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Theme session Report

An Unexpected Journey - continuing the pathway for oceanography in ICES science and advice

Conveners: Francisco Campuzano (Portugal), Tomasz Dabrowski (Ireland), Tycjan Wodzinowski (Poland)

During the 2022 ICES Annual Science Conference, the uptake and visibility of oceanography in ICES science and advice was explored as part of a network session and a theme session. The 2023 session is a continued effort towards incorporating environmental information on the ocean climate into fisheries, aquaculture and ecosystem science.

This theme session invited presentations and posters to demonstrate successful integration from physics to "fish" (or other ecosystem components), as well as examples of good practice. A key focus was to provide dialogue, networking, and information sharing opportunities for scientists from across ICES community.

ICES Working Groups on Oceanic Hydrography (WGOH) and on Operational Oceanographic products for Fisheries and Environment (WGOOFE) will gather key messages from the 2022 and 2023 sessions to ensure we continue our path along the "Unexpected Journey" to further integration of oceanographic data and information in ICES work.

The submissions to this session met the expectations of the organizers. Of the eighteen abstracts, nine were accepted for oral presentation, and the rest were admitted to the conference as posters.

Content

The panel was held on September 14, 2023 from 1:30 to 2:30 pm in two sessions. The panelists participated in a hybrid form. Most of the presenters attended in person. The in-person attendance on both sessions was around 50 persons.

Four presentations were delivered during the first part:

1. *Oceanography as a tool in predicting larval movements and recruitment,* A. Marie Power, C. Lordan, R. McGeady
2. *Filling knowledge gaps with Lagrangian IBMs: aspects to be considered,* L.M. García-García, M. Ruiz-Villarreal, G. González-Nuevo González, P. Sampedro-Pastor, J. Otero
3. *Physical oceanography as a contributor to explain small pelagic eggs and larvae dispersion Rosa,* T., Moura A., Peliz A., Piecho-Santos M.
4. *Identified Floating Objects (IFOs) in the Bay of Biscay for biophysical studies,* L. Ferrer, Y. Sagarminaga, Án. Borja, I. Zorita

It concerned modeling the movement of marine organisms taking into account the movements of water masses and ocean currents.

After the break, further five presentations on more diverse topics were presented:

5. *Forecasting future fisheries: integrated ensemble projections and species distribution modelling to promote resilience in small fisheries,* E. Ramirez-Romero, C. González-Andrés, D. Macías, B. Guijarro, M. Bonnet Dunbar, E. Massutí, G. Navarro

6. *Developing end-to-end models to simulate the dynamics of linked river and marine ecosystems* X. Yang, Y. Chen
7. *Temporal shifts in plankton community composition and phenology from the Bermuda Atlantic Time-Series (BATS),* J. Vad, N. R. Bates, L.-Anne Henry
8. *Multiple roles of oceanography in a coastal upwelling ecosystem: from plankton abundance and community properties to fish dynamics*, J. Otero, A. Bode, M.A. Louro, M. Ruiz-Villarreal
9. *Quantifying frontal dynamics at ecologically and economically relevant spatial and temporal scales,* S. L. Salois, K. J. W. Hyde

Conclusions

From the presentations and the discussions that took place during the panel, it is clear that despite the increasing accuracy of mathematical models, in-situ observations are still necessary. This includes the movement of water masses, physical and chemical parameters of water, changes in the behavior of marine organisms that constitute not only the living resources of the seas but also other parts of the trophic network. Undoubtedly, this will contribute to the creation of more accurate predictions of environmental models in the oceans. The introduction of new variables into the models allows for a new perspective on the importance of the influence of individual parameters of the phenomena described, which is confirmed by experimental observations. For example, this has taken place in tracking the migration / drift of the Portuguese Man O'war, taking into account the wind, the Ekman transport model and the individual physiognomy of organisms.

It is extremely important to develop work on the coupling of biological and oceanographic models to better predict the recruitment and management of living marine resources. This will also allow a better understanding of upcoming threats to individual species, their trophic relationships and habitats. Such model development is indispensable not only for predicting the future of the oceans, but also for deepening our knowledge of its past. Backward modeling, based on archival data, makes it possible to identify breakpoints in its changes. Developing coupled biological-physical models will enable taking into account more factors influencing the occurrence of breakthrough-like conditions in the evolution of the environment, and this can contribute to better prediction of the future of our planet. This is particularly important in the context of raising water temperatures and resulting changes in the behavior of marine organisms.

