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A History of ICES Data Management in Four Objects

Ingeborg de Boois

Data is essential for assessing the state of seas and oceans as well as for providing feedback on the effects of conservation and management measures. The management of marine data has been a key interest of ICES since its foundation. With the 100th anniversary of the ICES Journal of Marine Science and the forthcoming 125th anniversary of ICES itself, we believe that this is an ideal time to look back at all the changes in data management. We divide the history of data management at ICES into four distinct periods and we will discuss an enlightening item from each of them.

1902 - 1949: A strong start during turbulent times.

Data is essential for assessing the state of seas and oceans and the publication and distribution of data was an essential function of ICES from its foundation. The collation, management and publication of oceanographic data by the ICES “*Service Hydrographique*” was seen as a notable achievement. The data it managed represented the vast majority of the research data being collected in the North Atlantic, and it was producing pioneering scientific outputs.

1950s -1960s: Mechanisation of data management.

This period saw significant and long-lasting changes both in the overall activities of ICES and in its approach to managing data. Large scale expeditions with their commensurate increase in data volumes prompted a need to change the data handling process at ICES, particularly the International Geophysical Year 1957-58 Polar Front Survey. To support these larger volumes of data new technology for processing and storing data was required.

1970s - 1990s: The data explosion and the dawn of digitisation.

During this period the variety of data that ICES was managing increased as environmental data increased in prominence. The volume of data was also still increasing and being seen as a challenge. Significant technical changes occurred as ICES progressed from punch cards, to data being digitised and stored on computers, and then being published on the world wide web.

21st Century: Integrated, open, and online data.

This period saw significant changes in data management within ICES including the creation of a unified ICES Data Centre, and making data openly available by default. The volume and variety of data being managed also continued to increase, and the use of the internet and world wide web for distributing and publishing data became the default method.

Ocean acidification may increase the biological impact of legacy metal pollution, a case study from mine waste deposits in Arctic Norway.

Samuel Rastrick

Historically Norway has used fjords for the disposal of waste including mine-tailings, fine grained waste produced during mining which is often contaminated with toxic metals. At present advice to regulators regarding the possible legacy effects of proposed, present, and historic mine-tailing deposits in Norwegian fjords is based on current environmental conditions. However, little is known about how metals associated with these mine tailings will interact with climate change and ocean acidification and the subsequent effects on coastal fisheries and aquaculture. Recent studies of commercial bivalve species (*Arctica islandica*, *Venerupis corrugate*) show that elevated pCO₂ leads to adjustments in coelomic acid-base balance, with increased bicarbonate concentrations buffering pH in response to elevated pCO₂. However, this bicarbonate compensation is not observed in bivalves exposed to mine tailings resulting in significant acidosis and mortality. To investigate the mechanisms and breakpoints behind these physiological responses, bivalves were exposed to sediments collected from historic mine-tailing deposits (Repparfjorden, Norway) in combination with 5 different pH/pCO₂ treatments (pH 7.4 to 8.2). Mine-tailings reduced the activity of gill enzymes (Na⁺/K⁺-ATPase) involved in ion-regulation and critical for bicarbonate up-take. The effect of individual metals associated with mine tailings (Cu²⁺) on these critical enzymes was also investigated. Combined with effects on energetics and electron transport chain activity, and the possible increased bioavailability of metals under more acidic conditions, metal contamination may further exacerbate the negative effects of climate change. Furthermore, climate change may affect temporal and spatial fluctuations in hydrodynamics, modulating the resuspension and distribution of mine-tailing particles and so the concentration of mine-tailings organisms and ecosystems are exposed to at different depths and distance from the source. The findings from our investigations highlight the regulatory importance of considering future environmental conditions when assessing the possible legacy effects of proposed, present, and historic mining activities.

Sub-polar gyre impacts on silicate and spring phytoplankton dynamics in the north Atlantic Ocean

Brian R. MacKenzie

The sub-polar gyre of the north Atlantic is a component of the Atlantic Meridional Overturning Circulation (AMOC) and has large impacts on the distributions of water masses and their properties. The gyre expands and contracts due to multiple drivers including the movements of major currents and the magnitude of winter convection in areas such as the Labrador and Irminger Seas, and large scale wind patterns. Gyre dynamics have been shown to be coupled with the spatial distributions of a large number of marine taxa from phytoplankton to marine mammals. However, how the gyre has affected north Atlantic Ocean biological productivity in the past and how it might affect it in the future is less clear. Changes in the gyre dynamics and AMOC could therefore have unforeseen consequences for food webs and the provision of ecosystem services (e.g., commercial fisheries, carbon sequestration). Here we hypothesize that gyre dynamics affect regional marine ecosystems and their productivity via bottom-up

mixing and nutrient-related processes. We are investigating this hypothesis using historical time series of a subpolar gyre index along with biogeochemical model outputs for silicate and chlorophyll data for the years 1993-2022. New knowledge of gyre dynamics and their ecological impacts throughout the food web can potentially help understand how biota could respond to future variations of the gyre, including those due to climate change.

Machine Learning and Data Integration Approach: Understanding Phytoplankton Seasonal Succession and Forecasting algal blooms in the eastern English Channel

Raed Halawi Ghosn

Harmful algal blooms (HABs) poses a serious threat to water quality, marine biodiversity, ecosystem services, and shellfish aquaculture. Consequently, understanding HABs and predicting them is of paramount importance. The eastern English Channel is a diatom-Phaeocystis dominated ecosystem, where HABs are mainly caused by the Prymnesiophyceae Phaeocystis globosa and the diatom Pseudo-nitzschia spp. In the framework of understanding phytoplankton dynamics, we proposed a novel numerical approach combining high temporal (HR) resolution dataset from MAREL Carnot in-situ instrumented station with low temporal resolution (LR) phytoplankton abundance dataset from REPHY-SRN. First, we applied Multilevel Spectral Clustering (M-SC) to the HR dataset to identify the environmental states. Second, we integrated phytoplankton species abundance from the LR datasets with these environmental states, allowing us to characterize phytoplankton communities within each environmental state. Inspired by the historic Margalef's Mandala, a novel Margalef-based visualization diagram was developed based on six environmental variables, including nitrate, phosphate, silicate, photosynthetically active radiation, turbidity, and nitrate-to-phosphate ratio.

Based on this new knowledge about phytoplankton dynamics (used to train the model), we further integrated satellite, modelling and in-situ datasets and used a semi-supervised approach in order to develop a forecasting system. This semi-supervised approach combines M-SC and random forest (RF). Then, a majority vote approach was developed to account for possible differences in forecast outputs between the three used datasets. The highest accuracy was for modelling, followed by in-situ and then satellite. This forecasting system may serve as an early warning to alert shellfish farms and protect their harvest.

By integrating high-frequency with low-frequency datasets, our approach provides a novel framework for identifying key environmental drivers of phytoplankton dynamics in the highly turbulent eastern English Channel, and enhances our ability to detect conditions favorable for harmful and toxic algal blooms, offering forecasting system suitable for early warnings of HAB

Modeling Multi-Scale Ecosystem Complexity: An Integrated Approach Linking Physical Processes, Plankton Dynamics, and Small Pelagic Fish

Clara Menu

Marine ecosystems are characterized by complex and diverse biotic and abiotic components, making them difficult to describe and quantify. Mechanistic modeling provides a framework to represent the dynamics of key ecological processes, thereby improving our understanding of these systems and, potentially, anticipating their trajectories under global change. This integrative approach transforms modeling into a virtual laboratory for testing hypotheses and exploring scenarios. While abiotic components and their impacts on fish populations are now widely incorporated into models, the modeling of lower trophic levels (LTL), particularly

zooplankton, remains only rarely connected to higher trophic levels (HTL). This limitation resides partly from the scarcity of zooplankton observations, but also from contrasting spatio-temporal scales: LTL organisms exhibit short generation times and rapid dynamics, highly sensitive to fine-scale physico-biogeochemical forcing (days to weeks; meters to kilometers), whereas HTL integrate these fluctuations through growth, reproduction, mortality, and behavioral processes operating at seasonal to interannual and regional scales (tens to hundreds of kilometers). Improving the reliability of HTL models by embedding them within marine ecosystem models to build a fully integrated modeling chain—from physics to fish, through plankton—remains a major challenge. The CROCO–MUSTANG–BLOOM–FOIL modeling chain provides a holistic representation of the English Channel–Bay of Biscay system up to small pelagic fish by coupling hydrodynamic (CROCO), sediment (MUSTANG), and biogeochemical (BLOOM) modules with a population dynamics model for anchovy and sardine (FOIL). For fish, this framework models early life stage drift, individual development by integrating the effects of temperature and zooplankton throughout the life cycle using a bioenergetic (DEB) approach, and the emergent population dynamics resulting from the combined action of these processes. This integrated modeling framework thus captures the complexity of processes operating across multiple spatio-temporal scales. The first simulations produced by this coupled system will be presented to identify the key processes driving population dynamics and life-history traits of anchovy and sardine in the Bay of Biscay.

