ICES Annual conference 2026
15-18 September
Brest
Additional slides



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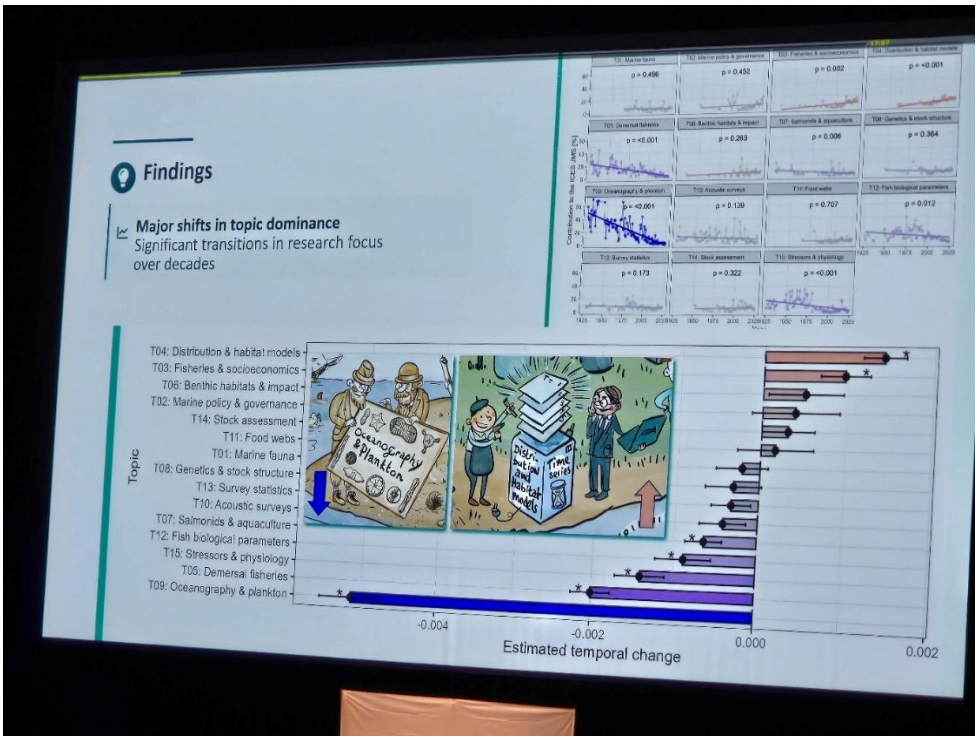
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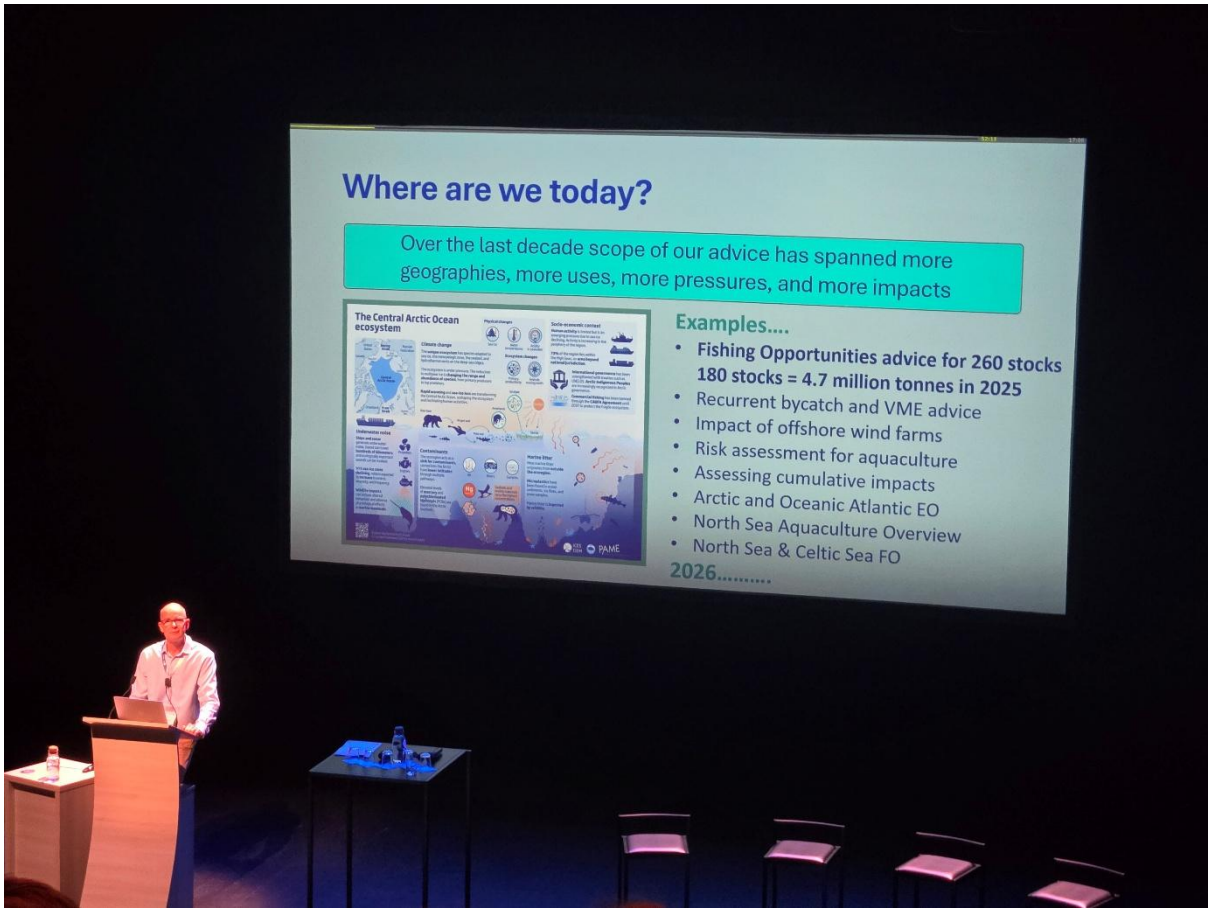
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100 years of ICES journal of marine science

Reading the past to shape the future: Insights from 100 years of ICES Journal of Marine Science (Szymon Smoliński, National Marine Fisheries Research Institute in Gdynia, Poland)





Plenary Keynote: Does seasonality matter? Unravelling the seasonality of the biological carbon pump and consequences for carbon sequestration in the ocean

Does seasonality matter? Unravelling the seasonality of the biological carbon pump and its consequences for carbon sequestration in the ocean

The biological carbon pump (BCP) comprises a suite of intertwined physical, ecological and biogeochemical processes that collectively transport billions of tonnes of carbon annually from the surface into the deep ocean. This process starts with photosynthesised particulate organic carbon (POC) sinking from the surface ocean (upper ~100m) into the mesopelagic zone, where it is progressively remineralised. As this downward flux of POC is attenuated, only a small fraction ultimately reaches the bathypelagic depths (below ~1,000 m), where it can remain isolated from the atmosphere for hundreds of years.

Despite some significant progress made in the field over the past 50 years, several open questions and uncertainties remain about the BCP functioning and its impacts. A major one is related to the efficiency of the aforementioned POC transfer, which is considered an important factor in regulating the air-sea CO_2 balance. Although this POC transfer efficiency is known to vary geographically across the ocean, the reasons behind this variability are still uncertain, with different studies reporting contrasting results. Central to these attempts to explain spatial variability is that they assume that the POC flux attenuation is temporally steady, despite growing evidence that it varies substantially across seasons. This poses a question - does this seasonal variability matter?

Answering to this question, this keynote will focus on the emerging importance of seasonality in shaping the biological carbon pump. Drawing on new observational analyses and modelling results, Fransisco will show how seasonal variations in carbon attenuation fundamentally reorganise global patterns of deep-ocean carbon transfer. In particular, the keynote will demonstrate that seasonal variability alone can explain regional differences in the efficiency of carbon transfer, providing a unifying mechanism behind previously conflicting interpretations, and offering fresh insights into the BCP's role in long-term carbon storage and climate regulation. Fransisco will then discuss some of the caveats and future directions for this study, as well as the implications for the BCP in a changing climate.

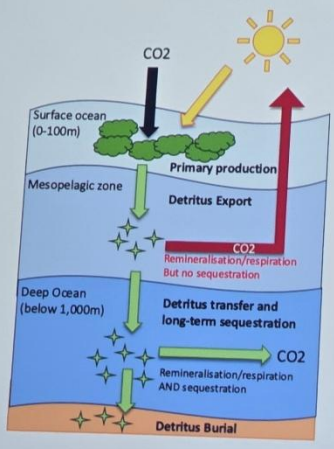
In addition to presenting the scientific advances and a brief historical and methodological perspective, Fransisco will reflect on how his own rather unconventional career path has shaped the way he approaches problems that bridge ecology, biogeochemistry, climate, and modelling. Fransisco will also discuss the essential role of professional and learned societies and community-led organisations, including ICES Strategic Initiative on Integration of Early Career Scientists (SIIECS), in his development as a researcher, collaborator, and member of the ocean science community.

2. Some conclusions

- Overall, the presence of seasonality increases TE, independently of the phase, and is key to keep nutrients and carbon deep.
- It is not only the variability of b^{model} that counts, but also the nonlinear feedback effects between the sinking speed and the various biological, physical and chemical processes in the model.
- **Biological carbon pump:** seasonality increases POC fluxes to deep ocean by at least 0.38 Pg C year^{-1} (a growth of 122% w.r.t. to the non-seasonal flux of 0.31 Pg C year^{-1} when $b^{\text{model}} = 1.388$).
- It is important to point out that the aim of this study was not to reproduce the observed nutrient and carbon distributions but to examine how do these fields change as a consequence of seasonality. One of the consequences is to move more material to depth.
- **Sampling:** while for a constant b it does not matter when you estimate it, for a non-constant b both the location and time of sampling are crucial since your estimate could be a local maximum, minimum or something in between. Its relative phase to e.g. PP and export is also important.