The observations themselves, which are the source of data for models, also need development. As with the models, development is needed not only of tools that give the ability to simultaneously observe the behavior of organisms and the physical parameters of water. We should target the construction of a network of interconnected measuring devices, and observations from ships and drones. Such activities are already underway, but still require standardization of operating rules and international cooperation.

Combining biological and physical models will be a useful tool for decision makers to take action to protect the environment and to ensure sustainable marine management.

Feedback

In view of the topics and conclusions from the presentations, we believe that the upcoming ICES ASC 2024 should also include a panel on oceanography. This will allow to present further progress in the development of this field of science, which is the beginning and background of all studies of ocean resources.

The conveners wanted to thank the organizers for the professional preparation of the conference room, the help of the volunteers and the operators of the live webcast.

Contents

CM 153: Oceanography as a tool in predicting larval movements and recruitment

Anne Marie Power[1], Colm Lordan[2], Ryan McGeady[3]

Many exploited stocks have pelagic life stages, which are critical to stock health yet also difficult to count, due to their ephemeral nature and high mobility. However, oceanic drift can be modelled in these stages, overcoming such practical issues. Some of the oceanographic drivers of larval transport (e.g., temperature changes in the water column) are simultaneously critical drivers of larval development and are profoundly implicated in larval survival. This presentation examines the information provided by coupled biological-oceanographic models for larval transport in small lobster (*Nephrops norvegicus*), a species which is highly sessile in the adult stage, but which can be carried away from suitable mud habitat patches as larvae, impacting negatively on its survival. The contrasting situation also occurs, where larvae are donated from a nearby patch and may impact positively on local recruitment. Focussing on the Irish Functional Management Units (FUs), we examine some of the factors affecting larval retention probability, including the oceanographic gyre in the Irish Sea, the effect of release date (hence water column temperature) on larval retention/survival, as well as the effect of global warming in this region. We examine trends in a simulated time-series of exchange (retention and donation) between Irish FUs, as well as larval donations to further afield. Finally, we consider the circumstances where coupled biological-oceanographic models may serve as a proxy for recruitment and offer an early warning of changes negatively impacting stocks. Overall, we expect that continuing improvements in regional and global hydrographic models offer an ever-increasing capacity to simulate larval transport and survival to better understand drivers in stock abundance, or even future-proof stock management with regards to climate changes.

Keywords: *Nephrops*, larval transport, retention probability, stock changes

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CM 203: Filling knowledge gaps with Lagrangian IBMs: aspects to be considered

L.M. García-García[1], M. Ruiz-Villarreal, G. González-Nuevo González, P. Sampedro-Pastor, J. Otero

Lagrangian Individual-Based Models forced with 3D hydrodynamic models are frequently used to study the advection and dispersion of the planktonic stages of small pelagic fish, considering also their biological behaviour (growth, vertical migration patterns, etc.). Different layers of complexity can be added to these models to build an end-to-end model, such as using the results of a biogeochemical model to feed the larvae stages in the calculation of growth and mortality, adding fish movement, etc. Environmental variability during the Early Life Stages (ELS) of fish has been recognized to be key for recruitment and connectivity studies. Modeling approaches that consider the interplay of the physical and biological traits involved have become established tools.

Uncertainty in these models comes mainly from two sources: 1) our lack of knowledge regarding certain aspects of the biological behaviour of the species and 2) the underlying effect of the physics, represented by the forcing of hydrodynamic models. In the first case, Lagrangian IBMs can be used to reduce some of the biological uncertainties by exploring different behavioural hypotheses that can be compared with the available observations to constrain the most plausible options. Focusing on two species of economic interest in NW Iberia -European sardine and common octopus- we will provide examples that demonstrate that Lagragian IBM models are useful tools to fill the knowledge gaps and to help building a full Early Life Stages Model for these species. The uncertainties related with the forcing of hydrodynamic models have an enormous influence on the model results. In this case, model aspects such as resolution and the parametrization of different physical processes are key and require attention. In this contribution, we will also show how we will tackle these problems in the DEMON project and show some results focused on biological applications, such as Harmful Algal Bloom tracking and Iberian sardine connectivity.

Keywords: Lagrangian models, IBMs, uncertainties, recruitment, connectivity

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CM 210: Forecasting future fisheries: integrated ensemble projections and species distribution modelling to promote resilience in small fisheries

Eduardo Ramirez-Romero[1], Cristina González-Andrés, Diego Macías, Beatriz Guijarro, Martha Bonnet Dunbar, Enric Massutí, Gabriel Navarro

Species distribution models (SDMs) coupled with climate projections are typically used to forecast climate change-derived spatial shifts. However, uncertainty assessment is commonly carried out on the SDM (statistical model) and not on the climate projections (physical model). In this study we gather 4 different Regional Climate Models (from CMIP5) to project the spatial distribution of the deep-water rose shrimp (*Parapenaeus longirostris*) in the Western Mediterranean (Spanish waters). This species showed a recent northward expansion trend in Spanish waters associated to the warming of intermediate waters (ca. 200m).