Anthropogenic warming has driven marine heatwaves in the Western Baltic Sea beyond historical precedent

Guilherme Pinto

No abstract

Domestication of European abalone (*Haliotis tuberculata*) modulates acclimation responses to ocean warming and acidification after three generations of size selection

Ronan Le Gall

Along the northwestern French coasts, restocking or stock-enhancement operations based on hatchery-reared juveniles are considered for restoring the European abalone (*Haliotis tuberculata*) populations that have collapsed. In such programs, a domestication process may occur in hatchery stocks, which is a major concern for restoration operations that need to define at which scales it can affect the responses and survival of released individuals to environmental variability. This question is particularly important in the context of global climate change as they will face significant environmental changes. To address this issue, a common garden experiment was conducted for six months to compare the responses of natural and cultivated abalone strains to environmental variability. Two strains of hatchery-produced individuals were compared: one originating from wild parents from Brittany and the other one from hatchery-reared parents (third generation of selection). Both strains were produced and raised in the same environment prior to the experiment, and placed in three contrasted temperature and pH conditions: (1) natural seasonal variations found in Brittany, (2) highly variable conditions as reported in the local hatchery and (3) projected natural conditions following IPCC models (SST +2.6°C/pH -0.3). Strain performance was measured through an integrative approach combining a wide range of phenotypic trait measurements, including behaviour, metabolic analyses and transcriptomic. From the start of the experiment, hatchery individuals were significantly bigger than juveniles from wild-parents. During the experiment, selected individuals presented bolder personalities, early gonadic maturation, higher

respiration rates and differential gene expression in gill tissue compared to wild-parents individuals. In addition, gonadic maturation showed differential synchronicity between wild- and selected-parents individuals. Finally, gene expression patterns varied between both strains, with wild-parents juveniles presenting a faster activation of pathways to cope with heat and acidity stress. Our findings suggest that selected individuals have a faster “pace of life”, different physiological pathways to cope with environmental variability and exhibit riskier behaviour, which could be the main concern for restocking programs.

Impacts of spatial distribution shifts and selectivity changes on CPUE-based management procedures: implications from simulation

Toshihide Kitakado

Catch per unit effort (CPUE) is a key input in stock assessment and management procedure (MP) frameworks, where it is used either to fit assessment models or directly inform management actions such as total allowable catch. CPUE standardization aims to extract temporal trends in exploitable abundance by removing bias due to vessel characteristics, gear configuration, targeting practices, and spatial distribution. However, climate-driven shifts in species distribution and differences in spatial usage among life stages may alter availability to the fishery and effective selectivity, thereby affecting the relationship between CPUE and exploitable abundance.

This study evaluates the impact of spatial distribution shifts on MP performance using a simple age-structured simulation model with multiple spatial areas and multiple age classes under a stock–recruitment relationship. CPUE is assumed to be available only from primary fishing areas. Two scenarios were examined: one with constant spatial distribution and another with gradual distributional shifts that alter spatial availability and age-specific selectivity over time. Several management runs were compared, including cases using naïve CPUE, availability-corrected CPUE accounting for spatial distribution, and updated reference points consistent with the underlying selectivity.

The results show that naïve CPUE increasingly overestimates stock status when spatial distribution shifts alter selectivity, leading to persistent depletion below target levels. Correcting CPUE for changes in spatial availability improves performance but remains insufficient when reference points are not updated consistently with the altered selectivity. Stock recovery is achieved only when both CPUE and reference points are adjusted in a consistent manner. These findings demonstrate that unaccounted changes in spatial availability and selectivity can substantially reduce the robustness of CPUE-based MPs. The results highlight the importance of incorporating spatial dynamics and age-specific availability into CPUE analysis and MP design. Approaches such as age- or size-specific CPUE indices and improved validation procedures may help ensure robust MP performance under changing environmental conditions.

The SPoRC stock assessment package: A generalized next-generation platform to assess spatial, age, and sex-structured populations

Matt Cheng

Fisheries managers increasingly rely on stock assessment models to provide sustainable management advice, which must balance complex and competing objectives. Although assessment models necessitate simplifying assumptions, there is increasing recognition to improve the integration of realistic biological and fishery dynamics. While ongoing and future development of increasingly complex stock assessments requires increased capacity (i.e., time, training, and personnel), there are concerns that the growing demand for assessment advice

cannot be adequately fulfilled under current resources. To address these needs, we present the Stochastic Population over Regional Components (SPoRC) model, a modern integrated analysis platform that is generalized, modular, and developed in a user-friendly programming language (R with Template Model Builder, RTMB). Development of SPoRC emphasized consideration of age, sex, and spatial dynamics at the outset, while ensuring the ability to integrate diverse data sources (e.g., catch, abundance indices, age/length compositions, and tagging). Moreover, state-space specification of time-varying processes through random effects and robust simulation capabilities were primary design features. Here, we highlight SPoRC's utility in cohesively implementing single- and multi-region applications, its ability to estimate time-varying processes as random effects, and the potential to conduct closed-loop simulations for evaluating the robustness of management procedures. By developing a generalized assessment platform in a user-friendly R package, we suggest that SPoRC reduces barriers to implementation of next-generation stock assessment models and facilitates team-based model development, which will ultimately help improve the capacity to implement stock assessments globally.

Bycatch and Mortality of Three Prohibited Shark Species in the Northeast U.S.

Lindsay L. Graff

Incidental capture in non-target fisheries can result in mortality of prohibited shark species. This risk is of particular concern for long-lived, low-productivity sharks. In the U.S. Northwest Atlantic, dusky (*Carcharhinus obscurus*), sand tiger (*Carcharias taurus*), and white (*Carcharodon carcharias*) sharks have been prohibited from retention for more than two decades, yet incidental interactions persist in various recreational and commercial fisheries. Using National Marine Fisheries Service at-sea observer data from 1993–2024, we estimated annual bycatch in gillnet and trawl fisheries and evaluated predictors of at-vessel mortality. Annual bycatch and mortality were estimated by scaling observer-recorded interactions to commercial fishing effort reported in Vessel Trip Report records (1996–2024) within spatial strata where interactions were documented, providing baseline estimates. Gillnets accounted for 72% of observed interactions. Mean annual expanded bycatch (mean number of individual sharks $\pm$ SD across years) in gillnet fisheries was 128 ± 127 dusky, 20 ± 14 sand tiger, and 4 ± 3 white sharks, compared to 85 ± 73 dusky, 45 ± 37 sand tiger, and 4 ± 3 white sharks in trawl fisheries. Mean annual at-vessel mortality was higher in gillnets (72 ± 85 dusky, 5 ± 5 sand tiger, 3 ± 3 white sharks) than in trawls (34 ± 38 , 3 ± 3 , and 1 ± 1 sharks, respectively), with anchored sink gillnets producing the highest mortality rates. Species-specific predictive models indicated higher mortality rate with increasing shark size and consistently higher at-vessel mortality rate in gillnets than in trawls. Expanded bycatch and at-vessel mortality generally declined over the time series for dusky and sand tiger sharks, whereas no consistent temporal trend was evident for white sharks. Spatial analyses identified clusters of incidental capture in the Mid-Atlantic Bight and Southern New England that overlapped extensively with juvenile essential fish habitat. Together, these results establish a multi-decadal empirical baseline for prohibited shark bycatch and at-vessel mortality in non-target fisheries, highlighting gear-specific risk and repeated interactions with juvenile life stages. These findings are directly relevant for stock assessment and for informing bycatch mitigation and monitoring of rare prohibited species across fisheries.

Methodological development for calculating uncertainty in the estimation of fishing discards

Joel Morales Chavez

One of the basic quantitative inputs in the process of scientific advice to the management of fisheries resources is the total catch by stock, as this allows for inferences about population losses due to fishing mortality, which in exploited marine stocks often far exceeds natural mortality. Commercial catches consist of landings and discards, both of which must be reported under current European regulations. However, due to known challenges in compliance with discard reporting by the industry, this figure is often estimated from scientific data obtained through on-board sampling programs. Nevertheless, these programs are usually based on complex multi-stage designs that pose a challenge when calculating the uncertainty of discard estimates, despite the critical impact that such mortality levels can have on the juvenile fractions of exploited populations, a concern widely acknowledged in fisheries science. In this study, we have set out to evaluate the estimation of discards by species and the associated variance using two methodological approaches. First, we use statistical formulas based on the multi-stage sampling design commonly used in on-board sampling programs, where the primary sampling unit is the vessel, the secondary sampling unit is the fishing trip, and the tertiary sampling unit is the fishing operation. Second, we apply bootstrap resampling techniques. Both procedures are tested on the same simulated dataset derived from real data from monitored European fisheries.

With this analytical framework, we aim to provide fisheries discard data submitters with a detailed methodological basis easily applicable to each specific case, addressing current difficulties in consistently quantifying discard variance. The ultimate goal is to improve the management advisory process, encouraging national fisheries data officers to transmit discard variance values. Thus, each national discard estimate can be weighted proportionally to its associated uncertainty in the assessment model and provide more accurate predictions of harvest control rules.