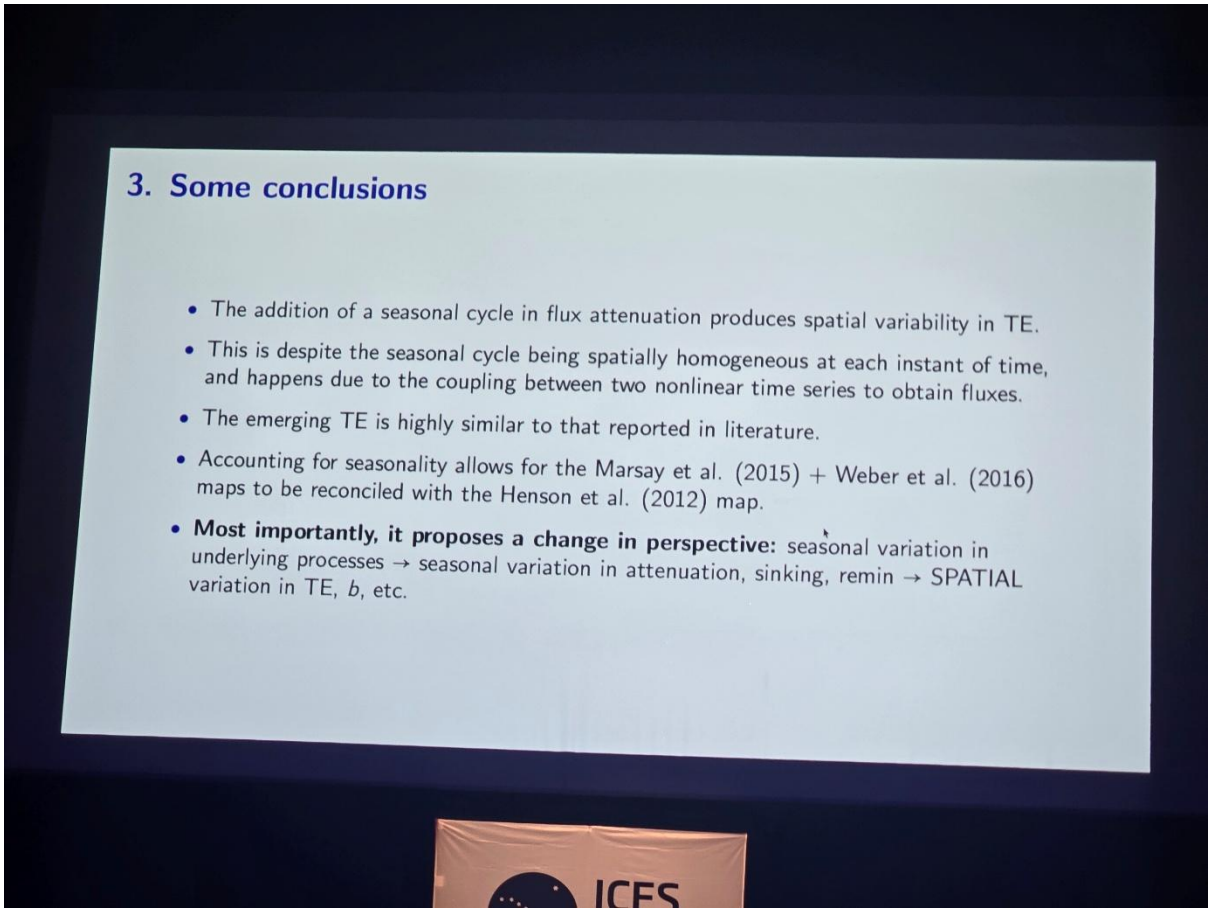
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1. The biological carbon pump (BCP) in a nutshell



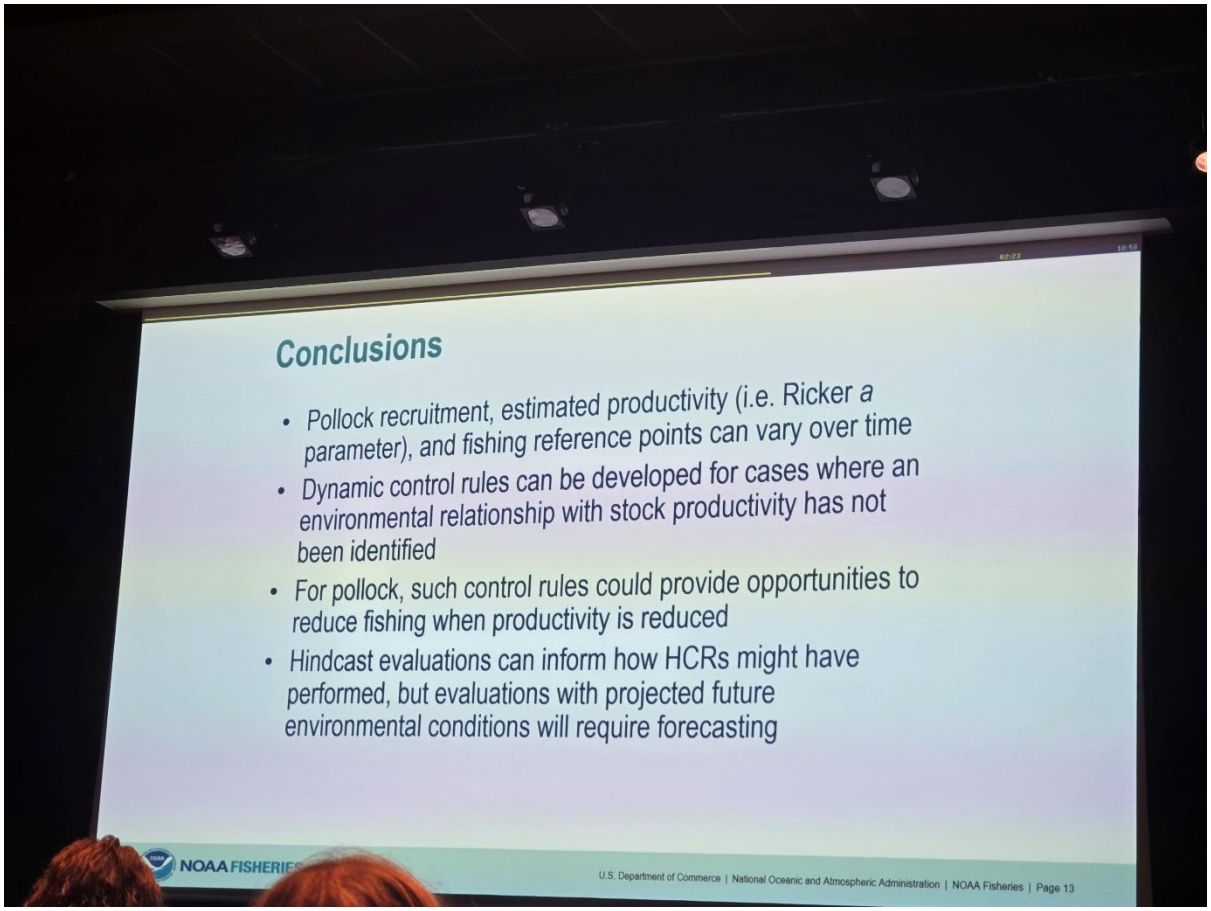
- **The BCP:** A collection of biological, chemical and geophysical processes whose net effect is to "pump" carbon to the deep ocean.
- **Carbon cycle importance:** The BCP is estimated to sequester over 1,280 Pg C at steady state (Nowicki et al., 2022), and in this way lowering the baseline atmospheric concentration of CO_2 by more than 50% with respect to the effects of physical and chemical equilibrium alone (Maier-Reimer et al., 1996).
- **Lots of uncertainties:** Despite of its importance, it is still poorly understood and constrained.

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Theme session B: Ecosystem-based management & fisheries management
Paul spencer

Rapidly changing ocean conditions in the north Pacific have prompted development of stock assessment models and management procedures that account for non-stationary trends in stock productivity and impacts on shifting fishing rate and biomass reference points. For eastern Bering Sea walleye pollock (*Gadus chalcogrammus*), recruitment and stock productivity are linked to temperature through effects on prey availability, with reduced productivity and lower optimal harvest rates expected under warmer conditions. However, environmental-recruitment relationships often have high variability, and some stocks may exhibit productivity shifts without clear correlations to available environmental indicators. To address this uncertainty, we developed a suite of harvest control rules (HCRs) for Alaska stocks, including approaches that explicitly incorporate climate covariates and others that adapt to changing productivity without direct environmental linkages. Simulation testing under projected future conditions indicated that climate-enhanced HCRs produced similar yields as the current static HCR, while maintaining higher biomass levels and reducing the frequency of fishery closures (triggered when biomass falls below 50% of the reference point). Although reference points are re-estimated as new data becomes available and thus have some inherent time variation, the application of stationary assessment models to non-stationary stocks may underestimate shifts in productivity. Additionally, we compared climate-enhanced HCRs and adaptive HCRs that respond to updated estimates of current stock productivity without an explicit link to climate. Either form of adaptive HCR can improve alignment between management advice and evolving productivity for eastern Bering Sea walleye pollock, while stabilizing fishery performance under changing ocean conditions.



Evaluating the relative performance of using random effects versus environmental covariates in single-species stock assessment models
Melissa Karp

Environmental-driven shifts in fish population dynamics have challenged the reliability of stationarity assumptions in traditional single-species stock assessment models. A key debate in fisheries science revolves around the relative utility of using random effects versus explicit environmental indicators to account for this variability. Relying solely on random effects and process error adjustments may "mask" the underlying biological and environmental drivers of stock condition. Thus there is a critical need to determine when environmental covariates should be explicitly modeled versus when random effects are sufficient for providing robust management advice. This study uses a simulation-estimation approach to evaluate the effectiveness of different modeling strategies for incorporating environmental variability within the single-species stock assessments. Our objectives are twofold: (1) compare the accuracy and predictive performance of models using random effects versus explicit environmental covariates, and (2) evaluate parameter identifiability when both random effects and environmental covariates are included in the model. We use two R packages {ecosystemdata} and {ecosystemom} to generate simulated observations from an ecosystem operating model (OM; Ecopath with Ecosim), which explicitly includes environmental drivers of recruitment for a focal fish stock. We then fit single-species stock assessment models for our focal stock based on generated input data and “true” biological information from the ecosystem OMs. We fit four estimation models using the NOAA Fisheries Integrated Modeling System (FIMS), a next-generation, community built, stock assessment platform, that differ in their structural assumptions around how recruitment is modeled: (1) random effects only, (2) environmental covariate (traditional regression approach), (3) environmental linkages informed by a dynamics structural equation model, and (4) null model (average recruitment assumption). Model

performance is evaluated based on the Relative Error (RE) in key management quantities—spawning stock biomass (*SSB*), fishing mortality (*F*), and recruitment—in addition to diagnostics for retrospective bias (Mohn's Rho) and prediction skill (Mean Absolute Scaled Error, MASE). This simulation study is ongoing and the presentation will focus on experimental design and preliminary findings from pilot runs. This goal of this research is to provide information to guide the incorporation of ecosystem linkages into FIMS, ensuring that the next generation of management advice is both ecologically grounded and statistically robust.





Quantifying Food-Web Dynamics to support fisheries management advice
Benjamin Planque

Effective ecosystem-based management relies on understanding and quantifying species interactions that can affect fisheries management and conservation goals. This presentation introduces a food-web assessment model that reconstructs the dynamics of fish, marine mammals, and fisheries in the Norwegian and Barents Seas over recent decades, based on available data and expert knowledge. The outputs of the assessment are time-series of biomass,

feeding interactions, and catches, with known levels of uncertainty. These are used to address key assessment and management questions:

- How did natural mortality of commercial fish stocks change in the last decades?
- Can multiple fisheries management and marine mammal conservation goals be achieved simultaneously?
- Do changes in marine mammal biomass impact fish stocks? By how much?

Results show that natural (predation) mortalities, though very uncertain, have varied in recent decades sometimes far from the rates commonly assumed in stock assessment models. The results also indicate that today's management and conservation goals can, in principle, all be met at the same time. Finally, the results highlight that marine mammals have had a much stronger, and also more uncertain, impact on fish than vice versa.

