, but cladocerans and doliolids also became important components of the community in summer and autumn. We found significant increases between the first and the second decadal periods in the abundance of copepods, appendicularians, holoplanktonic gastropods and siphonophores in the shelf. However, in the coast, copepod nauplii, doliolids, gastropods and siphonophores increased, while euphausiids abundance decreased significantly. These trends contrast with the ongoing decline of the sardine stocks in European waters. Increasing temperature and decreasing predation pressure are suggested to be the main drivers of mesozooplankton variability.

**Keywords:** Alboran Sea, environmental drivers, mesozooplankton abundance, SW Mediterranean, taxonomic composition, zooplankton time series

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# CM 402: Monitoring and modelling to support resilient fisheries on the North-West European Shelf

Richard Renshaw, Jonathan Tinker, Susan Kay

The Met Office runs ocean models for a range of timescales and regions. Together with National Oceanography Centre (NOC), Plymouth Marine Laboratory (PML) and Bundesamt für Seeschiffahrt und Hydrographie (BSH), we are funded by the Copernicus Marine Service (CMS) to produce analyses, reanalyses and forecasts for the North West European shelf seas (NWS). These are made freely available online.

Together these provide a vast resource of gridded information on temperature, salinity, currents, nutrients, oxygen, primary production, and also surface waves in the NWS. The forecasts provide predictions up to 10 days ahead. The reanalyses give values going back over several decades. They allow users to examine trends and changes in the ocean environment. For instance, sea bed temperatures from the reanalyses were used in a study of marine heatwaves and cold snaps in the North Sea. It was shown that extremes in temperature at the sea bed are linked to short and long-term impacts on catches of various species for North Sea fisheries. In another example, reanalyses are used to understand the occurrence of algal blooms in Scottish waters. Reanalyses are used to monitoring trends via the CMS “Ocean Monitoring Indicators” and in the regular “report cards” produced by the Marine Climate Change Impacts Partnership (MCCIP) that examine environmental change and impacts.

Additionally, the Met Office undertakes research into the climate of the NWS, from seasonal and inter-annual variability to decadal and longer timescale climate prediction. These projections have been used to assess the risk of non-native species colonizing regions of the NWS. A new set of NWS ensemble climate projections have just been completed. These will provide the underlying physical change for several end-user studies.

Here we present an overview of our modelling work and of the products available. We give examples of how they are used in research, both in climate studies and in studying changes to the ecosystem. We hope to encourage wider use in the marine community. We welcome suggestions on how to make model data useful to researchers and end users.

**Keywords:** North-West Shelf, reanalysis, climate

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# CM 436: Potential for resilience of deep-sea coral ecosystems to variability in NE Atlantic water masses

Janina V. Büscher, Eoghan Daly, Sheena Fennell, Aedín McAleer, Aaron Lim, Louise Allcock, Evin McGovern, Rachel R. Cave

Little is known about the variability in environmental conditions affecting cold-water coral ecosystems over relatively short distances of the order of a few 100km, driven by interaction with different water masses. Moreover, future climate change is likely to alter ocean circulation patterns at both regional and local scales. In addition to natural short-term variability, ecosystems are thus likely to have to adapt to longer term changes in water mass properties including pH and aragonite saturation.
A transect across the Rockall Trough west of Ireland, from 53N to ~54.5N has been repeated annually since 2009 by the Marine Institute with NUI Galway, and shows considerable variability in water masses each year. This transect does not gather data within the canyon ecosystems along the flank of the Rockall Trough, so in 2018, two consecutive surveys collected hydrographic data and carbonate chemistry samples in canyons along the eastern flank of the Rockall Trough, over a distance of ~ 600km. This study examines the differences in environmental conditions that organisms in these canyons may be experiencing north and south of the annual transect. Our results show both the different water masses impinging on the canyons north and south, and how these water masses and their mixing strongly control the carbonate chemistry. While waters in the southern canyons are influenced by warm, high-salinity Mediterranean water, northern canyons are much fresher and cooler, with a less pronounced oxygen minimum at mid-water depths of 800-1200m. The more saline southern waters are accompanied by increased alkalinity and dissolved inorganic carbon, resulting in lower pH and aragonite saturation states at depths where benthic ecosystems such as cold-water corals occur. Such variability in water properties in a relatively small area like the Rockall Trough highlights that there are many different niches for marine fauna. Oceanic changes including higher $CO_2$ levels may drive organisms closer to their tolerance limits in an already highly dynamic environment, but may also disclose both hotspots, areas where stressors are likely to increase, and refugia, areas where stressors may remain unchanged or reduce.