Accelerating Management Strategy Evaluation Grid-Searches: Using Bayesian history matching, acquisition functions and k-means clustering to optimise harvest control rules

Emma Bowen

Sustainable fisheries management requires a delicate balance of maximising long-term catch whilst keeping the risk of stock depletion below precautionary thresholds. Traditionally, Management Strategy Evaluation (MSE) grid searches are used to find optimal Harvest Control Rules (HCRs). However, simulating these complex, interconnected dynamics is computationally expensive and time-consuming, particularly as management shifts from single-stock assessments to more realistic, multispecies mixed fisheries.

This project introduces a computationally efficient framework for evaluating HCRs. Initially applied to a single-stock fishery, the framework utilises Gaussian process regression to independently model both catch and risk. Then, by combining the methods of Bayesian history matching, acquisition functions and k-means clustering, we are able to systematically map the sample space. This drastically reduces the need for expensive simulation runs.

Building on this foundation, we scale up this framework to complex mixed-fisheries scenarios. Here, the objective becomes identifying the fishing mortality for each of the interacting stocks that safely maximizes total long-term catch. This framework provides a powerful tool for marine policy by significantly reducing the computational burden of mixed-fishery MSEs. This method delivers timely, evidence-based MSEs that ensures that the stocks remain both economically viable and firmly within safe biological limits.

The good, the bad, and the buggy: the reality of developing next-generation stock assessment tools

Elizabeth Perl

Fisheries stock assessments rely heavily on free software tools that provide standardized, efficient, and tested methods for supporting management advice. However, the infrastructure supporting these tools is often fragile. Our recent survey of 33 software tool developers revealed a precarious ecosystem, highlighting an urgent need for institutions to better integrate and invest in tool development, maintenance, and documentation. Building on these findings, we examine the development of the NOAA Fisheries Integrated Modeling System (FIMS), a software system designed to support next-generation stock assessment, ecosystem, and socioeconomic modeling. FIMS explicitly aims to reduce the risks identified in our study by establishing sustainable software practices. Key progress includes shifting from a "single developer" reliance to a team-based approach and prioritizing documentation and training as primary drivers for developer and community recruitment. Despite these efforts, significant hurdles remain that prevent us from fully resolving the risks described in our study. These include an expertise gap, specifically the need for computer scientists to optimize code and workflows, as well as the challenges of scaling project management for a growing developer community. Furthermore, we face the ongoing trade-off between rigorous development/testing and the need for rapid adoption and ease of contribution. This presentation outlines how far we have come and the distance left to go, with the goal of generating dialogue on resolving these challenges and offering solutions for other fisheries tool developers.

Developing regional mitigation strategies for fisheries-independent surveys in offshore wind areas: a U.S. Northwest Atlantic case study

Kathryn Ford

As offshore renewable energy and other spatial ocean uses, including large-scale marine protected areas, expand globally, the risks to the integrity of long-term fishery-independent surveys that underpin fisheries and ecosystem advice are increasing. In the Northwest Atlantic, the U.S. National Marine Fisheries Service (NOAA Fisheries) Northeast Fisheries Science Center operates 14 fishery-independent scientific surveys to collect population and environmental data for fish, protected species, and ecosystem assessments. The surveys operate at a regional scale, covering much of the northeast U.S. continental shelf where multiple individual offshore wind developments (OWD) are being built and planned for the future. OWD are affecting survey operations and scientific design in multiple ways: the survey platforms may be unable to safely deploy survey gear in turbine arrays and cable corridors, the survey gear can be incompatible with OWD layouts, survey statistical design assumptions may be violated, new and unique habitats are introduced, and operational costs can increase due to lost sampling time due to longer navigational routes or disruptions in aircraft operations. Because of complexities associated with scientific surveying and in order to share mitigation solutions in a holistic and cost-effective way, efforts are underway to determine a mitigation approach that can encompass multiple OWD and multiple surveys operating with different methods and on various temporal and spatial scales. Recent ICES work to develop an international survey mitigation strategy has highlighted the need for standardized regional approaches that maintain survey integrity while adapting to increasingly crowded marine space. These approaches emphasize early coordination with planners and developers, testing of alternative sampling platforms and technologies, and development of regional survey mitigation programs capable of addressing multiple surveys and projects simultaneously. An example of such an approach is the NOAA Fisheries regional Federal Survey Mitigation Program for the U.S. Northeast (Program).

The Program is designed to serve as a scalable model for maintaining survey continuity in offshore wind areas. Key elements of the Program, including the method for establishing and allocating costs for the Program, will be presented along with reflections on obstacles and successes. The Program provides a case study for ICES and international partners working to develop coordinated strategies to sustain long-term fisheries and ecosystem monitoring in increasingly industrialized and spatially constrained marine environments.

Calibrating Long-Term Fishery-Independent Surveys: Insights from a Multi-Decadal Estuarine Monitoring Program

Jacquelynn Tran

Long-term, large-scale monitoring programs are foundational to aquatic ecology and conservation science, providing critical insight into ecosystem change under climate variability and anthropogenic pressures. Although consistent survey methods are considered best practice, survey protocols often evolve due to technological advances, logistical constraints, and shifting management priorities. Such changes can introduce methodological inconsistencies that complicate long-term data interpretation, particularly in extensive and enduring monitoring programs. Survey calibration can help remove variability in abundance indices attributed to these changes in protocol.

The Hudson River Biological Monitoring Program (HRBMP) is a long-term monitoring program with several survey components including the Fall Juvenile Survey (FJS). The FJS targets juvenile fishes and is one of the longest-running fish monitoring programs in North America, designed to monitor the abundance and spatiotemporal distribution of young-of-year, yearling, and older fishes in the Hudson River Estuary. FJS sampling protocols changed between 1974-2018 and again beginning in 2023. These modifications may have altered the survey catchability, creating challenges for comparability across years and locations and limiting data interpretability.

To address these challenges, we conducted a comprehensive evaluation of protocol changes and developed a framework to calibrate and standardize FJS data to ensure spatiotemporal consistency. Specifically, we: (1) identify key issues limiting effective use, interpretation, and data sharing; (2) develop a modeling framework to calibrate and standardize FJS data across time and space; and (3) generate calibrated datasets to correct for protocol-driven biases. Using the calibrated FJS data, we produce both design-based and model-based abundance indices for key species. More broadly, this project serves as a case study for long-term biological monitoring programs seeking to address challenges arising from changes in sampling protocols while maintaining data integrity, improving management applications, and facilitating transparent data sharing.

A quantitative geostatistical mapping of fish life cycles: anchovy and sardine in the Bay of Biscay

Pierre Petitgas

Life-cycles are often mapped qualitatively and for average conditions, with areas drawn manually to depict how life stages change habitats over seasons and life span. The extent of migrations and the occupation of habitats often depend on individual growth trajectories. A quantitative mapping of a life cycle thus requires integrating complex information and we here suggest a geostatistical procedure applicable to research survey data series. We suggest to: i) map the occurrence probability of life stages, defined by length classes, and ii) to track the

apparent movements of life stages across such series of maps, using of a growth curve. In effect, we may connect areas on the map at time t_i corresponding to length class L_u to those on the map at time t_j ($j > i$) corresponding to length class L_v ($v > u$), where the time interval between t_i and t_j corresponds to the growth between L_u and L_v . For the approach to be flexible, as individual growth curves are variable among individuals of a cohort and across years, we suggest to map the histogram of fish length and define life stages and corresponding length classes a posteriori and not a priori. Fisheries surveys have been undertaken for decades now and often seasonally, providing adequate data for such mapping.

We applied the approach on anchovy and sardine in the Bay of Biscay. We used the survey data series PELGAS (conducted in May since 2000), and of JUVENA (conducted in September since 2003). PELGAS monitors the pelagic fish community and its environment during anchovy and sardine spawning. JUVENA monitors anchovy and sardine juveniles, as well as the pelagic fish community. We used the occurrence probability of anchovy and sardine in length intervals of 0.5 cm (fish length histogram) in the pelagic trawl hauls. All years were pooled to estimate the average distribution over the years. We mapped the fish length histogram using a particular type of co-kriging. The fish length histogram in each species at each station was considered a function $f(l)$. It was fitted at each station by a linear decomposition on a basis of orthogonal polynomials (i.e., Legendre polynomials). The resulting coefficients were mapped on a grid by ordinary kriging and assembled to reconstruct function $f(l)$ at each grid point. Based on the time interval between surveys, fish length classes were defined to reflect seasonal and annual growth over the species life spans. Areas occupied by the different length classes were used to characterise the different habitats occupied during different seasons, over the years. Distance between gravity centres of occupied areas were used to characterise seasonal and interannual fish apparent movements. Anchovy and sardine seasonal migrations were oriented North-South and East-West, respectively.

The method provides the ability to map complex information from research survey data. The maps of anchovy and sardine length histograms are accessible on the repository seanoe.org.