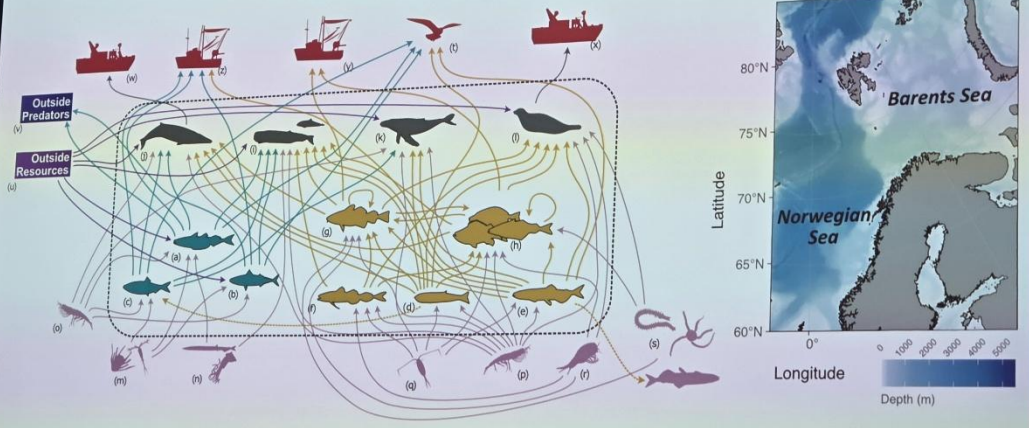
These results have direct implications for setting quotas, balancing conservation objectives, and managing multispecies trade-offs. They can be used to supports integrated ecosystem assessments and to evaluate multiple management objectives simultaneously, help identify where goals align, where they conflict, and what trade-offs are involved. For decision-makers this approach offers a practical and transparent tool to include ecological considerations in management design.



Assessment: single stock vs. food-web

Assessment	Single stock	Food-web
in	Survey & Fisheries data	Diets, life-history, stock assessment outputs
model	Population dynamics	Food web dynamics (e.g. mass balanced)
out	Numbers/biomass and catch	Biomass, consumptions, predation, catches
use	Advice for fishing opportunities (one stock)	multi-species trade-offs, predation mortality

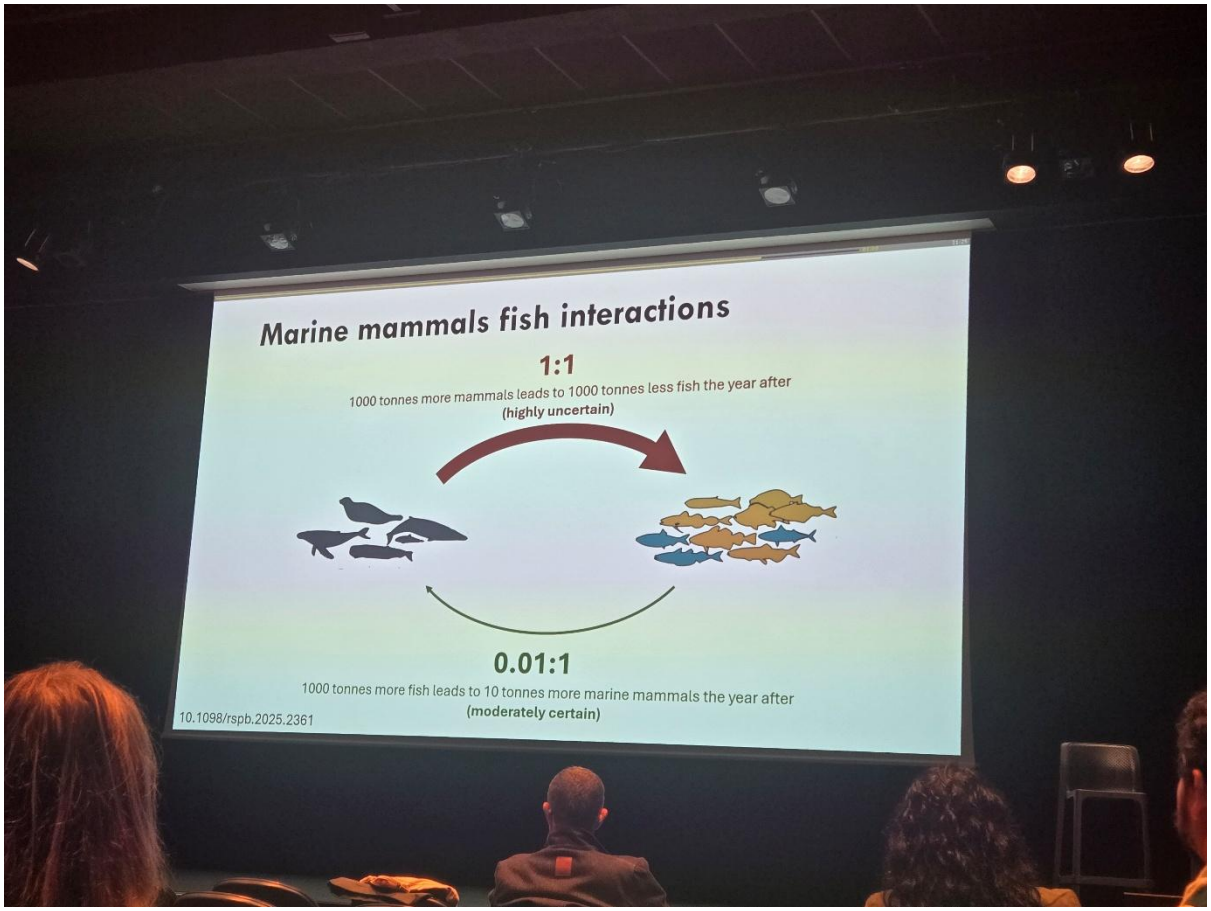
Food web assessment



10.1016/j.pocean.2024.103361

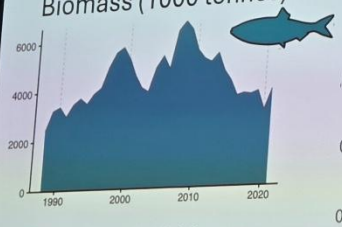
3 examples of policy/management relevant outputs

- How has predation-related mortality of herring changed historically?
- Are different fisheries management rules compatible with each other?
- Do changes in marine mammal biomass impact fish stocks? By how much?

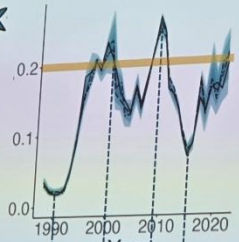


Herring predation mortality estimates

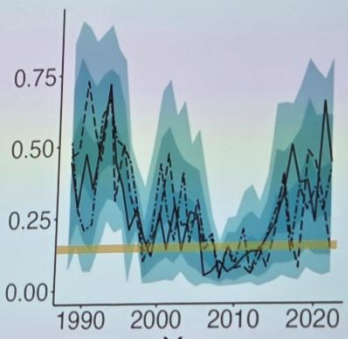
Biomass (1000 tonnes)



Fishing mortality (F*)

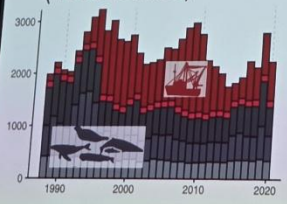


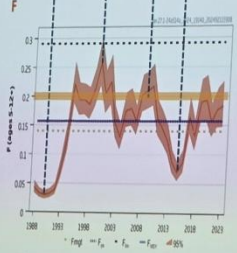
Predation mortality (yr^{-1})



M = 0.15 is the mortality assumption in single stock assessment

Predation & fishing (1000 tonnes)





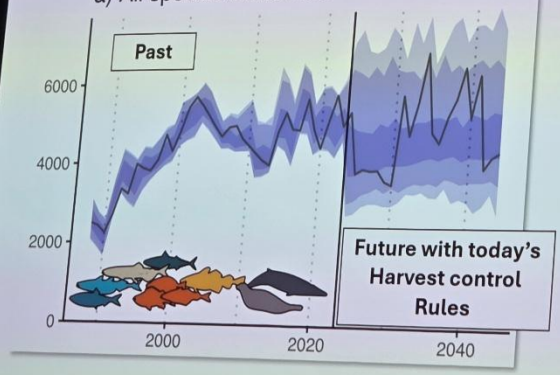
unpublished results

F(5-12yr+) from the WGWIDE stock assessment 2024

Compatibility across management and conservation objectives

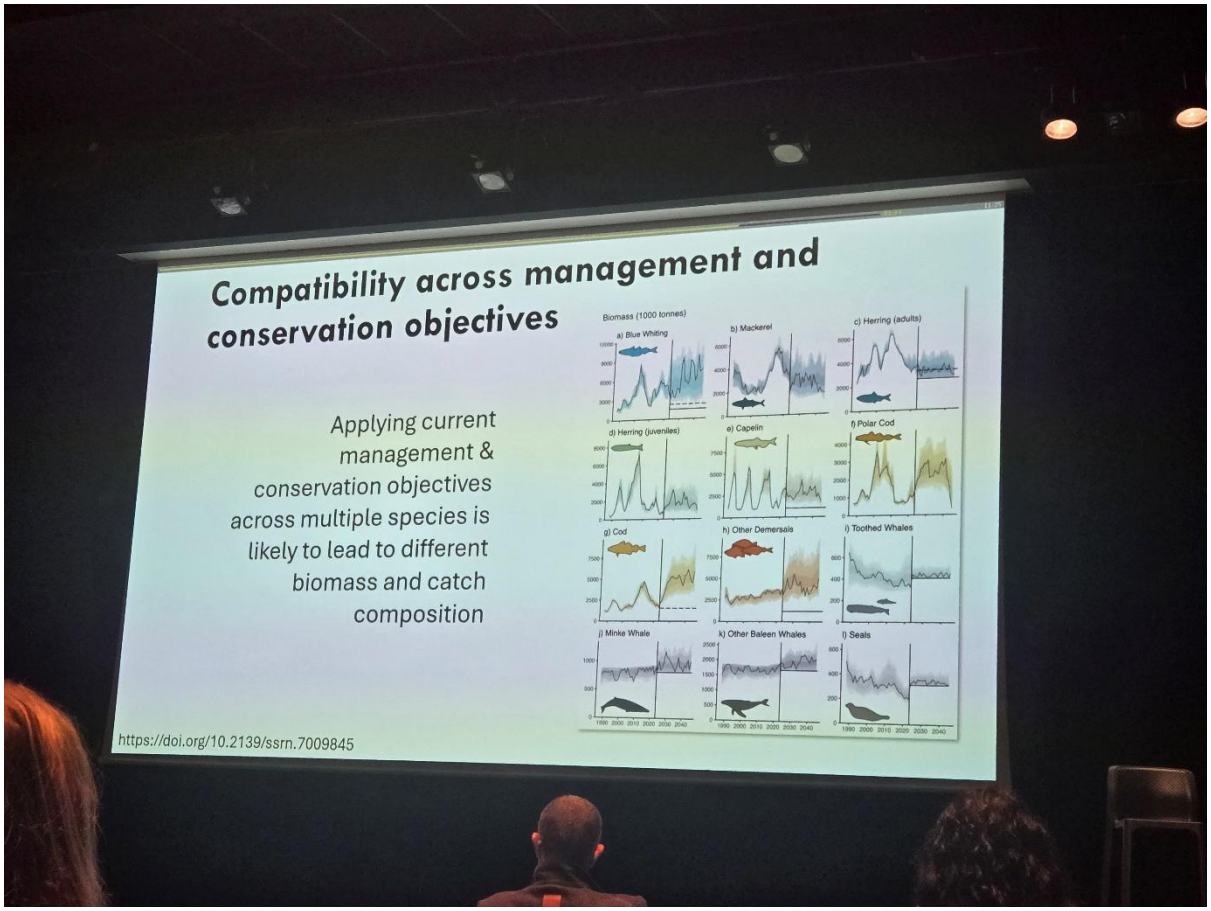
Catches (1000 tonnes)

a) All species combined



Applying current management & conservation objectives across multiple species can yield similar catches as today.

https://doi.org/10.2139/ssrn.7009845



Integrating Dynamic Energy Budget theory into a population dynamics model to explore energetic demands of a declining marine mammal, the northern fur seal (Callorhinus ursinus), under climate change.