**Keywords**: ocean acidification, cold-water coral ecosystems, canyons, environmental variability, hydrography, Rockall Trough

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# CM 440: Harmful Algal Blooms - distribution, modelling and predictive forecasting along the Atlantic margin of Europe

Dave Clarke, Keith Davidson, Bengt Karlson, Peter I. Miller, Eileen Bresnan, Andrey Kurekin, Junfang Lin

Harmful Algal Blooms (HABs) are naturally occurring events which often result from rapid increases in the growth and abundance of particular species of plankton due to favourable environmental conditions. These events can result in a number of harmful effects to marine ecosystems including mortalities of marine flora and fauna, water discolouration, surface foaming, oxygen depletion, and socio-economic losses through mortalities of farmed fish and shellfish harvesting closures, and can cause food safety human illnesses through the consumption of contaminated shellfish. Therefore, it is critical that food businesses, aquaculture operators and regulatory authorities have access to in-depth knowledge of their regions' HAB profiles through historical and *in-situ* monitoring, and also the capabilities to provide models and remote sensing for predictive forecasting of HAB events.

The recent IOC UNESCO Global HAB Status Report documents the diverse range of harmful algae events recorded in the North East Atlantic annually, with Diarrhetic Shellfish Toxins causing the most regionally widespread closures along the Atlantic coast of Europe. Paralytic Shellfish Toxins were less common but their consequences were more severe. Regional diversity of HAB events can be observed with impacts from Azaspiracids most frequently recorded in Ireland, fish mortalities from haptophytes and dictyochophytes recorded in Scandinavia, whereas Cyanobacteria caused problems mainly in the Baltic Sea. Impacts from benthic HABs have increased in frequency with Ciguatera Poisoning recorded in the Canary Islands and Madeira.

Recent and current projects focusing on the early detection, risk assessment and warning systems for HABs and their impacts on aquaculture are being developed in several coastal areas, and are discussed here. The Interreg Atlantic Area funded PRIMROSE (Predicting the Impact of Regional Scale events on the Aquaculture Sector) project advanced the capacity of North East Atlantic area countries to provide the aquaculture industry and its regulatory authorities with a range of tools and outputs to enhance the predictive forecasting of the onset of HAB events. These included the development of a report generator for automated HABs bulletins, a distributed WebGIS portal (https://primrose.eofrom.space/) and improvements to dataset layers in providing information on satellite remote sensing, in-situ analysis, and particle (cell) tracking hydrodynamic models. Improved risk assessment through "traffic light" alert systems has enabled the aquaculture industry to improve risk assessment and decision making during a HAB event.

**Keywords:** Harmful algal blooms, modelling, forecasting, prediction, seafood safety

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# CM 453: Oceanic fronts in the Northeast U.S. continental shelf: Applications for fisheries oceanography

Kimberly J. W. Hyde, Sarah L. Salois, Adrienne M. Silver, Avijit Gangopadhyay, Glen Gawarkiewicz

Oceanic fronts are narrow zones of enhanced horizontal gradients of water properties that represent major biogeographical/ecosystem boundaries and are often associated with enhanced primary productivity and biological hotspots of marine life and fishing. Using satellite imagery from high-resolution ocean color and thermal sensors we generated a time-series and climatology of sea surface temperature (SST) and chlorophyll (CHL) frontal gradients in the Northeast U.S. Continental Shelf Large Marine Ecosystem. We applied thresholds (0.4°C for SST and 0.06 $mgm^{-3}$ for CHL) to isolate prominent frontal features from the frontal gradient imagery and created metrics such as probability, intensity, persistence, and location of coincident SST and CHL fronts. The frontal climatologies document spatial, seasonal, and interannual variability of a variety of fronts in this region including tidal mixing fronts around Georges Bank and Nantucket Shoals, and the Shelfbreak Front, the boundary between the Slope Sea and continental shelf water masses.

In this study, we track the location and strength of the Shelfbreak Front and associated primary productivity in conjunction with shelf-break exchange processes such as warm core ring streamers and Slope Sea intrusions. Both warm core rings near the shelf-break and Slope Sea intrusions onto the continental shelf can affect the position and strength of the Shelfbreak Front and enhance primary productivity through upwelling of deep-water nutrients. Changes in these oceanographic shelf-break processes can affect critical marine habitats, aggregate prey, alter seasonal movement of fish and marine mammals, and influence fishing. For example, we identified relationships between the spatiotemporal distribution and increased catch of northern shortfin squid, *Illex illecebrosus*, and CHL frontal and warm core ring metrics. Thus, the isolation and tracking of SST and CHL frontal dynamics can be used to identify locations of high productivity while also having broad applications for the assessment and management of living marine resources. For instance, quantified frontal dynamics at ecologically and economically relevant temporal scales could be key inputs in dynamic ocean management tools to help fishers and managers evaluate how to sustainably allocate fishing effort.