Informing conservation and restoration actions in deep-sea environments targeted for mineral exploitation

Manuel Bellanger

The deep sea harbors some of the most unique and vulnerable forms of life on our planet, yet it remains one of the least explored ecosystems on Earth. It is nevertheless well established that the deep sea forms a vast and highly complex network of ecosystems whose functioning is essential to the broader biosphere, global biogeochemical cycles, and the ecosystems that sustain much of terrestrial life, including human societies. These environments are at potential risk of biodiversity and ecosystem function loss due to anthropogenic activities, notably deep-sea mining.

Drawing on the outcomes of the DEEP REST project (<https://deep-rest.ifremer.fr/>), we present an interdisciplinary perspective on contemporary governance challenges for the implementation of conservation and restoration measures in two deep-sea environments targeted for mineral exploitation: hydrothermal vents and abyssal plains. We emphasize that current ecological knowledge calls for a re-evaluation of how proposed management instruments, such as area-based management tools and the mitigation hierarchy, are applied to ensure the effective protection of these ecosystems. We provide recommendations for conservation, restoration, and governance based on the results of DEEP REST research and the integration of many years of exploration and experimentation initiated before the start of the project. Finally, we examine opportunities and practical considerations to align management needs for the protection of ecosystems and biodiversity in the deep sea and high seas with commitments formulated in

emerging international policy frameworks, including the Treaty on Biodiversity Beyond National Jurisdiction (BBNJ), the EU Nature Restoration Regulation, and the EU Biodiversity Strategy for 2030.

Automating and harmonizing large-scale cartographic syntheses to inform EU marine habitat evaluations: The CartHab tool

Fernando Tempera

In order to guide and evaluate progress in marine environment management and conservation policies, the French Office for Biodiversity regularly necessitates up-to-date benthic habitat synthesis maps covering mainland France's Maritime Space. Despite the knowledge gaps persisting outside the marine protected areas (MPA) network and in deep-sea regions, habitat maps produced by numerous programmes conducted over the recent decades provide an extensive geographical coverage. Complemented by broad-scale sources such as EUSeaMap, these datasets currently represent the best available information for characterising mainland France's seabed habitat composition and assessing the distribution of habitats of conservation interest.

However, differences in surveying technologies, geomatical frameworks and habitat classification systems used over time have made multi-source syntheses a complex and time-consuming process, requiring meticulous manual data processing.

The CARTHAB project aimed to develop a user-friendly tool to structure and automate the multiple operations required to produce on-demand, large-scale, multi-source cartographic syntheses compliant with the classification standards used by major EU policies, including the Marine Strategy Framework Directive (MSFD) and the Nature Restoration Regulation. The CartHab script chain processes geospatial information based on multi-institutional dataset inventories, while accounting for spatial quality and temporal relevance to ensure the resulting map is as exhaustive and up-to-date as possible. Where necessary, it also performs (i) geodesic, geometric and topological corrections, (ii) classification cross-walking, and (iii) hierarchical geospatial merging.

This communication presents the CartHab tool and the results of its application across all of mainland France seaboard. Key components are highlighted, including (i) the inventory of relevant datasets, (ii) the processing operations chain, (iii) metrics assessing the resulting synthesis spatial coverage and cross-walking robustness, (iv) improvements relative to European reference maps, and (v) an area-based assessment of protected habitats within the MPA network.

Insights from genetics data into meagre biology and population status in the Bay of Biscay

Trenkel Verena

The meagre (*Argyrosomus regius*) population in the Bay of Biscay has been exploited for many decades by small-scale fisheries. Despite the high value of this fast-growing species, little is still known about its population status and reproductive biology. Using genetic data, we estimated mature census population size using the close-kin mark-recapture approach and compared this to estimated effective number of breeders. The estimated mature census population size in 2020 was around 130 000 individuals, which was around 40 times larger than the estimated effective number of breeders. This could be due to the relatively low genetic diversity of this population. The reconstructed pedigrees also provided insights into the reproductive biology of meagre. It indicated an increase in the number of offspring with age of parent for both females and males, which was not observed before. Further, the existence of a large number of true

siblings in the sample suggested that either meagre females have a relatively small number of partners during a spawning season, which could be due to a small number of batches being fertilised by a small number of males. Alternatively, this result could indicate that the artificial fertilisation carried out by fishers for many years has had some success in maintaining this exploited population. Overall, this study demonstrates the range of information useful for fisheries management that can be obtained using genetic data.

Genomic evidence of population structure in a data-limited species: striped red mullet (*Mullus surmuletus*) in the Northeast Atlantic.

Lucie Fournil

Data-limited stocks are challenging for fisheries assessment and management, as limited biological information leads to uncertainty in stock boundaries and status. Genetic data can help address these uncertainties by supporting the identification of biologically meaningful management units. Among data-limited stocks, striped red mullet (*Mullus surmuletus*) is commercially exploited across the Northeast Atlantic, yet no genetic study has previously been conducted in this region.

To address this gap, we investigated *M. surmuletus* population structure in the Northeast Atlantic using low-coverage whole genome sequencing (lcWGS). We sampled 606 individuals from southern Portugal to northern Scotland in 2013, 2014, 2015 and 2023 across seasons and additionally included four replicate samples to generate genome-wide single nucleotide polymorphism (SNP) data.

Our results reveal a strong spatial structure, with southern samples (Portugal and Bay of Biscay) clearly differentiated from northern samples, and a transition zone located in the western English Channel. This result suggests the presence of distinct biological units within the Northeast Atlantic. Preliminary analyses also revealed a structural variant on chromosome 13, which might play a substantial role in the differentiation of *M. surmuletus* populations.

As the first genetic study of *M. surmuletus* in Atlantic waters, this study establishes a baseline to improve biological knowledge and support more spatially informed management and assessment of this data-limited species.

Application of low coverage whole genome sequencing for stock delineation in exploited demersal fish in the NE Atlantic: lessons from pollack and striped red mullet.

Sabrina Le Cam

Reliable stock identification is a fundamental prerequisite for effective stock assessment and management, as it determines the appropriate spatial scale at which biological data should be aggregated. Defining population structure is therefore essential to delineate biologically meaningful management units. Assessing the level and spatial distribution of genetic diversity provides critical insights into population connectivity, resilience, and long-term sustainability of exploited stocks. In Northeast Atlantic, several commercially important species such as *Mullus surmuletus* (striped red mullet) are classified as a data-limited stock (DLS) despite their high fisheries value. Others, such as *Pollachius pollachius* (pollack) are subjected to Total Allowable Catch (TAC) regulations, yet their population genetic structure remains insufficiently characterized, limiting the robustness of current assessments.

Using a unique dataset spanning ICES areas IXa to Iva with seasonal and temporal (10 years apart) sampling schemes, we performed low-coverage whole-genome sequencing (lcWGS) on 864 *P. pollachius* and 624 *M. surmuletus* individuals. Our preliminary results revealed markedly

contrasting patterns of genomic structural variation, genetic diversity and population structure between the two species, highlighting species-specific connectivity patterns. These findings emphasize the importance of genomic tools for refining stock boundaries and improving fisheries management frameworks, particularly for data-limited or genetically understudied stocks.

Coupling population genomics and physical dispersal modelling to unravel gene flow barriers in the great scallop *Pecten maximus*: implications for hatchery-based enhancement management.

Grégory Charrier

The great scallop (*Pecten maximus*) is a bivalve of great economic value, harvested in NW France for decades. Landings in the Bay of Brest declined drastically following intense fishing pressure and the exceptionally cold winter of 1962–1963. Since 1983, stocks have been enhanced by seeding hatchery-produced scallops to restore and support local populations. In this context, it is critical to understand the forces driving the genetic structure and diversity of the remaining wild populations, to support management strategies that may maintain the long-term persistence of these populations. To this end, a paired-end Genotyping-by-sequencing approach was conducted on 175 individuals sampled across seven sites in the Bay of Brest and surrounding areas along the coasts of western Brittany. Sequencing reads were mapped onto the two available chromosome-level reference genomes to assess the impact of their provenance on population structure inference at a regional scale. The SNP dataset was integrated with a particle dispersal matrix output from the high-resolution hydrodynamic model MARS3D to study the relationship between oceanographic connectivity and genetic differentiation among sampling sites. The absence of genetic differentiation between the Bay of Douarnenez and the Bay of Brest was supported by particle dispersal modelling, which revealed low but significant connectivity between these sites, suggesting that gene flow buffered diversity loss despite the demographic decline. In contrast, the Morlaix population exhibited a distinct differentiation from all other sites, consistent with the absence of connectivity revealed by the particle dispersal matrix. The Ushant thermal front, occurring at the same time as the spawning period, was identified as a potential barrier to gene flow, likely driving the differentiation of the Morlaix population. Genome-wide analyses showed that differentiation between Morlaix and other populations was uneven across the genome, which was mostly carried by the chromosome 18. On this chromosome, a PCA revealed a three-cluster pattern, typical of a segregating chromosomal inversion. Three other putative chromosomal inversions were found on chromosomes 2, 15 and 19, though they were not associated with population differentiation. However the inversion on chromosome 18 appeared to contain variants that were potentially under selection, whose nature remains to be determined. This intrinsic genomic barrier coincides spatially with the extrinsic barrier formed by the Ushant front and may strengthen the differentiation of the Morlaix population beyond neutral expectations. These results demonstrate the value of combining genomic data, structural variant detection, and physical dispersal modelling to characterize the architecture of gene flow in a commercially exploited species, directly informing hatchery-based enhancement management.