Anna Sulc

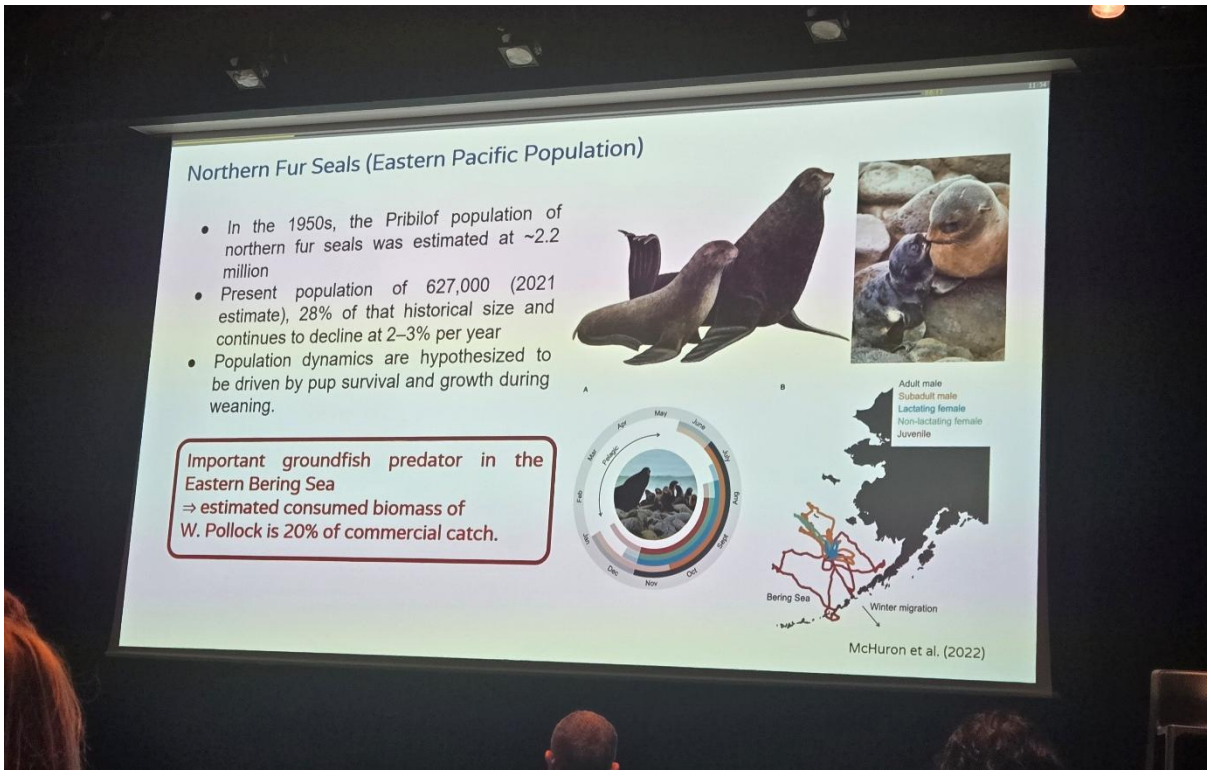
Marine ecosystems globally are changing rapidly and experiencing unprecedented environmental conditions which result in the alteration of their dynamics. These rapid changes lead to a wide scale of impacts on marine food webs ranging from changes in abundance and productivity of a population to the modification of trophic interactions. However, most fisheries stock assessments do not account for these dynamics and still consider a single-species approach. To provide more reliable fisheries management advice, models must consider predator-prey interactions to better assess tradeoffs between fisheries yield and ecosystem resilience to ensure sustainable management going forward. CEATTLE, a climate-enhanced multispecies stock assessment model, considers predator-prey dynamics between different species of groundfish but omits interactions with other predators, such as marine mammals, in the ecosystem.

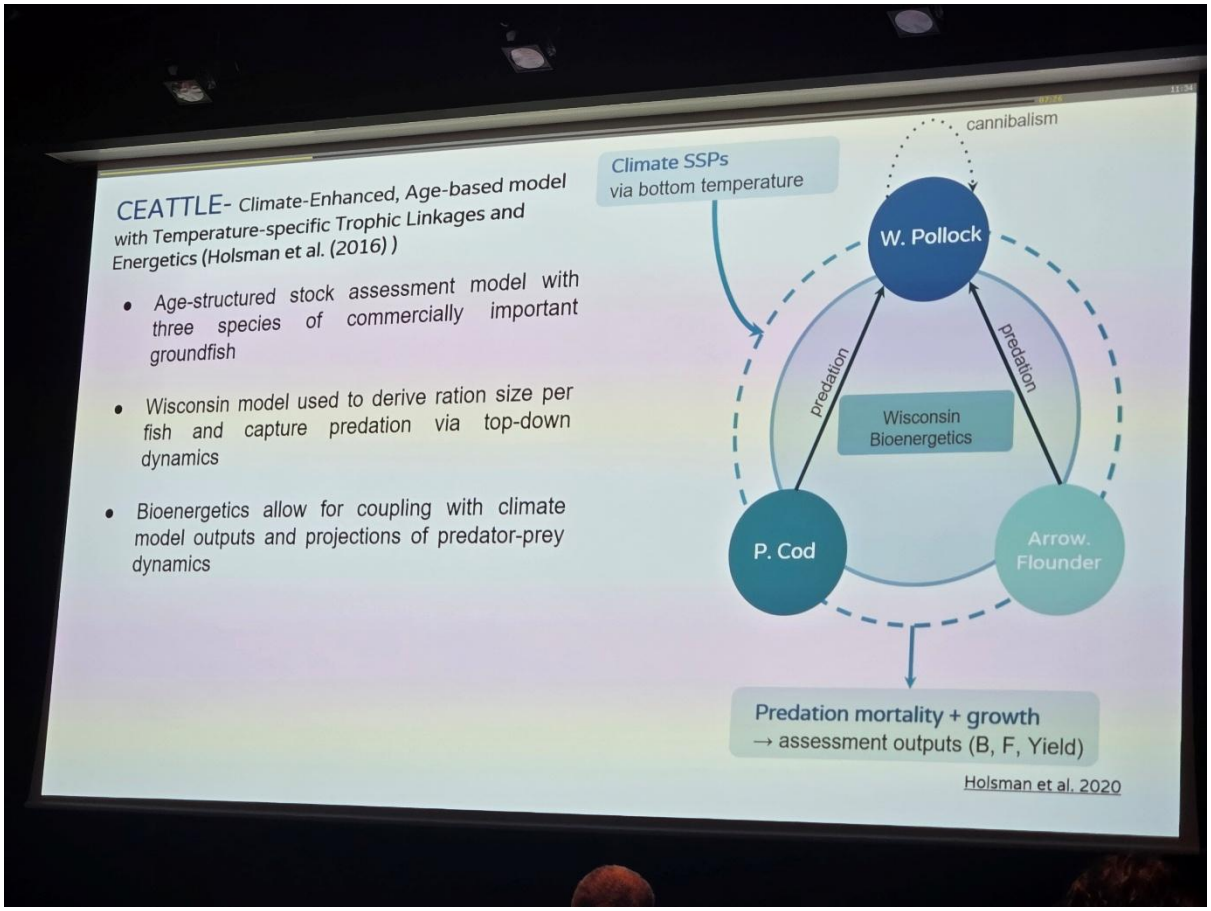
The northern fur seal (NFS) (*Callorhinus ursinus*) is a top predator in the Eastern Bering Sea (EBS) marine ecosystem playing an important ecological and economical role through consumption of large amounts of commercially valuable Walleye Pollock (*Gadus chalcogrammus*). The NFS is also culturally important, as they are harvested by local native communities for subsistence and tradition. Local populations have experienced ongoing declines since the mid 1990s that are hypothesized to be driven by food availability, specifically for lactating females whose ability to find food during an energetically intense time period is a strong driver of offspring growth and survival.

Here we develop a Dynamic Energy Budget (DEB) model for NFS, a bioenergetic theory that captures how an individual acquires and uses energy and essential nutrients for life processes such as development, growth, maintenance, and reproduction across its entire life cycle via

reservoirs and fluxes. The DEB framework supports exploration of growth under optimal conditions as well as the consequences of food limitation on development and survival. Given the importance of pup growth and survival for NFS, we focus on gestation and lactation dynamics while accounting for species-specific traits such as size dimorphism, molt, and seasonal weight gain. This individual-level model is coupled with an age-structured population dynamics framework and forced with projected food availability from CEATTLE across a range of climate scenarios through 2100. We use this integrated framework to evaluate how shifting prey availability may affect mother-pup dynamics and long-term population trajectories, and to quantify the potential for conflict between NFS predation demand and pollock fishery removals. By embedding a bioenergetic predator model directly within a stock assessment context, this work contributes towards efforts to implement ecosystem based fisheries management in the EBS and provides a template for incorporating marine mammal trophic dynamics into fisheries decision-making more broadly.