Using the unique SDM Generalized Additive Model (GAM) representing species niche, based on sea bottom temperature and depth, we forecasted the expected density and presence of the shrimp in the years 2010, 2050, and 2100, and under the climate scenarios RCP4.5 and 8.5. Forecasting future dynamics of the Mediterranean Sea is particularly complex due to local and intense processes, such as the formation of deep-waters around the Gulf of Lion derived from atmospheric forcing. However, all the simulations captured the same response to climate change and a reasonable robustness of the predictions. A northward increase in species distribution and abundance linked to warming is projected in the whole area. Consequently, the most distant projected year (2100) and the warmest scenario (RCP 8.5) present the highest densities and range expansion.

Within the current context of global warming, uncertainty assessment and ensemble simulations are crucial for supporting stakeholders in developing climate change response strategies and promote resilience in small fisheries.

Keywords: *Parapenaeus longirostris*, ensemble, SDM, RCM, climate change

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CM 232: Integrating oceanography and pelagic fish distribution in the Bay of Biscay using a glider

Ivan Manso-Narvarte[1], Guillermo Boyra, Asier Nieto, Beatriz Sobradillo, Udane Martinez, Anna Rubio

Gliders are Autonomous Underwater Vehicles (AUVs) that profile the water column without propellers in a silent and non-invasive way for the underwater environment. Changes in the internal density, the linear motion of the batteries inside and the wings produce a forward motion in a saw-tooth pattern that allows the glider to navigate very efficiently, covering long distances and periods of time. Depending on the installed payload they can perform high-resolution measurements of different hydrographic, ecological or environmental magnitudes providing information of great value about the state of the ocean. The use of echosounders installed on gliders is a quite novel approach for obtaining high-resolution data on fish species distribution which can be combined with simultaneous hydrographic and environmental measurements. In this study, the potential of gliders for integrating oceanography and pelagic fish ecology is showcased.

In September 2022, “Xixili” glider collected temperature, salinity and pelagic fish and vertebrae acoustic backscattering data by means of a Conductivity Temperature Depth (CTD) device and an echosounder along transects perpendicular to the Basque coast (SE Bay of Biscay) in the upper 200 m of the water column. Several of the glider transects were concurrent to the JUVENA survey, which provided a context of spatial distribution and composition of pelagic fish and vertebrate species in the area. This survey was conducted onboard the research vessel Angeles Alvariño and based on a trawl-acoustic methodology using calibrated, split-beam echosounders and pelagic trawl hauls. The information gathered during JUVENA was used to validate the acoustic data of the glider, which also provided acoustic and hydrographic information on the water column before, during and after a 5-day storm, as well as in the weeks following the JUVENA survey. These data are explored to study the effects of the changing environmental conditions on the small pelagic community in the upper water column.

Keywords: glider, fish, pelagic, storm, echosounder, acoustics, Bay of Biscay

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CM 246: Using ecological and oceanography techniques to evidence fish stock and habitat benefits of Offshore Aquaculture to inform future management and policy

Llucia Mascorda-Cabre[1], Emma Sheehan

Reporting lower environmental impacts and higher growth potential compared to traditional inshore farms, offshore mussel farming has the potential to become one of the most sustainable, large-scale source of healthy protein. With the potential to provide a wide range of benefits such as food security and economic resilience, enhancing the seafood industry and contributing to marine conservation goals as a Biodiversity Net Gain industry. By creating structure and excluding the damaging effects of bottom-towed fishing, offshore bivalve aquaculture has the potential to restore degraded fishing grounds and contribute to ecosystem services whilst providing one of the most sustainable sources of protein. By annually monitoring the UK's first offshore, long-line mussel farm since it was first developed in 2013 in Lyme Bay UK, the University of Plymouth has used ecological and oceanographic techniques to evidence how the farm has delivered increases in pelagic, epi-benthic and infaunal biodiversity.

To further assess the ecosystem services and benefits of this development and assess the restoration of essential fish habitat (EFH) extent, biodiversity and associated healthy fish stocks (biomass) and its connectivity with the adjacent MPA and spillover effect to fishing grounds, this project's methodology is based on a multi-trophic level approach combining ecological and oceanography techniques. This project is using cutting edge, cost-effective and non-destructive remote sampling techniques such as an echosounder, multibeam and ground truthing cameras deployed from local fishing boats to produce high resolution data on the presence, biodiversity and extent of EFH (mussel reef on seabed and water column) and associated mobile species. Fishes and crustaceans are also being tracked using acoustic tags via the world's first multi-farm (mussel, scallop, and seaweed) aquaculture telemetry network.