A multidecadal cormorant diet time series as a complementary tool for Danish coastal fish monitoring

Frederick Fleet

Many marine and coastal bird species depend on fish, and their diet can provide insight into the state of local ecosystems. At Aarhus University, we have compiled a unique multidecadal dataset (1980–2025) documenting the diet of Great Cormorants (*Phalacrocorax carbo*) in Denmark. The data are derived from regurgitated pellets collected at breeding colonies across the country, primarily during April–June. This long-term time series provides an opportunity to examine predator–prey dynamics and temporal changes in coastal fish assemblages. Changes in diet composition over more than four decades suggest correspondence with local prey availability. Conventional fish monitoring programmes are typically structured around passive gear in complex habitats and active gear in non-complex habitats, with primary emphasis on commercially important species and larger size classes. In contrast, cormorants predominantly consume fish between approximately 5 and 25 cm and can forage in structurally complex environments such as reef systems and eelgrass beds. They also exploit very shallow coastal areas that are often inaccessible to conventional survey gear. As a result, diet-derived data may capture components of the fish community that are underrepresented in standard monitoring.

There are, however, important limitations. Cormorant prey selection is constrained by morphological factors, particularly prey body width relative to bill gape, which influences the size spectrum represented in pellets. In addition, local depletion effects during the breeding season may alter prey availability and therefore diet composition over short temporal scales. Despite these constraints, multidecadal cormorant diet data have potential as a cost-efficient and non-invasive complementary source of information for Danish coastal fish monitoring programmes.

Marine habitat redistribution and connectivity-driven vulnerability of diadromous fishes under climate change

Gaspard Dubost

Diadromous fishes are among the most climate-exposed marine taxa due to their life cycles linking freshwater, estuarine, and coastal ecosystems. While substantial attention has focused on freshwater pressures, the marine phase of many diadromous species remains comparatively underexplored, limiting our ability to anticipate climate-driven shifts in habitat availability, redistribution potential, and long-term population viability.

We assessed present (2000–2019) and projected (2040–2059 and 2080–2099) marine habitat distribution for ten diadromous species (*Alosa alosa*, *Alosa fallax*, *Anguilla anguilla*, *Osmerus eperlanus*, *Platichthys flesus*, *Petromyzon marinus*, *Lampetra fluviatilis*, *Salmo salar*, *Salmo trutta*) across the North-East Atlantic, integrating both anadromous and catadromous taxa. Ensemble species distribution models (six modelling algorithms) were calibrated using long-term fisheries-dependent and independent occurrence data at the ICES rectangle scale. Models incorporated oceanographic variables (temperature, salinity, oxygen, pH, productivity) together with freshwater–marine connectivity metrics based on distance to functional river basins. Projections were conducted under intermediate (SSP2-4.5) and high-emission (SSP5-8.5) scenarios for mid-century (2040–2059) and late-century (2080–2099) periods. Results reveal pronounced interspecific differences in redistribution intensity, habitat persistence, and net habitat opportunity under climate scenarios. Species constrained to nearshore and estuarine conditions (e.g., *Osmerus eperlanus*, *Lampetra fluviatilis*) exhibit limited redistribution, which may lead to potential and higher vulnerability. Species with broader environmental tolerances (e.g., *Alosa alosa*, *Petromyzon marinus*) displayed more pronounced poleward displacement and larger shifts in projected coastal marine habitats. Despite this, persistent hotspots of suitability remain tightly structured by freshwater connectivity,

highlighting the importance of cross-ecosystem linkages in marine climate impact assessments.

By integrating marine environmental drivers with connectivity structure, this study provides a transferable framework for identifying redistribution hotspots, areas of habitat persistence, and emerging priority zones for climate-adaptive conservation. More broadly, this work highlights the importance of integrating land–sea connectivity into regional climate impact assessments and ecosystem-based management frameworks.

Artificial reefs as a conservation tool for cod (*Gadus morhua*) in the Baltic Sea: evidence from Hanö Bay

Stefan Skoglund

The eastern Baltic Sea cod (*Gadus morhua*) stock has declined markedly over recent decades due to overfishing, habitat degradation, and changing ecosystem conditions, with no signs of recovery despite a fishing ban implemented in 2019. The decline includes both reduced abundance and a loss of large individuals, which are critical for stock productivity due to their higher reproductive output and production of more viable offspring.

Artificial reefs are increasingly used to enhance habitat complexity and provide shelter and feeding opportunities for predatory fish; however, their ecological effects in temperate systems remain poorly understood.

Here, in collaboration with academia, management authorities, and local stakeholders, we investigate how Atlantic cod interact with artificial reefs in the southern Baltic Sea, combining innovative monitoring and analytical approaches to advance understanding of cod ecology and behaviour.

As part of the privately initiated Hanö Artificial Cod Reef Project, 35 artificial concrete reefs were deployed in Hanö Bay, Sweden, in 2023. Reef and reference sites were monitored using stationary underwater cameras during seasonal surveys (2023–2025), and video data were analysed using machine-learning algorithms to detect cod and estimate body size.

The results demonstrate higher cod abundance at reef sites than at control sites, including a greater representation of larger individuals. The broad size distribution observed at reef sites, together with behavioural observations, indicates that the reefs provide suitable feeding habitats and shelter for both juvenile and adult cod, thereby facilitating the coexistence of multiple age classes. No increase in predation pressure from potential predators, such as seals and cormorants, was observed.

This study advances understanding of Atlantic cod ecology and their interactions with artificial structures, while also presenting monitoring and analytical approaches applicable to conservation practice. The findings may further inform nature-inclusive design of marine infrastructure, including offshore wind farm foundations.

Common trends in fish population recruitments in Northeastern Atlantic in the 21st century

Michael Gras

Recruitment variability is a central source of uncertainty in fisheries science, especially under accelerating climate change. Because many fish species exhibit high fecundity, they retain the potential to bounce back from low spawning stock biomass (SSB), which supports the resilience of their populations. Linking recruitment with SSB and fishing pressure has been a challenge for decades. Growing evidence suggests that the environment is a key driver in recruitment, potentially leading to the synchronisation of stock dynamics. We investigated

common recruitment trends among 65 ICES-assessed fish stocks in the Northeast Atlantic (2000–2024) and explored the contributions of various factors. Recruitment time series were analysed using Dynamic Factor Analysis (DFA) to identify shared temporal patterns. Environmental covariates included large-scale oceanographic indices (Atlantic Meridional Overturning Circulation – AMOC, North Atlantic Oscillation – NAO, East Atlantic pattern, Subpolar Gyre Index), sea surface temperature (SST), and chlorophyll concentration (CHL) were considered in the analysis. Stocks were clustered according to DFA loadings, and associations with fishing mortality, SSB, spatial position, and life-history traits were examined. Three dominant common trends emerged: (1) a long-term decline stabilising after 2016; (2) a U-shaped pattern with a marked trough around 2012; and (3) a recent decline beginning around 2019. Trend 2 and 3 were significantly correlated with large-scale circulation indices, particularly AMOC and the Subpolar Gyre proxy, consistent with environmentally driven synchrony (Moran effect). Six recruitment clusters were identified. Increasing recruitment patterns were partly associated with stock recovery following reduced fishing pressure. In contrast, recent widespread declines – especially after 2019 – were generally not explained by changes in fishing mortality or SSB, suggesting stronger environmental drive. The 2012 trough was sharper in northwestern stocks and aligned with circulation-related indices. Life-history traits did not explain much of the variation, although populations far from species biogeographical limits remained less variable (species-range hypothesis). Faster-growing and shorter-lived species were more frequently associated to increasing trends, whereas slower-growing species tended to be linked to recent declines. Overall, recruitment dynamics in the Northeast Atlantic during the 21st century exhibits the combined influence of exploitation history and large-scale oceanographic variability. The strong association with circulation indices highlights the potential for climate-driven changes in Atlantic dynamics to shape future recruitment and to hinder the resilience of a significant proportion of fishery resources.