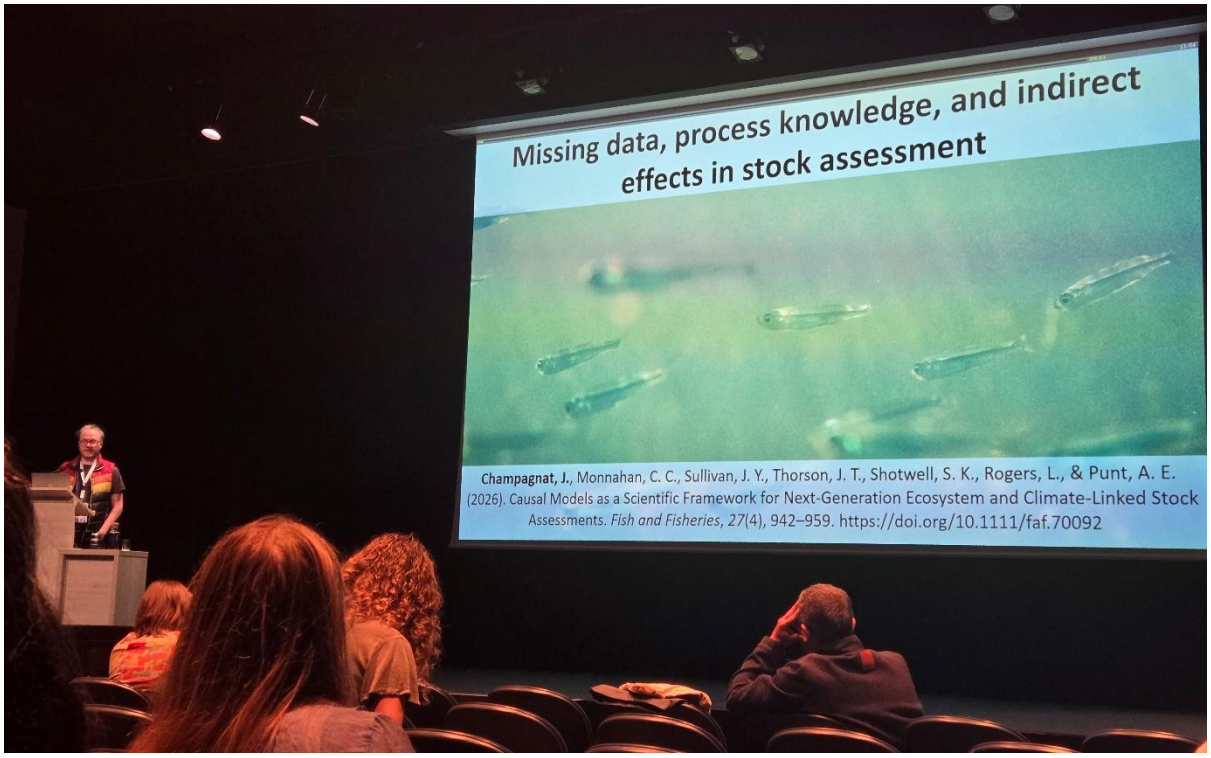


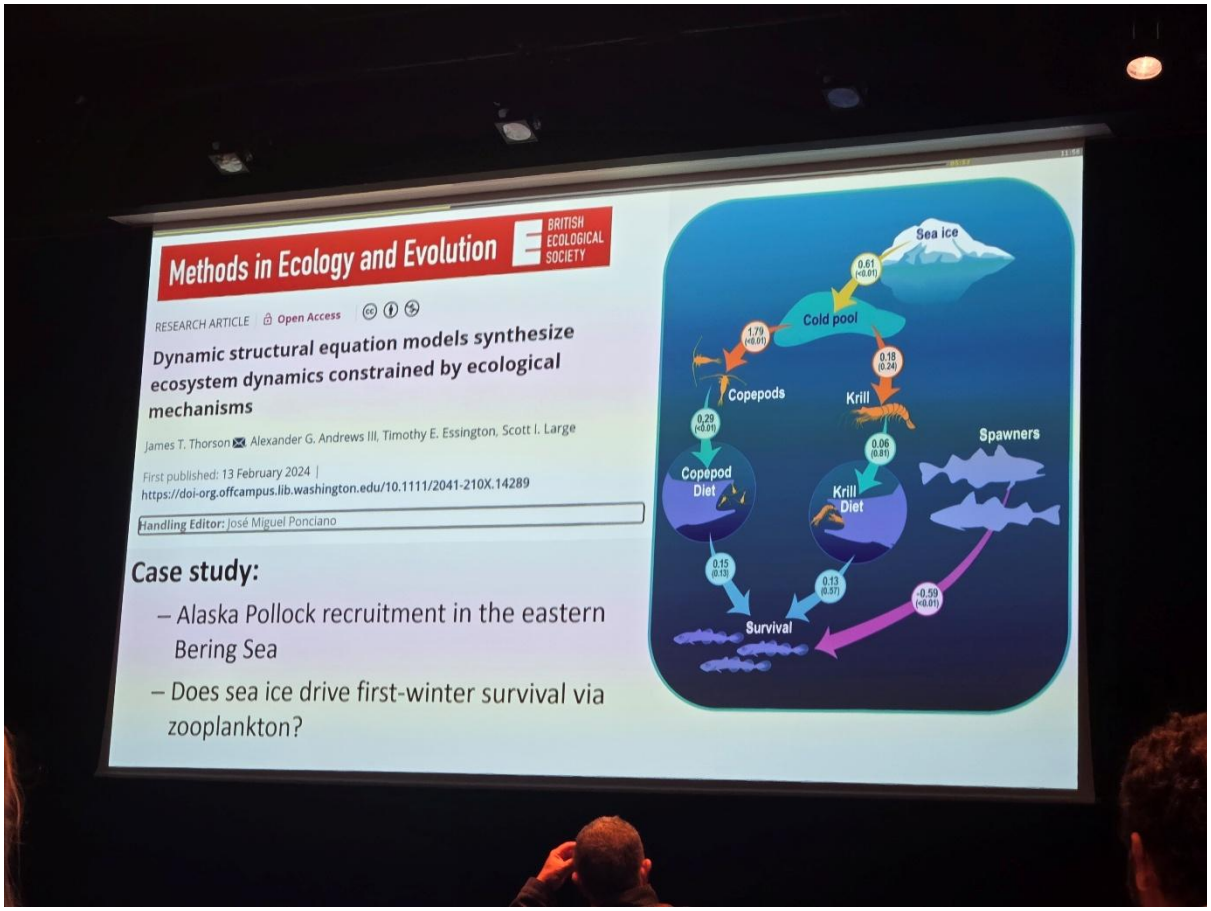


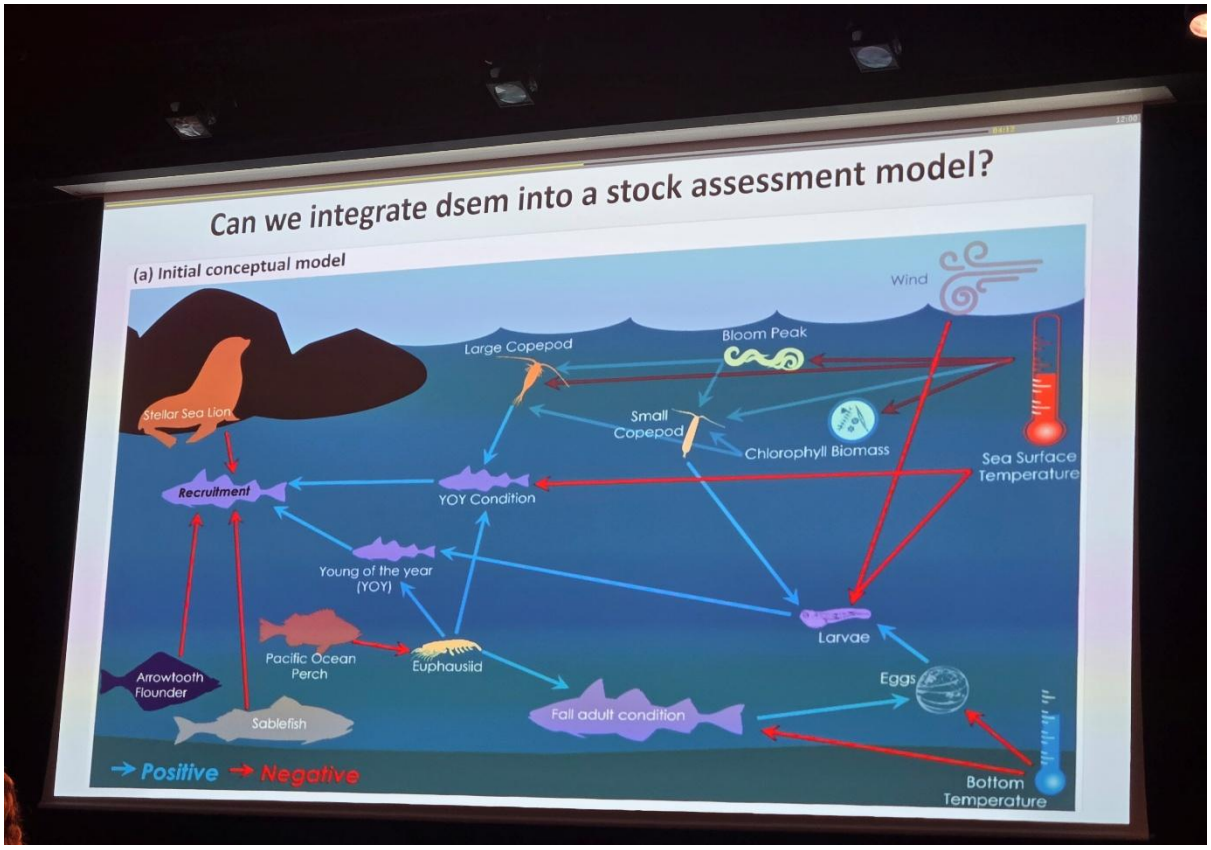


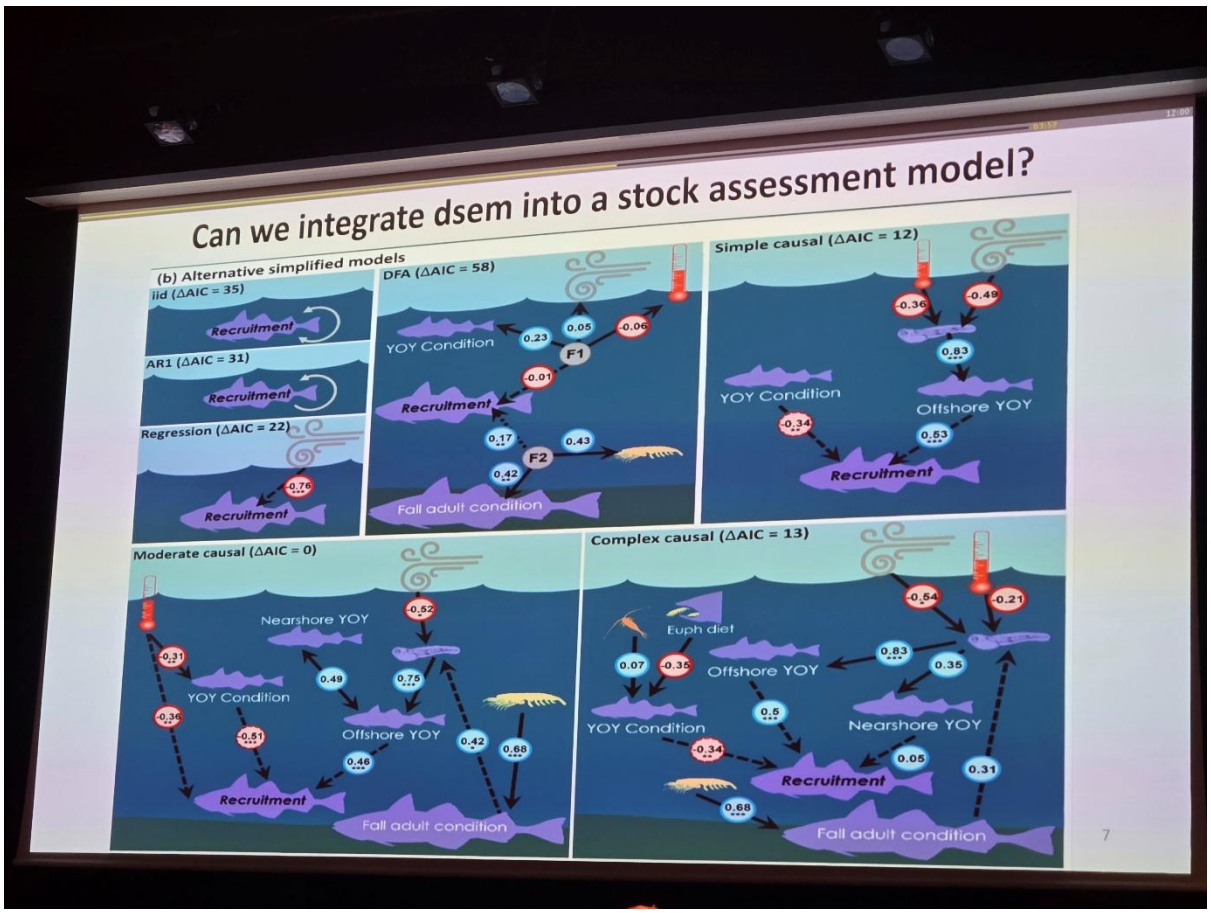
Causal models as a scientific framework for next-generation ecosystem and climate-linked stock assessments
Jim Thorson