**Keywords:** ocean fronts, satellite remote sensing, shelf-slope exchange, Shelfbreak Front, productivity

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# CM 455: Integrated trend analysis at regional scale hides finer scale dynamics in the Bay of Biscay

Sigrid Lehuta, Luca Marsaglia, Morgane Travers-Trolet

Integrated trend analysis (ITA) aims at monitoring and reporting major changes and concomitant trends in the components of an ecosystem. However, the delineation of such an entity is often fuzzy and it is questioned how sensitive ITA conclusions are to the spatial scale considered. The Bay of Biscay (BoB) subregion (ICES division 8ab) is an example of an area subject to strong physical and anthropogenic pressures that are unevenly distributed but still considered as a management unit. In the BoB, physical environment creates both latitudinal and longitudinal contrasts between: i) a broad plateau in the North and a very narrow continental shelf in the South and ii) coastal areas highly influenced by the two main rivers, a mud bank where sediments deposit, and offshore areas influenced by the topography of the shelf break. The fishing pressure and other anthropogenic activities also are heterogeneously distributed mainly in relation to the distance to the coast.

The aim of our study is to assess if the global trends identified at the BoB scale by ITA are generally valid for the entire BoB or if they mask heterogeneous ecosystem changes depending on the spatial unit considered. To do so, our study first focusses on identifying contrasted habitats intended as homogenous areas in terms of physical and ecological characteristics. Second, in each selected contrasted habitat, trend analyses are performed using biological survey data on the demersal and pelagic communities. Results were then compared across habitats.

Analysis of fish species trends over the available time series shows that in the coastal habitat, demersal species biomass has mainly decreased, while in the two other habitats, demersal species biomass has increased. The opposite pattern is observed for pelagic species. When assessing trends of species mean weight, both demersal and pelagic fish species show a decreasing trend in their mean weight, regardless of the habitat.

Such results illustrate that regional patterns observed at the Bay of Biscay scale hide the coastal biomass dynamics that are opposite to the dynamics observed offshore, maybe due to different anthropogenic or environmental pressures near the coast, to displacement of populations in time or to the uneven occupation of space by different life stages. Conversely, decrease of mean weight is homogeneous over the region, which could be linked to large-scale pressure, such as climate change.

**Keywords**: Integrated trend analysis, Bay of Biscay, spatial scale, habitats, demersal, pelagic

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# CM 457: Spatio-temporal distribution of the North Sea winter protozooplankton community and size-structure between 2013 and 2021

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Interactions between phytoplankton and mesozooplankton have been well-studied in the North Sea over large spatiotemporal scales in the past. However, studies that include the protozooplankton component as a central link between the base of the food web and higher trophic levels are scarce. This overlooked small-sized component of the plankton community is a vital link in marine food webs, grazing on phytoplankton standing stocks and in turn providing food for larger mesozooplankton. During periods of low productivity, such as in winter, more carbon is recycled via the microbial loop compared to the classical, linear food chain (e.g. from large phytoplankton to copepods to higher trophic levels) and thus the role of protozooplankton is expected to be vital. Here, we monitored the broad-scale distribution of the winter protozooplankton community and size-structure in the North Sea over nine consecutive years (2013-2021). Samples were taken during the ICES coordinated International Bottom Trawl Survey Q1, a routine, large-scale fisheries survey covering the entire North Sea basin in January-February. The community was mainly dominated by heterotrophic dinoflagellates followed by ciliates and silicoflagellates with total mean abundances between 1099.0 and 3470.6 Ind $L^{-1}$. Annual mean protozooplankton biomass ranged between 1.6 to 2.4 µg C $L^{-1}$ where ciliates contributed 55% to the total biomass. We observed a substantial inter-annual variability in both community composition and size structure. Moreover, we examine possible drivers for these changes and discuss how the small-sized plankton community is responding to varying environmental conditions during winter.