Mapping biomass and growth rates of the King scallop *Pecten maximus* in the Bay of Seine: toward an assessment of the potential influence of underwater noise

Mathilde Gudin

The King scallop *Pecten maximus* is the leading species landed in France in both tonnage and value. Fishing is concentrated in the English Channel (48 kt; 99.7% of catches), where the Bay of Seine is a major seabed, with nearly 19 kt landed (over one third of the total) during the 2024–2025 fishing season (ICES, 2026). The Bay of Seine is among the most anthropogenically impacted areas of the Channel: shipping traffic, fishing, explosions, granulate extraction and offshore wind farms (Dauvin *et al.*, 2020). These activities generate high underwater noise levels (Farcas *et al.*, 2020; Merchant *et al.*, 2020), yet this acoustic environment and its potential influence on fisheries resources remain uncharacterized. *In situ*, a cause-and-effect relationship between vessel noise and valve closure, potentially reducing feeding activity, has been demonstrated in the filter-feeding bivalve *Mytilus galloprovincialis* (Torres-Guijarro *et al.*, 2025). Experimental studies on King scallops show that industrial sounds (pile driving, drilling) can affect reproduction and multiple life stages, depending on their nature and intensity (Gigot *et al.*, 2023, 2024; Olivier *et al.*, 2022). Population-scale impacts are therefore plausible but remain unquantified under natural conditions. Characterizing underwater noise in the Bay of Seine and its potential impacts on this ecologically and economically important population is therefore essential. The EBESCO project aims to map the spatio-temporal distribution of King scallop biomass and growth, at fine spatial resolutions compatible with the soundscape mapping. Generalized linear mixed models (GLMMs) were developed from COMOR (COquilles Manche ORientale) survey data, explicitly accounting for the spatial structure of the observations through Gaussian Markov random fields. Individuals are counted and weighed by

age class to estimate demographically structured biomass. Since 2022, a standardized scientific protocol (cleaning, high-resolution scanning, macroscope photography; Varenne *et al.*, in prep.) enables the reading of daily growth striae of *Pecten maximus* from three two-year-old individuals per haul. An image-processing algorithm combining manual annotation and supervised learning was developed to measure daily growth increments. Biomass by age and daily individual growth rates are spatialized using GLMMs including environmental drivers and an area effect accounting for fishing pressure under a rotational harvesting system (Mogeeon and Foucher, 2024). Resulting maps will be compared with noise level maps produced by Prawirasasra and Bernard (in prep.). Underwater noise will be integrated as a covariate in the distribution models to quantify its contribution to variability in biomass and growth through the proportion of variance explained in the latent spatial and spatio-temporal fields. This approach will assess the extent to which underwater noise may structure spatial and temporal patterns of King scallop biomass and growth.

Diet composition of Nephrops in Iceland: is lobster and plastic a healthy diet?

Jacob Kasper

Nephrops norvegicus is an important ecological and commercial species throughout Europe. Due to recruitment failure, *Nephrops* harvest in Iceland has been banned since 2021. Despite its ecological and commercial importance, the diet for *Nephrops* in Iceland has not been previously investigated. This study presents the stomach content analysis of *Nephrops* from Icelandic waters, based on 246 stomachs collected from a trawl survey and commercial bycatch in 2025 across nine *Nephrops* grounds. For each individual, carapace length and sex were recorded, stomachs were excised and preserved in 70% ethanol and 6% glycerol prior to further analysis. Prey items were identified to the lowest possible taxonomic level, counted, dried, and weighed. Diet composition and ontogenetic changes were evaluated using the vacuity index (CV%), %PSIRI and trophic level (TROPH). Overall stomach fullness was high (vacuity coefficient 1.61%). The estimated trophic level was 3.62 ± 0.47 (mean $\pm$ SD), which is within the range previously reported for other functional units. The dominant prey groups across all fishing grounds were Crustacea (including *Nephrops* itself, reflecting cannibalistic behavior), Polychaeta, Mollusca, and Echinodermata. Clear ontogenetic shifts in diet composition were detected across three size classes (small: CL <40 mm; medium: 40–60 mm; large: ≥ 60 mm). The diet of smaller individuals contained more Mollusca and Polychaeta than larger individuals whose diet contained more Crustacea. Conspecific predation increased markedly with size, with *Nephrops* accounting for ~26 %PSIRI in the largest size class compared to ~5 %PSIRI in the smallest. A notable finding was the high prevalence of plastic debris in stomach contents. This high incidence has potential implications for individual condition and for the transfer of plastic through the food web via predators of *Nephrops*. These results provide important baseline dietary information for Icelandic *Nephrops* populations during an unfished state and will contribute to ecosystem modelling studies.

Are there Alternative Reproductive Tactics (sneakers and consorts) in the squid *Loligo forbesii*?

Domonique Gillen

Many loliginid squid show dramatic variability in size-at-maturity. Researchers have attributed Alternative Reproductive Tactics (ARTs) to two size classes of sexually mature males: ‘sneakers’, which are small at maturity, and ‘consorts’ which are larger. Interestingly, studies have suggested male loliginid ARTs correlate to differences in the morphology of reproductive

structures. Our goal is to dive deeper into this topic by studying mature male *Loligo forbesii* to assess morphological characteristics of their spermatophores and spermatozoa and a possible correlation to 'sneaker' and 'consort' categorization. Reproductive organs (Spermatophoric Complex of Organs (SCO)) were obtained from mature male *L. forbesii* collected in Irish and Scottish waters. Spermatophores were removed from the SCO and the following measurements were obtained from ten spermatophores from each sample: spermatophore length (SpL), sperm mass length (SML), ejaculatory apparatus length (EAL) and cement body length (CBL). The morphology of the cement bodies was also analysed. Sperm masses were removed from the spermatophores and crushed to release sperm, 20 of which were. These features were analysed to identify differences across mantle lengths. Mantle lengths of mature males *L. forbesii* ranged from 81 to 535mm. All internal structures of the spermatophores and the spermatophores themselves increased continuously with mantle length. The cement body intermediate region had multiple morphologies that remained consistent between spermatophores of the same individual but differed between individuals. One morphotype of cement body was found in samples with mantle lengths smaller than 240mm and the other in individuals larger than 194mm. Sperm length did not increase continuously with mantle length: individuals with smaller mantle lengths had a greater variety of sperm lengths while larger individuals had smaller sperm lengths. This split also occurred at a mantle length of 240mm. There is strong evidence for male Alternative Reproductive Tactics in *Loligo forbesii*.

Lighting the Way: Understanding Variability in Scallop Potting Catch per Unit Effort

Bea O'Neill

Scallops are a high value resource which support major demersal fisheries worldwide. Wild caught scallops are primarily harvested using dredges and trawls, but interaction between mobile gear and the seabed can cause damage to fragile benthic habitats and organisms. Growing consumer awareness of the environmental impacts of food production is increasing interest in lower-impact fisheries, with these products often able to attract a premium price. King scallops (*Pecten maximus*) exhibit positive phototaxis, a behaviour which has recently been exploited to develop a novel scallop potting metier by incorporating LED lights and purpose-designed entrances into pots. This study evaluates the relationship between scallop density on the seabed and catch per unit effort (CPUE) in scallop pots, alongside environmental and operational covariates. Field trials were conducted in the Port Erin Marine Nature Reserve in the Isle of Man. This site has been closed to mobile fishing gear for over 35 years and is known to support high, but spatially variable densities of scallops. A video and still imagery survey was conducted across the reserve to evaluate habitat type and scallop density. Using data from this survey, scallop pots were subsequently deployed in areas of differing scallop density, enabling assessment of the density–CPUE relationship. To investigate seasonal differences in CPUE, 20 strings of 10 pots were deployed in summer 2025 (June) with the sampling effort repeated in winter 2026 (January – February).

Across all deployments, 1,784 scallops were caught, 89.35% of which were above the Isle of Man Minimum Landing Size (110 mm). Catches ranged from 0 to 239 scallops per string (0 – 48 scallops per pot), with strong seasonal differences. An average of 7.5 scallops per pot was recorded in the winter compared with 1.5 scallops per pot in the summer. A compound Poisson–Gamma generalised linear model was implemented to test the effects of scallop seafloor density, habitat type, soak time, season and light intensity on CPUE. The model showed a significant positive relationship between CPUE and seabed density ($p = 0.004$), indicating that catch rates increased with local scallop abundance. CPUE was also significantly higher in winter compared with summer ($p = 0.004$), suggesting strong seasonal effects on catchability. No other variables included in the model had significant effects. These results indicate that

while density influences CPUE in scallop pot fisheries, the strength of this relationship is highly seasonal. This seasonal effect may be partly driven by lower ambient light levels and shorter daylight hours in winter, which may increase the visibility and duration of visibility of pot lights to scallops relative to summer. Further research is needed to understand the behavioural mechanisms driving scallop attraction and movement, and to evaluate the commercial and operational viability of potting across a broader range of habitats and locations.

Climate change impacts and systematic failures: governing non-managed fisheries in the EU

Paul Müller

European fisheries are significantly impacted by climate change, which is driving shifts in primary production, food-web dynamics and species distribution. It is, however, not only affecting marine ecosystems, but by extension the institutional structures and processes that govern them - calling into question the institutional foundations of European fisheries governance. This makes it necessary to assess the institutional adaptive capacity of the European fisheries governance system and its ability to deliver social-ecological sustainability for vulnerable coastal fisheries and fishery dependent coastal communities.

With future risks expected to intensify, identifying regional patterns in how species respond is becoming essential for effective management and conservation under climate change. While commercial quota species are the focus point of these assessments, little research has been done on non-managed species – even with their significant regional impacts both in terms of landings and value in coastal fisheries. This poses a serious risk to regionally relevant coastal fisheries in Europe and highlights several governance shortcomings.