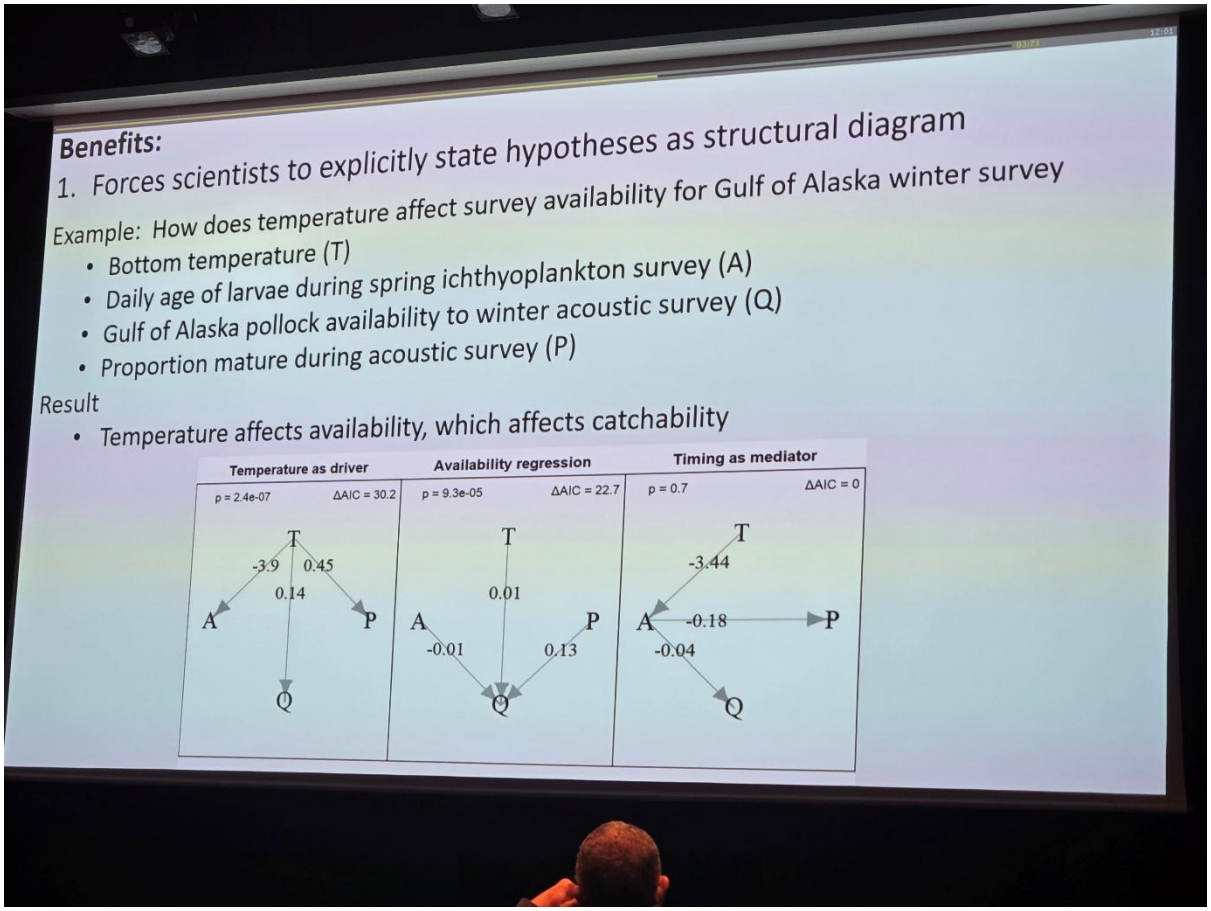
Rapid changes in marine ecosystems highlight the need to account for time-varying productivity in stock assessment models used to support fisheries management. Common approaches incorporate annual variation or regress processes such as recruitment, natural mortality, or growth on environmental variables. While the latter represents a step towards biological realism, it often fails to account for interactions among variables and may yield biased inferences when key drivers are correlated or unmeasured. We introduce a novel framework, Structural Causal Enhanced Stock Assessment Modelling (SCEAM), which integrates a Dynamic Structural Equation Model (DSEM) into a state-space stock assessment. SCEAM encompasses and extends the full range of existing time-varying approaches within a single framework, enabling direct comparison among them. We applied SCEAM to walleye pollock in the Gulf of Alaska to improve recruitment forecasting, comparing three causal models of increasing complexity to recruitment modelled as random deviations around a mean, a first order autoregressive process, or regressed on a single variable. We found that a causal model with intermediate complexity best balanced fit, parsimony, and predictive skill. This configuration reduced unexplained variance of recruitment by 69% and improved one-year-ahead forecasts. Key variables included juvenile body condition and juvenile and larval catch rates. Our study represents the first application of a structural causal model embedded within a fisheries population model. SCEAM offers a unified, hypothesis-driven approach to integrating multiple non-independent variables. We therefore propose that SCEAM can serve as a general scientific and statistical framework for building next-generation ecosystem- and climate-linked fisheries stock assessment models.


Missing data, process knowledge, and indirect effects in stock assessment
Champagnat, J., Monnahan, C. C., Sullivan, J. Y., Thorson, J. T., Shotwell, S. K., Rogers, L., & Punt, A. E. (2026). Causal Models as a Scientific Framework for Next-Generation Ecosystem and Climate-Linked Stock Assessments. Fish and Fisheries, 27(4), 942–959. https://doi.org/10.1111/faf.70092


Methods in Ecology and Evolution
BRITISH ECOLOGICAL SOCIETY
RESEARCH ARTICLE
Open Access
Dynamic structural equation models synthesize ecosystem dynamics constrained by ecological mechanisms
James T. Thorson ✉ Alexander G. Andrews III, Timothy E. Essington, Scott I. Large
First published: 13 February 2024 |
https://doi-org.offcampus.lib.washington.edu/10.1111/2041-210X.14289
Handling Editor: José Miguel Ponciano
Case study:
– Alaska Pollock recruitment in the eastern Bering Sea
– Does sea ice drive first-winter survival via zooplankton?
Sea ice
0.61 (<0.01)
Cold pool
1.79 (<0.01)
0.18 (0.24)
Copepods
Krill
0.29 (<0.01)
0.06 (0.81)
Spawners
Copepod Diet
Krill Diet
0.15 (0.13)
0.13 (0.37)
-0.59 (<0.01)
Survival


Can we integrate dsem into a stock assessment model?
(a) Initial conceptual model
Wind
Large Copepod
Bloom Peak
Stellar Sea Lion
Small Copepod
Chlorophyll Biomass
Sea Surface Temperature
Recruitment
YOY Condition
Young of the year (YOY)
Larvae
Pacific Ocean Perch
Euphausiid
Arrowtooth Flounder
Eggs
Sablefish
Fall adult condition
Positive
Negative
Bottom Temperature


Can we integrate dsem into a stock assessment model?
(b) Alternative simplified models
iid (ΔAIC = 35)
Recruitment
AR1 (ΔAIC = 31)
Recruitment
Regression (ΔAIC = 22)
-0.76
Recruitment
DFA (ΔAIC = 58)
YOY Condition
0.23
0.05
-0.06
F1
-0.01
Recruitment
0.17
0.43
F2
0.42
Fall adult condition
Simple causal (ΔAIC = 12)
-0.36
-0.48
0.83
YOY Condition
Offshore YOY
-0.34
0.53
Recruitment
Moderate causal (ΔAIC = 0)
-0.52
Nearshore YOY
-0.31
0.49
0.75
YOY Condition
-0.36
-0.51
Offshore YOY
0.42
0.68
0.46
Recruitment
Fall adult condition
Complex causal (ΔAIC = 13)
-0.54
-0.21
Euph diet
0.07
-0.35
Offshore YOY
0.83
0.35
0.5
YOY Condition
Nearshore YOY
-0.34
0.05
0.31
Recruitment
0.68
Fall adult condition
7



Assessing the Effects of Size-Selective Fishing on Population Structure and Community Dynamics in the Northern Humboldt Current Ecosystem Using an Individual-Based Ecosystem Model

Juliane Niewar

Fishing pressure not only reduces the population size of target species but also alters their demographic structure, often resulting in juvenilized populations as a consequence of size-selective fishing practices. However, the ecosystem responses to fishing strategies that employ different catch size regulations are still poorly understood. The Northern Humboldt Current System (NHCS) is a highly productive fishing region, relying predominantly on its anchoveta (*Engraulis ringens*) fishery. The fishery of the fast-growing Humboldt Squid (*Dosidicus gigas*) has increased notably in recent years. In contrast, the slow-growing hake (*Merluccius gayi*) has been overexploited for decades, exhibiting a juvenile-biased demographic structure.