**Keywords:** North Sea, winter, protozooplankton, size, broad-scale, community composition

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# CM 461: Future offshore windfarm effects on ecosystem productivity: upscaling to the southern North Sea

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The North Sea has become a focus of renewable energy production with an increasingly large number and size of offshore wind farms (OWFs) planned in the German and British sectors in far deeper waters than before. As the North Sea is also a complex ecosystem that is strongly driven by hydrodynamical features such as tidal fronts and seasonal stratification, these large OWFs can be expected to impact the ecosystem dynamics in the area. Here, we use the coupled ecosystem model ECOSMO, previously used and validated for the area, to explore the consequences of large scale OWFs for marine ecosystem productivity. The model is forced with results from two model simulations of a high-resolution regional climate model, one with and one without implemented wind-farm parameterization using a near future wind farm scenario that includes existing and planned OWFs. Our major research focus lies on the large-scale, integrated effects imprinted on the ocean physics and ecosystem by changes in the atmospheric conditions rather than small scale processes. The simulations were integrated over the time period of one year and the average system response was analysed. The model shows a clear and direct response to the modifications in the atmosphere with respect to surface current speed, sea surface elevation and vertical transport depending on the wind direction. However, these immediate impacts are not visible in the ecosystem variables. Instead, the ecosystem shows an integrated (over the year) response related to the general modifications in stratification, transport pattern and bottom shear stress. It becomes evident that we cannot conclude a general increase/decrease pattern of change in ecosystem productivity, instead we can see changes in both spatial distribution and phenology of the lower trophic level ecosystem components, which we expect to be relevant for fish connectivity pattern and early larval survival for economically relevant fish species.

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# CM 469: Using an ecosystem model to hindcast changes in the North Aegean Sea (Eastern Mediterranean) and explore fishing and climate scenarios

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An Ecosim time dynamic ecosystem model was developed for the North Aegean Sea ecosystem (Eastern Mediterranean, Greece) after fitting to catch and relative biomass time series for the period 1993-2020. The fitted model included fishing (fishing capacity with a technology creep factor), Sea Surface Temperature (SST), trophic interactions and a Primary Production (PP) Anomaly as drivers, highlighting the synergistic effect of environmental and anthropogenic processes during the hindcast period. Trends in biomasses, catches and ecosystem indicators confirmed that substantial changes have been observed in the past three decades, summarized by a decline from 1993 to 2010 and a strong recovery thereafter. Sea warming scenarios for the period 2021-2050 indicated contrasting responses to increased temperature among the main commercial functional groups (FGs), i.e. winners and losers of climate change. As expected, changes were amplified in the IPCC-RCP 8.5 (worst-case scenario) compared to the IPCC-RCP 4.5 (moderate scenario), however this was not true for all FGs, highlighting the existence of complex trophic effects. Simulations of changes in productivity - a probable and important effect of climate change associated with high uncertainty - had relatively straightforward effects on the ecosystem, i.e. overall positive under increased productivity and the opposite when directing to more oligotrophic conditions. Two scenarios of 10% and 25% reduction in fishing effort revealed quick increases in the biomass of most FGs which were coupled with lower catches due to reduced fishing, except for six FGs that their population increase was high enough to compensate for the reduced effort. Although the 25% effort reduction resulted in high recoveries in the short term, it didn't lead to constantly high biomasses for all species that were initially favoured, and this was reflected in their reduced catches towards the end of the forecast period, in contrast to the more moderate fishing reduction scenario. When impacts of reduced productivity were added to temperature effects, the model forecasted lower biomass increases for winners of sea warming and even higher decreases for losers. Biomass losses were mitigated by applying a 10% reduction in fishing effort but, with the exception of few pelagic FGs, this was not enough to counterbalance total losses in catches. The time dynamic model developed here is a useful tool to explain observed changes in the past and to understand directions of change in future simulations, as well as to advance EBFM in the area.

**Keywords:** climate change, food web, ecosystem modelling, ecosystem approach to fisheries, trophic interactions

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# CM 474: Oceanographic data products and services in support of the ICES community

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The Marine Institute is responsible for the provision of oceanographic and modelling services to the Irish government and the wider research community. Here, we describe some of the ongoing oceanographic research and data products under development:

(a) A near annual repeat hydrographic transect across the south Rockall Trough has allowed the development of a timeseries since 2004. This dataset was investigated for interannual variance and changes to physical and biogeochemical ocean properties. The capacity of ocean models, such as the Marine Institute NE Atlantic ROMS model and CMEMS reanalysis products, were assessed to add value, gap fill and deseasonalise the observational data. Hydrographic results were analysed alongside various fisheries datasets and ocean chemistry to investigate physical processes, biophysical relationships and implications for fish stock abundance and variability.

(b) The Marine Institute and Marine Scotland Science are developing a 50-year temperature and salinity climatology from CTD derived data of the NE North Atlantic shelf seas and the North Sea to constrain variation across a gridded field (1/6° longitude by 1/10° latitude) for stakeholder groups, such as fisheries, MSFD and academia. Comparison of three WMO 30-year baselines within the climatology highlight long-term ocean climate change and are available to ecosystem response research. An open source product is planned with online visualisations through a bespoke user focused landing page.