Despite its dense policy and scientific architecture, the EU fisheries governance system continues to underperform even for its best-documented, TAC-managed stocks. A significant number remain overfished or below biomass targets, with only a subset meeting both exploitation and rebuilding objectives. This systemic failure of well-monitored, high-profile stocks implies an even greater vulnerability for the species that fall outside the core TAC structure and lack regular assessments, explicit constitutional level harvest control rules, or integration into high-level indicators. Non-managed species are effectively governed at the margins of the CFP, rendering their status largely invisible in narratives of policy success or failure. Anticipating the impact of climate change on non-managed species is even more difficult as the same environmental volatility acts on far thinner data and weaker institutional triggers, making it difficult to detect climate-driven declines, range shifts, or trophic changes before severe impacts occur.

This talk discusses non-managed species sitting at the intersection of these three problems within EU fisheries: (1) systemic failure even for high-profile TAC stocks, (2) institutional governance bias, and (3) rapidly changing ecosystems under climate change. Together, these make the neglect of non-managed species both a governance blind spot and a climate risk amplifier for European fisheries and coastal communities.

Harvesting the aliens - fisheries management dilemmas in the Eastern Mediterranean Basin

Nir Stern

The ongoing introduction of non-indigenous species (NIS) into the Mediterranean Sea is a well-documented phenomenon that has been intensively investigated throughout the past century. In regions affected by these invasions, commercial fisheries have periodically

incorporated newly exploitable species, while the emergence of nuisance, poisonous, or venomous NIS has driven spatiotemporal shifts in fishing practices.

Along the Mediterranean coast, more than one hundred fish NIS have been recorded to date, spanning from bycatch and nuisance species to those with commercial value. Although several NIS have been present for a century, the continued arrival of newcomers occasionally results in sudden population surges. Such events alter catch composition and compel rapid operational adjustments within local fishing fleets.

Over the past decade, fisheries management in the Israeli Mediterranean has undergone extensive reform, with particular emphasis on implementing spatiotemporal restrictions aimed at promoting sustainable fishing practices.

This presentation will highlight several case studies from the Israeli coastline, illustrating current challenges regarding the attention given to NIS within the commercial, artisanal and recreational sectors. These examples will explore the ongoing debate over whether NIS should be targeted, controlled, protected, or simply disregarded within existing regulatory frameworks. Finally, given the expectation that climate change will continue to accelerate the spread and establishment of NIS across the Mediterranean Sea, the operational dilemmas experienced in Israel are likely to emerge elsewhere. Consequently, the considerations discussed here are poised to become integral to future planning for fisheries managers and marine practitioners throughout the Mediterranean Sea, and beyond.

What Makes Bycatch Estimates Work? A Meta Analysis of ICES Assessment Results

Morgane Pommier

Bycatch is a major obstacle to the conservation and recovery of endangered, threatened, and protected (ETP) species worldwide. Despite long-standing awareness of this threat, its extent is difficult to quantify because of data scarcity, limited monitoring coverage, and the inherent variability and complexity of the bycatch processes. As a result, estimates can be biased and are often widely uncertain, limiting effective management and mitigation.

As part of the LIFE CIBBRiNA project, we aim to improve bycatch assessment methods to identify, quantify and account for some of those biases. This work builds on the Bycatch Estimation and Assessment Matrix (BEAM) framework developed by the ICES working group on bycatch (WGBYC) and CIBBRiNA partners.

In its current form in WGBYC, BEAM is used to estimate bycatch rate (Bycatch Per Unit Effort, BPUE, per day at sea) and total bycatch for the year of assessment at a species × ecoregion × métier level 4 scale, where data allow. We conducted a meta-analysis of BEAM outputs from the 2023 ICES bycatch dataset to identify key requirements and barriers to producing reliable estimates.

Using the nearly 14,000 combinations (species × ecoregion × gear) processed by BEAM each year, we assessed under which conditions bycatch rates could be estimated, and when estimates were considered uncertain or more reliable. We particularly focused on the effect of monitoring coverage, and whether this effect varied by métier, taxon, or region. We further explored sources of variability in species-specific bycatch rates within an ecoregion × métier level 4 fleet, including target assemblage (métier level 5), vessel length, spatial and temporal patterns (ICES areas, year, quarter), and monitoring or sampling methods. Finally, we identified cases where BPUE was available but could not be scaled up to produce fleet-level bycatch estimates, highlighting gaps in monitoring data and variability across monitoring protocols. BPUE could be estimated for only ~6% of the species × ecoregion × gear combinations assessed in BEAM. The primary hurdle is simply the presence of at least one observed bycatch record, as BEAM can estimate BPUE for ~97% of combinations that include at least one event. Beyond this structural requirement, our preliminary results indicate a non-linear relationship between

monitoring coverage and our ability to estimate bycatch rate: at very low levels, small increases in monitoring coverage substantially improve the likelihood of BEAM producing a BPUE estimate, whereas additional effort beyond this initial range shows weak and inconsistent effects, likely reflecting variability associated with species traits and fishing characteristics. Overall, the results highlight how structural and sampling constraints, along with the intrinsic rarity of many bycatch events, shape the conditions under which BEAM can produce robust and useful bycatch estimates across European fisheries.

Ecosystem-based indicators to support advice on emerging invasive species fisheries in the Mediterranean

Karolina Czechowska

The rapid spread of invasive alien species (IAS) in the Mediterranean Sea is creating new fishing opportunities but also raises questions about how these fisheries should be evaluated and managed from an ecosystem perspective. While targeted exploitation is often proposed as a management response, structured approaches for assessing the ecological sustainability of IAS fisheries within ecosystem-based fisheries management frameworks remain limited. Here, we present an indicator framework designed to support ecosystem-based fisheries advice for the management of emerging and established IAS-targeting fisheries. The approach builds on the environmental component of the Adriatic Responsible Fisheries Management (ARFM) scheme, which already integrates ecosystem indicators derived from Ecopath with Ecosim (EwE) models. In this study, we adapt and apply that framework to IAS and their potential exploitation. Species were selected from the Occurrence Records of Mediterranean Exotic Fishes (ORMEF) to ensure consistent taxonomic status across basins. Exploitation scenarios assumed that no new fleet was introduced; instead, existing fleet segments were modelled as partially redirecting effort towards IAS.

The indicator set captures two main dimensions: (i) the ecological role of IAS within recipient ecosystems, including keystone-ness, trophic level, connectivity and functional redundancy; and (ii) the ecosystem effects of their exploitation, including direct and indirect food-web impacts, fishing mortality, selectivity patterns and overall ecosystem footprint. Rather than predicting invasion trajectories, the framework provides a transparent basis for comparing how IAS fisheries interact with different food-web structures.

Preliminary results show marked basin-specific differences in ecosystem responses to IAS exploitation. These differences are driven largely by variation in fleet composition and gear selectivity among basins of the Mediterranean Sea, rather than by IAS trophic role alone. In systems dominated by bottom trawling, ecosystem impacts differ substantially from those where small-scale coastal fleets are more likely to target IAS. This indicates that the ecological sustainability of emerging IAS fisheries depends not only on species characteristics, but also on the configuration and behaviour of existing fleets. By tying ecosystem model outputs to clear sustainability criteria, this work makes ecosystem indicators more operational in fisheries advice and clarifies how strongly the impacts of IAS fisheries are shaped by regional fleet structure.

Speaking truth to power: Notes from the science-policy interface.

Ewen Bell

Having your science make a visible impact on decision making is a great feeling! However, getting to that point is often not straightforward and involves a different communication style as well as navigating through a quite alien landscape. Understanding what to say, who to say it to,

how to say it and when to say it are all important skills that are rarely taught and many of us learn through trial and (unfortunately) error.

In this talk I will explore the role of scientists in the decision-making processes and how to walk the tightrope between policy and science in order to retain our independent credibility. I will also look at strategies for how to get your research the attention it deserves to maximise the chances of it being acted on (spoiler alert, it's mostly around concise, unambiguous and targeted messaging!).

The West Florida Shelf Fishery Ecosystem model – a data integration and simulation tool to estimate red tide mortality on managed fish stocks.

David Chagaris

Red tides are a harmful algal bloom caused by the toxic dinoflagellate, *Karenia brevis*, that may result in massive fish kills, mortality on marine megafauna, persistent hypoxic conditions, respiratory distress in humans, shellfish harvest closures, and loss of fisheries and tourism revenues. Red tides also present challenges for assessing and managing Gulf of Mexico fish stocks and can be a major source of uncertainty when setting catch limits if a bloom is ongoing or recently occurred. Therefore, timely assessments of red tide impacts are needed to inform management of fisheries in the Gulf of Mexico, and especially on the West Florida Shelf where red tides occur most often. The West Florida Shelf Fishery Ecosystem Model (WFS-FEM) was developed using Ecospace, the spatially explicit component of Ecopath with Ecosim (EwE). The model is forced with output from the MOM6-NWA-COBALT regional physical and biogeochemical model. Monthly red tide severity maps were created by combining in situ water quality samples with satellite-derived maps from the NOAA VIIRS and input to the model. Maps of reef habitat and species-habitat preference functions for managed reef fishes were developed from the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources, along with other fishery independent datasets. Logistic functions were used to model lethal and sublethal (movement, feeding, and growth) responses to red tide exposure. The Ecospace model was calibrated to timeseries and spatial abundance data using a new genetic algorithm to estimate key predator-prey parameters, dispersal rates, habitat preferences, and red tide response functions. The model produces annual age-specific red tide mortality rates that have been used in recent stock assessments and management projections for gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*). Red tide mortality is often highest on juveniles of these species because they are distributed nearshore where red tides tend to be more severe. However, older ages are impacted in years when red tide blooms persisted further offshore. This represents the first use of ecosystem model information in actual management advice in the Gulf. Future work will focus on incorporating biogeochemical feedback and hypoxic events that lag red tides and operationalizing the model for routine management application.