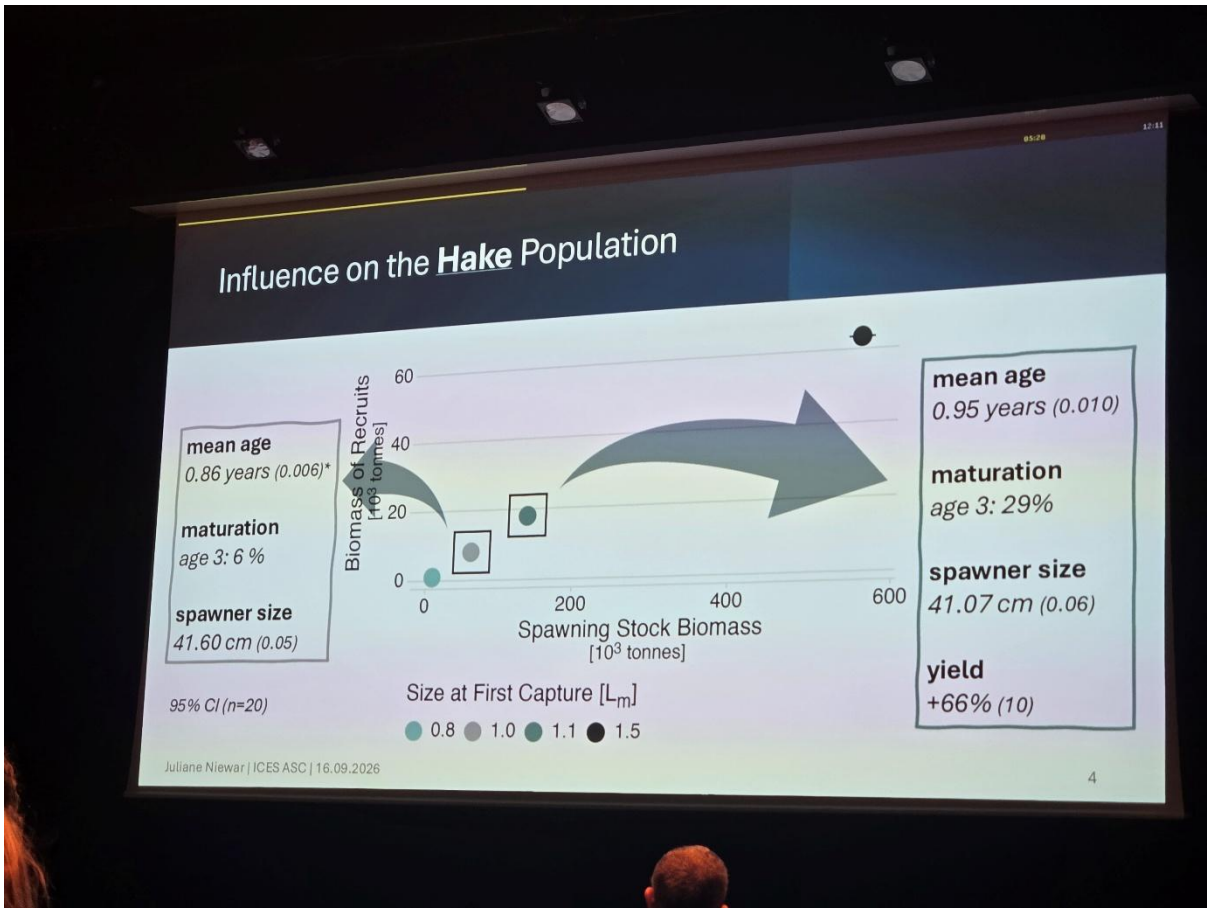
In this study, we employed the multispecies, individual-based model OSMOSE to assess the impacts of different minimum catch size regulations for anchoveta, hake, and Humboldt squid on their demographic structure and on the community dynamics of the NHCS.

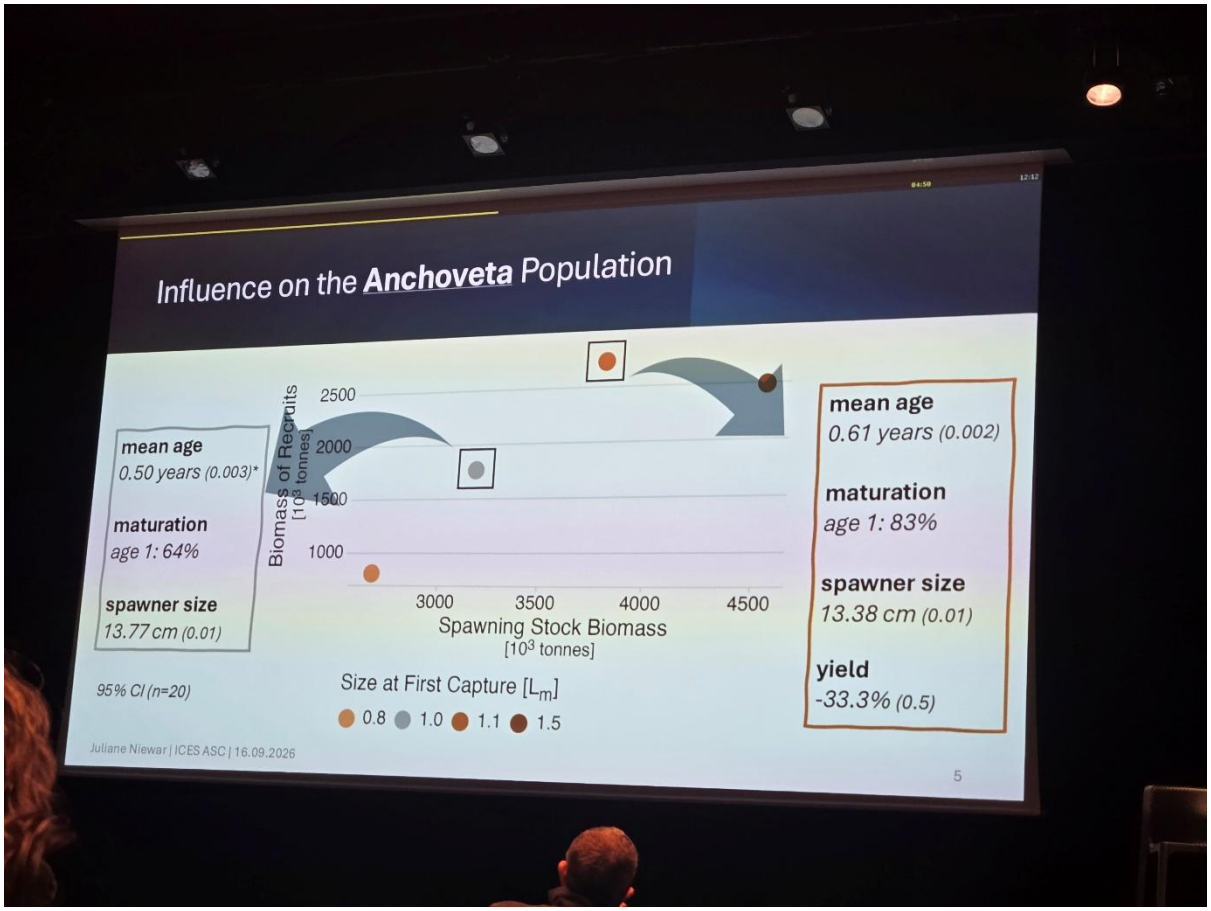
We observed an increased stock size and a more mature demographic structure for anchoveta and hake in fishing scenarios restricted by larger catch sizes relative to current ones. These alterations in population structure also affected the community composition of the NHCS through trophic propagation. Our results emphasize the important position of anchoveta in the NHCS food web, as its biomass was negatively associated with the biomass of its predation competitors, such as squat lobster (*Pleuroncodes monodon*) and jack mackerel (*Trachurus murphyi*). In contrast, varying the minimum catch size of the fast-growing Humboldt squid neither altered its population structure nor affected the community composition.

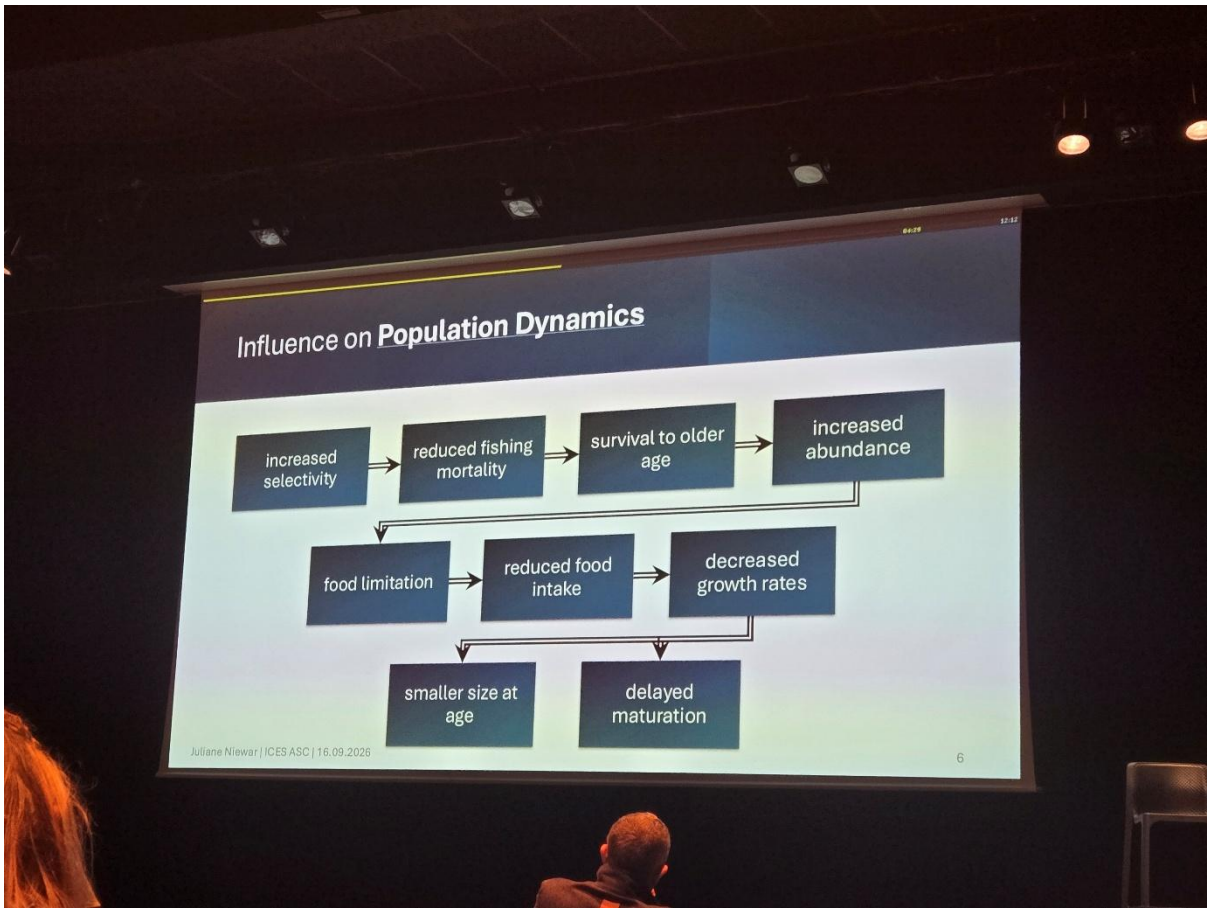
Our findings suggest that adjusting catch size regulations can be an effective mechanism to ensure sustainable fishing, particularly for depleted fish stocks with slow life histories, such as hake. Moreover, fishing strategies that benefit the anchoveta stock may result in a decrease in

other commercially important species, such as jack mackerel. These insights can contribute to the development of ecosystem-based management strategies for fish stocks by improving our understanding of how target species and the community in the NHCS respond to size-selective fishing scenarios.