The outcomes of this project will fill evidence gaps and deliver essential evidence regarding the role of offshore aquaculture as a nature-based solution towards sustainable fisheries management and inform Fisheries Management Plans, the Mariculture Strategy, Biodiversity Net Gain, Sustainable Development Goals and Global Ocean Alliance targets.

Keywords: Offshore aquaculture, conservation, biodiversity, ecology, fish stocks, mussel farm, MPA, multibeam, acoustic survey, echosounder

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CM 287: Developing end-to-end models to simulate the dynamics of linked river and marine ecosystems

Xiangyan Yang, Yong Chen

Many fish species use both river and marine ecosystems to complete their life histories, emphasizing the ecological connectance between these two kinds of habitats. Meanwhile, at the interface of land and ocean, the discharge of estuaries may extend anthropogenic impacts along rivers into the marine ecosystem through biogeochemical and physical processes. As fisheries management increasingly strives for an Ecosystem Based Fishery Management approach, it is essential and necessary to consider river and marine ecosystems as a whole ecosystem considering both ecological and environmental interactions within these two habitats. To better understand the connectance and dynamics of linked river-marine ecosystems in the context of ongoing climate change and intensifying anthropogenic exploitation, end-to-end models which integrate ecosystem models with physical and biological processes are advocated. The Hudson River (HR) and New York Bight (NYB) provide critical habitats for many ecologically and economically important fish species, with the HR estuary serving as a corridor to connect these two areas. Using the data collected in the Hudson River Biological Monitoring Program and state and federal survey programs, we will first employ a combination of multivariate statistical methods and general regression analyses to identify spatio-temporal structure of various ecosystems included in this study and quantify the relationships between and among various ecosystem components (e.g., phytoplankton, fish community, benthic community) and environmental variables (e.g., temperature, salinity, DO, water quality). Such analyses will allow us to identify key drivers and stressors that regulate ecosystem dynamics and thus support further ecosystem modeling. By coupling the Object-oriented Simulator of Marine Ecosystems (OSMOSE) with biogeochemical model Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) and hydrological model Finite Volume Coastal Ocean Model (FVCOM), an end-to-end multispecies individual-based model will be built to model the trophic dynamics from plankton to top predators, within which the FVCOM-NPZD model describing the spatio-temporal dynamics of low trophic level (LTL) groups and the OSMOSE model describing the dynamics and interaction of high trophic level (HTL) species. The unknown parameters will be estimated from the model calibration by fitting the simulated species biomass and distributions to observed survey/stock assessment data. The parameterized and calibrated end-to-end ecosystem model can be used to explore how long-term changes in key environmental variables may influence the HR-NYB ecosystem dynamics and provide critical information for supporting ecosystem-based fisheries management and marine conservation in the HR-NYB ecosystem.

Keywords: end-to-end model, Hudson River, New York Bight, Ecosystem Based Fishery Management

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CM 325: Temporal shifts in plankton community composition and phenology from the Bermuda Atlantic Time-Series (BATS)

Johanne Vad[1], Nicholas R. Bates[2], Lea-Anne Henry[1]

Understanding how plankton communities respond to environmental variation is key to predicting the consequences of climate change on open-water ecosystems. As part of the Horizon 2020 iAtlantic project which aims to assess the status of deep-sea and open-ocean ecosystems across the Atlantic Ocean, we analysed time-series of phytoplankton and zooplankton community composition and size structure from the Bermuda Atlantic Time-series Study (BATS). Univariate statistical analysis of yearly phenological indices (characterising the timing of the spring bloom) were combined with multivariate approaches such as redundancy analysis and trajectory analysis to identify shifts in plankton composition and annual cycling between 1993 and 2019. We found that phytoplanktonic community composition changed significantly since the early 1990s with larger phytoplankton groups such as Diatoms and Cryptophytes decreasing in abundance over time and smaller groups such as *Synechococcus* and *Prochlorococcus* increasing in prevalence. In addition, biomass of small zooplankton groups (200 µm to 500 µm) significantly declined specifically between 2006 and 2012 while larger zooplankton taxa (2,000 µm) increased in prevalence during the same period. This contributed to a shift in total zooplankton biomass, which was found to increase until 2012 and then decrease in the following decade. Analysis of phytoplankton and zooplankton phenology revealed high inter-annual variability in the timing of the spring bloom. Despite this considerable level of natural variability, pronounced shift in the timing of the phytoplankton and zooplankton blooms to earlier in the year could be identified, which may hint to a potential mismatch between phytoplankton and zooplankton annual cycles in the later years of the time-series. These shifts in both phytoplankton and zooplankton community composition and phenology were related to changes in environmental conditions, specifically temperature, salinity, dissolved oxygen and CO_2 as well as nutrients concentrations. Indeed, under the effects of Climate Change, conditions in the Sargasso Sea are known to have changed. Temperature and salinity have both increased by 0.85°C and 0.11°C respectively while dissolved oxygen concentrations have declined by 17.76 µmol/kg since 1983 (Bates and Johnson, 2020). Our analysis provides clear evidence that the plankton communities at BATS have responded to Climate Change. How these shifts in the upper reaches of the water column have impacted transport of carbon to deeper settings is currently under further investigation.