One of the remits of the Marine Institute is to provide ocean data publicly from a wide collection of platforms (e.g. Irish Marine Data Buoy Observation Network), through services, such as ERDDAP, data catalogues and data requests. In developing automated and standardised processing and quality control systems, through services such as Jupyter Notebook, we can provide a rapid turnover of quality assured oceanographic data from source to client. This is particularly useful when accessed in relation to fisheries studies (e.g. variability around spawning grounds), to climate studies (e.g. identifying ocean heatwaves) or for regulatory advice and decision making (MPAs, SACs, spatial planning etc.).

As the ocean data sphere evolves, we will continue to drive technological development, research and collaborative scientific endeavour, more pressing than ever in the face of accelerated earth system change.

**Keywords:** Oceanographic data products, ocean climatology, northeast North Atlantic, observational ocean platforms, hydrographic timeseries transects, Rockall Trough

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# CM 508: An assessment of extreme marine events on habitats and aquaculture off the SW coast of Ireland

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Climate change is impacting the ocean with increased warming, acidification and deoxygenation observed in many regions globally. Such changes in marine environmental conditions threaten to modify natural habitats and ecosystem structure. The objective of this work is twofold: firstly, to evaluate the impacts of extreme marine events, such as marine heat waves, on marine ecosystems and the aquaculture sector located in SW Ireland; secondly, to design a system that can predict harmful extreme events that our co-developers in aquaculture have asked us to investigate.

Remote sensing together with hydrodynamic and biogeochemical models were used to gather surface and at-depth seawater temperature, pH and dissolved oxygen data in coastal waters. The frequency, duration and intensity of marine heat waves and other extreme events were examined together with biological data to identify undesirable thresholds. Data products developed were overlaid with existing spatial data on habitats distribution, Special Areas of Conservation (SACs), biological Essential Ocean Variables (EOVs) and at established aquaculture sites, where different target species of environmental and economic interest were considered, resulting in an assessment of sensitive habitats to changing environmental conditions. These results along with a 6-day extreme marine event forecasting system are presented.

**Keywords:** climate change, extreme events, habitats, Special Areas of Conservation, Essential Ocean Variables

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# CM 523: Stakeholder workshops to develop simulation modeling tools for evaluating impacts of offshore wind on fishery-independent survey operations and data products

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Offshore wind development in the Northeast US will prevent the Northeast Fisheries Science Center (NEFSC) Multispecies Bottom Trawl Surveys from accessing certain areas in the historical sampling range. The Survey Simulation Experimentation and Evaluation Project (SSEEP) was established to understand the consequences of these spatial interactions and to quantify the impacts of preclusion of the survey to wind areas under a range of scenarios, including effects of habitat change as a result of wind installation, to understand resulting impacts to survey data products, and evaluate the relative performance of supplemental monitoring strategies aimed at maintaining the integrity of data streams that are relied upon for scientific advice for fisheries management. A critical component of the participatory approach chosen for SSEEP is a series of stakeholder workshops to ensure that both the structure and design of the models, and the questions the model framework will be used to evaluate, are relevant to the concerns and scenarios most likely to be faced by the monitoring, assessment, and management of the expected overlap between offshore wind and the bottom trawl survey. Two initial workshops were held in January and February 2022 to co-develop project scope and tools. Workshop #1 was aimed at understanding the questions most of interest for the simulation exercise to answer, while Workshop #2 focused on defining a range of scenarios for mechanisms underlying system change, wind installation, and sampling alternatives.

Here we describe our participatory approach to engagement before, during, and following these workshops, and provide an overview of project and workshop design, process, and synthesis of workshop outcomes as they pertain to simulation model formulation. Workshop components included establishing terms of reference based on simulation modeling needs, reducing variations in participant interpretation by establishing common language and background, incorporating guidance from an expert Steering Committee, and engaging with a large set of stakeholders representing scientific, decision-maker, and industry groups from both fisheries and wind sectors. We cover how the participatory approach was optimized in a virtual setting, the simulation modeling priorities identified by stakeholders, and the differences between project team expectations for the terms of reference and final outputs. Overall, feedback from the workshops provided unique insights and prioritization of the simulation modeling tools to be developed due to the inclusion of stakeholders in the decision-making process, and was further enriched by involving participants of different sectors and specialties.

**Keywords:** offshore wind, participatory decision making, stakeholder engagement, remote engagement, fishery-independent surveys

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