Long-term trends and the impact of fishing on blackspot seabream (*Pagellus bogaraveo*) in the Celtic Sea and Western Channel

Rui Vieira

Blackspot seabream (*Pagellus bogaraveo*), also known as Red seabream, has been commercially exploited in ICES subareas 6, 7 and 8, where landings and stock size showed a severe decline in the 1970s–80s. The stock is considered by ICES to be seriously depleted, even in the absence of biological reference points. In 2014, ICES recommended the establishment of a recovery plan for the stock, including protective measures in areas where juveniles occur. However, there remains some uncertainty over the status of the stock and presence of the

species in the wider Celtic Seas. A comprehensive review of biological and catch data from ICES and UK national databases were conducted to contribute to a better understanding of the stock status and distribution of blackspot seabream around the British Isles.

Available landings information and data extracted from ICES DATRAS are indicative that blackspot seabream is still present in the Celtic Sea and Western Channel. Historical accounts suggest that blackspot seabream has been caught in the North Sea, but recent fisheries-independent surveys have not recorded the species in these waters. Initial results are suggestive that the substantial reduction in the standing stock and difficulty in stock recovery since the 1980's may be linked to long-term effects of historic bottom trawling on blackspot seabream habitats. While a definitive assessment of cause and effect was not possible, other causes are plausible and suggested the need for improvements in the evidence base that would contribute to the ICES' stock assessment and assist the development of guidelines for the evaluation of any rebuilding plans.

Towards a European small-scale fishing vessel tracking programme: overview, challenges and opportunities

Tania Mendo

Small-scale fisheries (SSF) account for more than three-quarters of all active vessels in the European fleet, yet remain largely absent from marine spatial planning due to limited spatial data. This persistent data gap has contributed to the marginalisation of SSF in policy and governance, despite their ecological, economic, and socio-cultural importance. The recent revision of the EU Fisheries Control Regulation (CR 2023/2842)—which requires all fishing vessels, including those under 12 metres, to be tracked by 2029—creates a pivotal opportunity to embed SSF within formal spatial and fisheries management frameworks. Drawing on contributions from researchers across 24 European institutions, this paper reviews the current state of SSF tracking, estimates existing coverage, and identifies key opportunities and obstacles for establishing an EU-wide SSF tracking system. We estimate that only around 12% of the SSF fleet is presently tracked, with coverage concentrated in net, trap, and dredge fisheries. Although the value of spatial data for planning and ecosystem assessment is widely recognised, progress is constrained by high implementation costs, limited institutional capacity, and fragmented or incompatible data infrastructures. We recommend: (i) establishing clear technical standards and harmonised data protocols; (ii) using tracking data to support participatory and adaptive management; and (iii) promoting inclusive governance that acknowledges the socio-cultural dimensions of SSF. As Member States advance toward full implementation of CR 2023/2842, early design choices will shape both the technical foundations of tracking systems and the future governance of European SSF. A more equitable and integrated approach is necessary.

Mapping Cumulative Impact Risk and Testing Management Scenarios in the Bay of Biscay

Olga Lukyanova

No abstract

Exploring the balance between ecological sustainability and socio-economic equity in Western Mediterranean fisheries

Tanguy Genthon

The Mediterranean Sea faces considerable challenges in terms of sustainable fisheries management, due to several decades of overfishing, increasing pressures linked to climate change, demand for seafood products and increased spatial competition between human activities. In 2020, the multi-annual management plan for demersal stocks in the Western Mediterranean (WestMed) was adopted to achieve Maximum Sustainable Yield (MSY) for five assessed species: European hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), blue and red shrimp (*Aristeus antennatus*), Norway lobster, and deep-water rose shrimp (*Parapenaeus longirostris*). However, this objective has not yet been reached, which calls for the development of further management measures to improve stock status.

In this context, the bioeconomic Impact Assessment Model (IAM) was implemented to Western Mediterranean fisheries to simulate management scenarios and assess their biological and socio-economic impacts. This implementation was initially carried out for the STECF (Scientific, Technical and Economic Committee for Fisheries) working groups on *Fishing Effort Regime for Demersal Fisheries in the Western Mediterranean Sea*. This modelling effort allowed to refine fisheries advice by improving the consideration of socio-economic factors and to highlight the need to implement selectivity measures to improve demersal stock status in the area.

Within the framework of the GEMMBE project, we aim to broaden the application of the model to explore the ecological, economic and social trade-offs associated with fisheries regulations, providing short and long term socio-ecosystemic insight.

As part of this effort, we use IAM to evaluate the biological and socio-economic performances of French and Spanish fleets under the current regulation and compare them against alternative management pathways.

Specifically, we simulate the implementation of selectivity measures and explore diverse effort allocation strategies between fleets, ranging from uniform reductions across all fleets to optimized allocations based on various equity criteria or profit maximization at the national level.

By explicitly simulating multi-stock and multi-fleet dynamics, our model evaluates the system's capacity to reach MSY for multiple stocks, while focusing on the distribution of the socio-economic impacts across fleets. This research highlights the complex interaction between ecological sustainability and socio-economic considerations in fisheries management, encouraging the integration of socio-economic factors when implementing fishery policies.

Analyzing the response of European small pelagic trade networks to fishery shocks

Jennifer Beckensteiner

Fisheries for small pelagic fish (SPF) play a central role in food security, cultural heritage, and international seafood trade -yet they are increasingly exposed to biological, regulatory, and market-driven shocks. Little is known about how SPF-related socio-ecosystems respond to these external shocks, particularly with respect to market resilience. This study applies network analysis to examine the temporal evolution of European sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*) trade networks from 2000 to 2019, using international exchange volume data disaggregated by product form (fresh, canned and frozen). We characterize these markets and assess their responses to three major disruptions, including the Bay of Biscay anchovy fishery closure (2005-2009), the Gulf of Lion's sardine crisis (2010-2014), and recent environmental challenges affecting fisheries in the Atlantic Iberian waters (2015-2019). While the number of importing countries remains relatively stable over time, we find that the number of import links and network density increase, indicating progressively more interconnected trade systems over the study period. This rising connectivity, combined with a stable core of trading partners, suggests that SPF trade networks are dynamic and resilient, allowing rapid transformation in response to localized shocks while preserving long-term

structural continuity. Nevertheless, countries adopt markedly different positions depending on species and commodity, reflecting both biological constraints and market organization. While management frameworks are often designed at local or national scales and focused on stock dynamics, our findings underscore the importance of incorporating the dynamics of globalized seafood markets to better understand the interconnectedness of SPFs.

Participatory pathways for achieving sustainable and desirable fishing in the Gulf of Lion, Mediterranean Sea

Adrien Chevallier

During two successive participatory workshops, we invited a diverse group of 25 French stakeholders from the fishing and conservation sectors to: define and prioritise environmental, economic, social and governance indicators for achieving sustainable and desirable scenarios for the Gulf of Lion fisheries by 2050; and develop indicator-based pathways to achieve these scenarios. To do so, we first defined the states or trends that were perceived as sustainable for each indicator. We then assessed the current value and relevance of each indicator. For the most relevant indicators, we collectively defined short-, medium- and long-term objectives for 2050, as well as the associated risks. Using a backcasting approach, we defined the set of measures to be implemented at EU, national and local levels in order to achieve each series of objectives successively. Using thematic analysis, we were able to assign one or more STEEP dimensions (social, technological, economic, environmental and political) to each of these measures, as well as an overarching theme. Through analysing the dimensions of the indicators associated with the various sustainability objectives, as well as those of the proposed measures to achieve them, we statistically observed that political measures are critical to achieving nearly all of the indicators' objectives, except for the economic ones. Technology plays a minimal role, except for indicators associated with improving the status of the marine ecosystem. Transdisciplinary and interdisciplinary approaches support the achievement of each objective, and most proposed measures require a combination of political with environmental, economic, and social dimensions. The most common themes among the measures were linked to governance and environmental indicators, with funding being the only theme common to achieving all indicators. Finally, we analysed the correspondence between the measures proposed by stakeholders in the Gulf of Lion and those mentioned in the most recent policy reports at the global (FAO), Mediterranean (GFCM) and European Union (CFP) levels. While the measures associated with environmental objectives were well aligned, those associated with social, economic and governance objectives were less directly addressed in the international reports, highlighting a significant policy gap.