Keywords: phytoplankton, zooplankton, BATS, community structure, phenology, climate change

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CM 326: Identified Floating Objects (IFOs) in the Bay of Biscay for biophysical studies

Luis Ferrer[1], Yolanda Sagarminaga, Ángel Borja, Izaskun Zorita

Using ships of opportunity and research vessels, since 2015 we have released a large number of Identified Floating Objects (IFOs) to study surface water circulation in the Bay of Biscay. Our IFOs are very small surface drifting buoys and natural cork stoppers for wine bottles. To date, these IFOs have been released in different areas of the Bay of Biscay. Understanding the surface water circulation in this bay will allow us to estimate the most likely region of origin and drift of algal blooms, eggs and larvae, sediments, oil spills, marine litter and peculiar organisms living at the air-sea interface, such as *Velella velella* (by-the-wind sailor) and *Physalia physalis* (Portuguese man-of-war). This information is essential for aquaculture and fisheries management, environmental impact studies and beach clean-up activities. For example, it is common to find in the Bay of Biscay algal blooms and tiny *V. velella* (< 5 mm long) during the spring season. Here we show that the wind, directly or indirectly, is the main mechanism controlling the drift of our IFOs. We found that our IFOs drift, on average, towards the east. This means that their drift depends more on the cyclonic conditions than on the anticyclonic ones. Furthermore, we found that it is a difficult task for our IFOs to leave the Bay of Biscay, suggesting that this bay acts as a retention region. Our results demonstrate how IFOs can help to understand surface water circulation. We anticipate our experiment with IFOs to be a starting point to obtain a reliable drift model. This model will allow us to study a wide range of biophysical processes in the open and coastal ocean regions. This research is supported by the following EU-funded projects: GES4SEAS (Achieving Good Environmental Status for maintaining ecosystem SErvices, by ASsessing integrated impacts of cumulative pressures; grant agreement no. 101059877; www.ges4seas.eu), OBAMA–NEXT (OBserving And MApping marine ecosystems – NEXT generation tools; grant agreement no. 101081642; www.obama-next.eu) and BIOTOX (Exploración de alternativas para minimizar el impacto de los cierres derivados de los eventos de biotoxinas en la Zona de Producción de Moluscos de Mendexa; grant agreement no. 00002-INA2021-33).

Keywords: Bay of Biscay, buoy, drift, IFOs, wind

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CM 353: Assessing the impact of an offshore longline mussel farm on local circulation in a highly hydrodynamic energetic bay

Llucia Mascorda-Cabre[1], Emma Sheehan, Martin Attrill, Phil Hosegood

Mussel aquaculture has rapidly expanded serving as an important supply of protein, but its development has been limited due to competition for coastal space and the associated environmental impacts of farming in inshore waters. Offshore aquaculture developments have the potential to overcome such issues. Offshore mussel farm studies report an increase biomass or numbers of benthic and pelagic organisms around the farm relative to control sites using the structure for shelter, refuge, and nursery. Coupled with the exclusion of fishing activities from farmed grounds, this may provide the potential to enhance both commercial and non-commercial species producing a spill over effect but also present the prospect for benthic habitats to be restored to previous state, serving as a de facto marine protected area (MPAs).

However, the effects of large offshore developments on water currents is still not fully understood. As high hydrodynamic regimes can have an effect on the dispersion of farm biodeposits and organic loading, farm-induced flow alterations have the potential to impact on water residence time, particle and sediment dispersal (including larvae and biodeposits) and seabed sediment resuspension which in turn can have its own ecological impacts.

Farm-induced flow changes of the UK's first large scale suspended longline mussel farm were assessed by a combination of oceanographic mooring and vessel-mounted acoustic Doppler current profiler (ADCP) measurements. This study demonstrates that suspended mussel farms produce within-farm current attenuation, but this is in turn compensated by an acceleration of the flows above, beneath the ropes (downwelling) and around the farm's flanks. As the farm accelerated currents towards the bed, it does exactly the opposite to what is achieved naturally by seabed friction, which can have an impact on the ecology below and near the farm. Contrary, waves created by storms were attenuated by the farm.

Results demonstrate that velocity changes are dependent on the different tidal phases, the design of the farm as well as the density and amount of developed ropes which provide more or less drag. This farm was designed to withstand the highly hydrodynamic conditions of the area thus, headlines were highly separated from one another, suspended 3m below the sea surface and placed in the same direction to the flow, minimising the farm's drag. Having a thorough understanding of the hydrodynamics of the area is important on a range of scales and each of those important for a range of ecosystem services. Due to the novelty of such industry, this study will contribute to decipher the knowledge that the scientific community has in regard to offshore aquaculture-environment interactions.

Keywords: Offshore aquaculture, mussel farm, hydrodynamic flow, currents, ADCP, biodeposit, ecosystem service, environmental impacts

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CM 372: Multiple roles of oceanography in a coastal upwelling ecosystem: from plankton abundance and community properties to fish dynamics

J. Otero[1], A. Bode, M.A. Louro, M. Ruiz-Villarreal

Upwelling systems are characterized for the fueling of cold and nutrient-rich waters from the deep often seasonally and through sequences of pulses and relaxation periods. This feature, together with the input of nutrients from continental sources, fertilizes the water-column inducing the blooming of primary producers that propagate a cascade of reactions in secondary producers and upwards the food web. As a result, these ecosystems are within the most productive regions in the ocean and sustain the largest marine fisheries. However, many aspects that complicate relationships within and across the different food web compartments still remain to be fully understood in this a priori simple oceanographic route. Using data from three decades of physical, chemical and plankton observations at a shelf station off A Coruña (NW Spain), we examined how oceanographic variability modulates the responses of the phytoplankton and zooplankton assemblages, affects the pelagic ecosystem functioning across trophic levels, and ultimately influences the population dynamics of planktivorous fish. Phytoplankton species had different responses to the physical drivers mediated by their functional traits with fast-growers though less efficient in taking up nutrients thriving in favorable upwelling conditions underpinning the dominance of intermediate size species during blooms. At the assemblage level, phytoplankton used resources more efficiently at greater upwelling intensity. Additionally, both richness and when diatoms dominate were important for maintaining planktonic biomass production suggesting the relevance of complementarity and selection effects, respectively. By contrast, zooplankton used resources less efficiently when phytoplankton biomass was dominated by diatoms suggesting that diatoms would be a poor food source for zooplankton. Furthermore, these relationships were not static but varied annually. More specifically, primary production responded more steeply to changes in phytoplankton diversity with higher species' synchrony, lower Taylor's power law (less variability of abundant species) and lower size-abundance scaling (increased importance of smaller cells). Moreover, phytoplankton diversity-productivity relationships were steeper in years with higher upwelling and sea surface temperature seasonality, and more predictable temperature. Overall, significant shifts in plankton composition were observed by the end of the 1990s. At that time, the stock size of sardine also shifted from high to low values. Population dynamics of this fish was, in part, modulated by the primary production responses to phytoplankton diversity, with recruitment favored in years when productivity was dominated by diatoms that had higher capacity of producing carbon resources more efficiently, which in turn, would presumably benefit the sardine early life stages increasing their recruitment success.

Keywords: upwelling, nutrients, temperature, phytoplankton, zooplankton, diversity, small pelagic fish, NW Iberian Peninsula

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CM 375: The Portuguese automatic ocean observing system

A. Miguel P.S.[1,2]

The Portuguese Ocean Observing System (OBSERVA.PT) is the main ocean observation program under development and ongoing at the Portuguese Institute for the Sea and the Atmosphere (IPMA), in collaboration with the Centre of Marine Sciences of the University of Algarve (CCMAR), in which the main objective is the development of autonomous ocean observing systems. It will presented the ongoing systems and future plans for enhance the existing ones. Totally autonomous systems (no human action), integrating several meteorological and oceanographic parameters are being installed on board fishing and cargo vessels. These observing systems allow high-resolution in situ monitoring and spatial coverage of the ocean and coastal areas. The use of fishing and cargo vessels is one way to make long-term scientific measurements sustainable, since these vessels ply the ocean and coastal seas at all times of the year and in almost all-weather conditions. These data with large space coverage and time resolution, mainly in the coastal regions, is difficult to obtain with other observing platforms. A good example of a collaboration between the fishing industry and science is the installation of a "ferrybox"-type (Undersee_water) equipment in a cod trawler vessel that sailed from Portugal Mainland to the Grand Banks of Newfoundland (May-June 2022) and to the Barents Sea (September-December 2022). The "ferrybox" measured continuously temperature, salinity, chlorophyll, dissolved oxygen, pH, ORP and turbidity from water pumped from the surface. However, the ferrybox only measured surface parameters and the next development will be towards methodologies for the installation of sensors on fishing gears that allow water column measurement. It is also showed a good collaboration between science and the shipping industry with the installation of meteorological stations on board cargo vessels that sail to the Portuguese Islands (Madeira and Azores), also under the Portuguese Voluntary Observing Ships (VOS) programme in the frame of the international programme of the World Meteorological Organization (WMO). In order to complement these programmes on board ships of opportunity, Portugal is developing ARGO.PT, the Portuguese contribution to the International Argo Programme. ARGO.PT are deploying Argo floats, including BGC-Argo floats, in the Portuguese Seas, namely in the Gulf of Cadiz. All these activities support the development of new products for more safe and efficient maritime operations, to support fishing and maritime activities and to better integrated management of the marine ecosystems of major importance for keeping them in good health.

Keywords: ocean observing systems, autonomous systems, fishing vessels, ferrybox, Argo floats

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CM 452: Exploring the impact of physical oceanography on inter- and intra-stock connectivity of a highly commercial species in the Mediterranean Sea

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Marine organisms can disperse actively and passively. During early life stages, eggs and larvae of a plethora of taxa may be subject to transport over large distances by ocean currents, while adults often exhibit rather sedentary behaviors. Next generation stock assessment schemes broadly call for the need to include climate and oceanographic considerations, yet little progress has been made globally towards this direction. Red mullet *Mullus barbatus* is an important demersal resource in the Mediterranean with relatively long pelagic early-life stages suggesting a large dispersal potential. Here, we use two different putative stocks of red mullet in the Western Mediterranean Sea to test the effects of surface currents on the demography and inter- and intra-stock individual exchanges. The connectivity between spawning and nursery areas was investigated by simulating multi-annual lagrangian indices of larval retention, import, and self-recruitment. Our study demonstrates a certain degree of inter-stock connectivity along the main corridors of transport but also a substantial variability with some years when population sub-units appear to be more isolated. Regarding intra-stock metrics, we found that the main persistent spawning area of the Northern Spanish Coast stock may act as an export of individuals ending up in coastal nursery areas further south within or even outside the boundaries of the stock unit. By evaluating the passive dispersal and its impact on the spatial population structure and the intra-stock spatial dynamism of an exploited resource, our study provides insights to improve fisheries management with the incorporation of information on physical oceanography (from observing systems and operational models). Importantly, our methodology may readily be applied to other systems and/or be combined with additional methods (e.g., chemical, molecular or artificial markers) to facilitate the improvement of current management schemes and inform conservation strategies.

Keywords: *Mullus barbatus*, lagrangian modelling, flow network, high-resolution ocean modelling, passive dispersal, pelagic duration

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CM 458: Collaborative ocean observation with the fishing industry: a win-win for science, industry, and sustainability

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With increasing pressure for a more ecosystem approach to marine fisheries management to increase resilience to the effects of climate change, there is a growing need for enhanced subsurface observations to enable integrated modeling and decision support tools. The observational tools in use today are limited and less cost-efficient for scalable deployment. Fishing vessels can serve as platforms to host and deploy an assortment of oceanographic instrumentation; and the fact that many fishing gear types already profile through the water column presents a unique subsurface data collection opportunity. Fishing vessel ocean data collection integrations complement existing ocean observing networks by enabling the cost-effective collection of subsurface ocean data to dramatically increase coverage in data-sparse regions. Counterintuitively, the shelf and coastal regions most relevant to fisheries science are among the most data scarce, especially for subsurface physical oceanographic data which fishing vessels are so well suited to collect. These data can benefit fisheries sciences by providing high precision fishing activity location with coupled environmental data, improving physical ocean model backbones for understanding ecosystem dynamics, and promoting the participation of fishery stakeholders into the scientific process. This data collection is a win-win because the fishing industry can use these data to fish smarter and in the longer term adopt innovative solutions to improve fisheries sustainability, profitability, and community resilience.

To maximize these benefits and complement existing ocean observing networks an emerging global network: the Fishing Vessel Ocean Observing Network (FVON) has formed to foster the proliferation of ocean data collection integrated with fishing, by learning from local programs, maximizing data value and impact, establishing best practices and common standards, as well as facilitating observation uptake. FVON's goals are to foster collaborative fishing vessel-based observations, democratize ocean observations, improve ocean predictions, while promoting sustainable fishing.

Keywords: ocean observation, science-industry collaboration, oceanography, citizen science, ocean data

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CM 582: Quantifying frontal dynamics at ecologically and economically relevant spatial and temporal scales

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The Northwest Atlantic is a highly productive and commercially important temperate ecosystem that is currently undergoing rapid change. These changes have resulted in significant impacts on the marine ecosystem and living marine resources in the region. Satellite remote sensing data are a powerful tool for quantifying these rapid changes, as they provide environmental information on the ocean climate via reliable synoptic coverage of oceanographic variables, such as sea surface temperature (SST) or ocean color (i.e., chlorophyll), at spatial (1-4 km) and temporal (~daily) resolutions not attainable by *in situ* sampling. Furthermore, these data can be used to identify oceanographic features, such as frontal zones. Oceanic fronts, narrow zones of enhanced horizontal gradients of water properties, represent major biogeographical/ecosystem boundaries and are often associated with enhanced primary productivity and biological hotspots of marine life and fishing. Thus, the primary objective of this study is to quantify the rapidly changing frontal dynamics in the region and better understand how the physical changes impact the productivity and habitat conditions in this region. 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. Using a neighborhood processing algorithm, we isolated prominent frontal features from the frontal gradient imagery and created metrics such as the intensity, persistence, and location of coincident SST and CHL fronts. We compared a range of neighborhood sizes, selected and informed through a species-specific lens. Specifically, we used high-resolution fishery-dependent data sets from the Northeast Fisheries Science Center (NEFSC)'s Study Fleet Program and the Northeast Fisheries Observer Program, to identify realistic spatial footprints for a variety of regional stocks. This approach allows us to track the location, strength and temporal variability of sea-surface temperature and chlorophyll fronts as well as the associated primary productivity at ecologically relevant spatial scales. Changes in these oceanographic frontal processes can aggregate prey, alter seasonal movement of fish and marine mammals, and influence fishing. 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. Additionally, understanding multiple species' relationships to particular oceanographic features could be an important management tool for evaluating stocks from an ecosystem-based perspective.

Keywords: high-resolution remote sensing, high-resolution fisheries-dependent data, oceanography, oceanic fronts, ocean management, primary productivity

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CM 585: Physical oceanography as a contributor to explain small pelagic eggs and larvae dispersion

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It is commonly assumed by the scientific community that recruitment variability of small pelagic fish (SPF) is largely determined by survival during its early life stages (ELS; e.g. eggs and larvae). It is also accepted that this "survival", among other biological factors, is related with the environmental conditions prevailing during its development, which means that the overall process can only be well understood by the knowledge of the physical processes occurring in the ocean. This is the motivation for the research presented, which includes the description of the main shelf physical oceanographic processes, hypothesized as being major contributors to the dispersion and retention of eggs and larvae of SPF. The area of study is the NW Portuguese shelf, which is documented as an important spawning area of SPF species such as *Sardina pilchardus*. The NW Iberia margin is characterized by complex interactions between ocean and atmosphere processes, responsible for the different seasonal slope and shelf ocean circulation, commonly described in literature and observed in the area: summers are characterized by upwelling type circulation with the development of equatorward currents at surface, while winters are associated with coastal convergent type circulation and poleward coastal currents. Despite these two situations being commonly described in literature, the transition mechanisms, and the coupling between the development of the hydrodynamic structures over the shelf, are not yet fully understood. The study was developed using results from ROMS 3D numerical model, applied to the NW Portuguese shelf, and obtained after a 15-year realistic simulation. The analysis focused mainly on the seasonal aspects of the shelf hydrodynamics with the identification of the main oceanographic features present in the system, and its monthly evolution throughout the year. These include the Iberian Poleward Current on the slope; the surface upwelling jet and coastal inner shelf poleward currents, as well as hydrologic features such as the seasonal development of density fronts and deeper or shallower mixed layers. Eddy type circulation was also identified. It is hypothesized that all these features may be mechanisms influencing the dispersion of SPF eggs and larvae, as well as the definition of retention areas. It is expected that this research will be the first step of a larger study, which aims to integrate the results obtained into a biophysical dispersion model, able to simulate the transport, retention, and survival of SPF eggs and larvae in the NW Iberian shelf.

Keywords: shelf dynamics, numerical modelling, upwelling, stratification

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