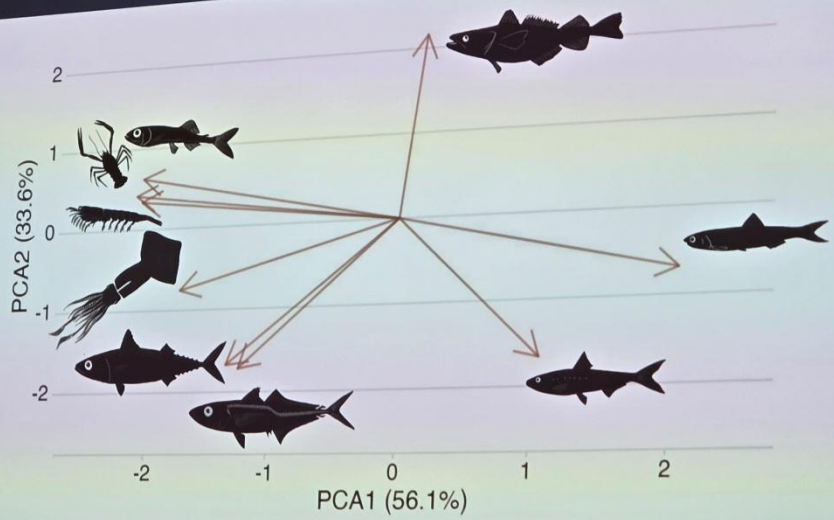





Influence on the Anchoveta Population
mean age
0.50 years (0.003)*
maturation
age 1: 64%
spawner size
13.77 cm (0.01)
95% CI (n=20)
Biomass of Recruits
[10³ tonnes]
2500
2000
1500
1000
3000
3500
4000
4500
Spawning Stock Biomass
[10³ tonnes]
Size at First Capture [Lm]
0.8 1.0 1.1 1.5
mean age
0.61 years (0.002)
maturation
age 1: 83%
spawner size
13.38 cm (0.01)
yield
-33.3% (0.5)
Juliane Niewar | ICES ASC | 16.09.2026
5


Influence on Population Dynamics
increased selectivity
reduced fishing mortality
survival to older age
increased abundance
food limitation
reduced food intake
decreased growth rates
smaller size at age
delayed maturation
Juliane Niewar | ICES ASC | 16.09.2026
6

Species Interactions



Key Take-Aways



LOOK BEYOND BIOMASS



LOOK BEYOND PREDATOR-PREY INTERACTIONS



OSMOSE ALLOWS MULTI-SCALE PERSPECTIVE

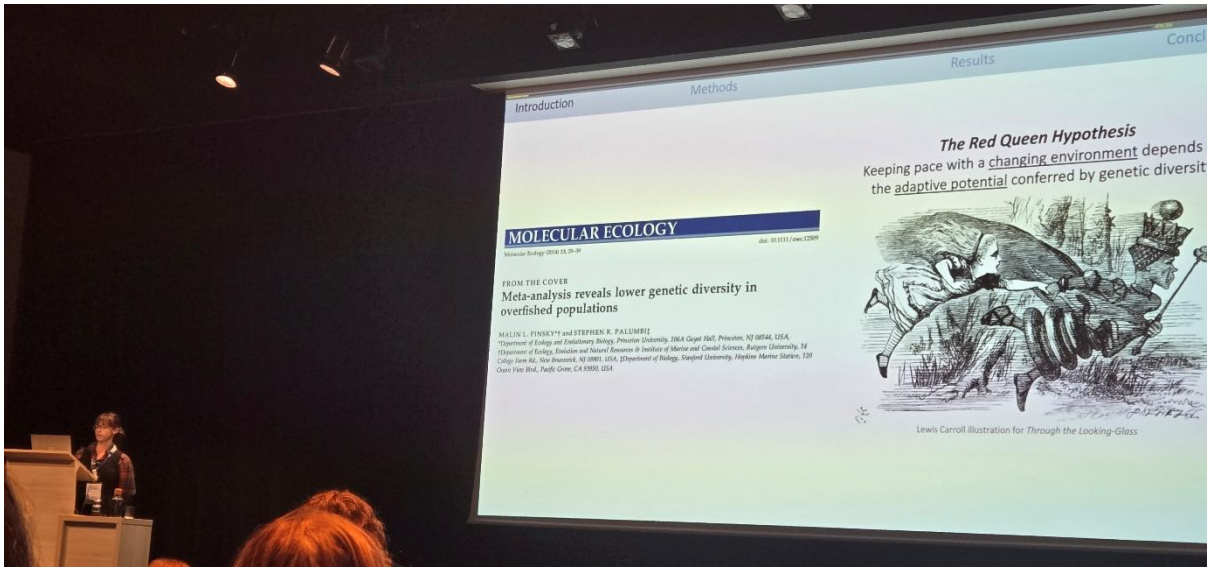
Ecosystem dynamics shape effective population size response to fishing: implications for single-species advice

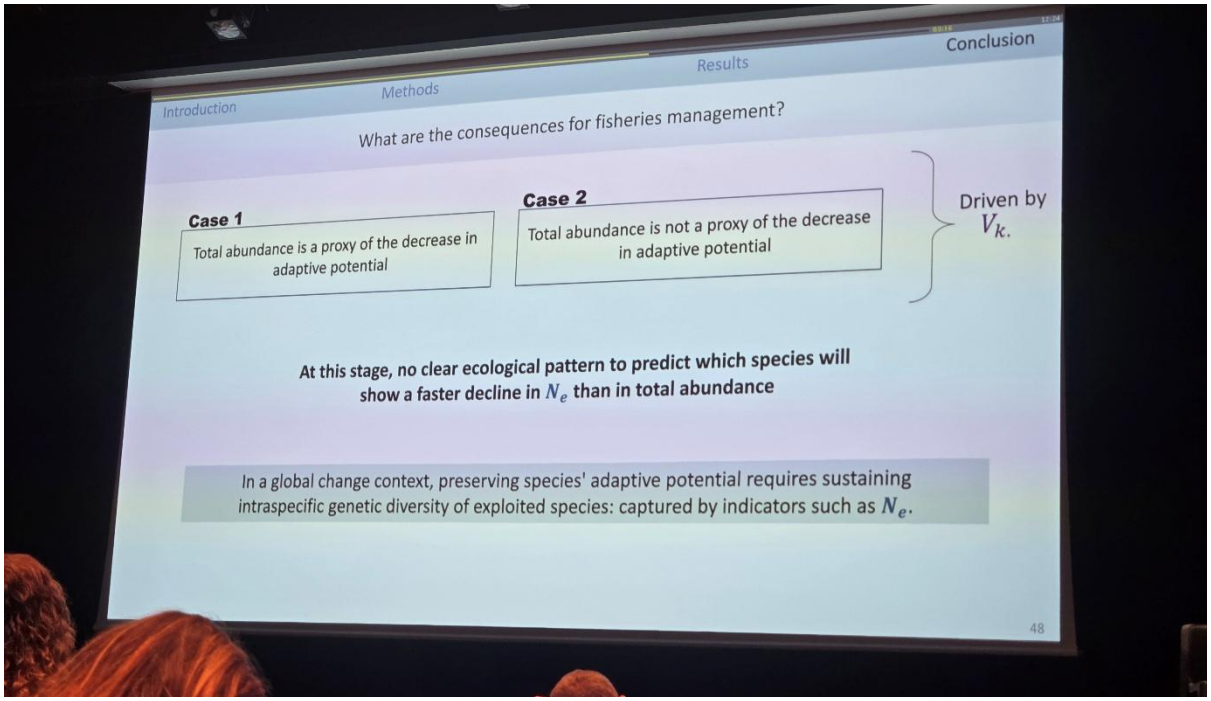
Marine Beneat

Single-species fisheries advice is usually based on abundance- or biomass-based indicators, yet these may not fully capture changes in population resilience under exploitation. In particular, effective population size (N_e) reflects the rate of genetic diversity loss, and thus the erosion of adaptive potential, whereas census population size (N) tracks demographic decline. The ratio N_e/N can therefore indicate whether genetic diversity is being lost more slowly or more rapidly than abundance. This distinction is important for risk interpretation in stock assessment and forecasting contexts, but it is usually examined in **mono-specific** models that omit ecological interactions.

Previous mono-specific models predict a decline in N_e with increasing fishing mortality due to reduced recruitment, but an increase in N_e/N as abundance declines faster than genetic diversity. However, population dynamics can be driven by ecological processes such as competition and predation, which are occluded in mono-specific models. We used OSMOSE, a spatially explicit, size-based **multispecies** individual-based model, to simulate harvested fish populations under contrasting fishing pressures and quantify responses in N_e (estimated from life-history traits), N, and N_e/N. In this framework, emergent trophic interactions generate time-varying natural mortality and reproductive conditions through predation, competition, and environmentally constrained bioenergetics, resulting in less predictable life-history variation and N_e/N ranges than those observed in monospecific model populations.

Our results challenge the expectation of a consistently positive linear relationship between N_e/N and fishing mortality. Instead, they show that genetic diversity loss and abundance decline under exploitation are species-specific, potentially compromising sustainability beyond what abundance-based indicators alone would suggest. To interpret these patterns, we investigated the links between fishing mortality, natural mortalities, fecundity, generation length, variance in reproductive success and N_e, thereby improving our understanding of N_e and N_e/N dynamics. For single-species applications, we sought indicators to distinguish between species that lose genetic diversity faster from species that primarily experience abundance decline. Overall, our findings suggest that robust single-species advice would benefit from accounting for ecosystem dynamics when evaluating relative losses in genetic diversity and recovery potential in abundance and genetic diversity, as neglecting these processes may misrepresent stock resilience to exploitation.





Integrating predation mortality into Pacific hake assessment
Raquel Ruiz Diaz

Pacific hake (*Merluccius productus*) is the largest commercial fishery on the U.S. West Coast and a keystone species in the California Current ecosystem. Current stock assessments, conducted annually under the Pacific hake/Whiting treaty, rely on catch-at-age single-species models that assume time-invariant natural mortality, potentially biasing population estimates. Here, we address this gap by applying the multispecies model CEATTLE (Climate-Enhanced Age-based model with Temperature-specific Trophic Linkages and Energetics) to explicitly quantify predation mortality for Pacific hake. We expanded CEATTLE to incorporate predators with diet-limited information (lacking prey-at-age data) and partition natural mortality into predation from key predators and residual sources (e.g., disease, senescence), producing more robust, age- and time-varying mortality estimates. Our model includes predation by Arrowtooth flounder (*Atheresthes stomias*), Sablefish (*Anoplopoma fimbria*), California sea lions (*Zalophus californianus*), and hake cannibalism. Cannibalism emerged as the dominant source of predation mortality, but predation from other included predators was also relevant, particularly for age-1 and age-2 hake. Accounting for predation modified population estimates and revealed increased competition for age-2 hake between the fishery and predators, especially sea lions. CEATTLE outputs can be directly compared with single-species assessments and used to derive multispecies biological reference points. By explicitly quantifying predation mortality, our approach provides a more realistic representation of ecosystem dynamics and fisheries interactions. This work demonstrates that multispecies assessments are not only feasible but also operationally relevant, offering actionable insights that can guide management decisions, improve stock sustainability, and support ecosystem-based fisheries management strategies.


Toward ecosystem-based advice for Pacific hake: accounting for predation mortality
Raquel Ruiz-Díaz
University of Washington
September 16th 2026
Annual Science Conference
ICES 2026


Toward EBFM
Ecosystem processes can be a major drivers of stock productivity.
single-species catch-at-age model
Fishing
Environmental variability
Predator-prey interactions
Habitat
Adapted from The Pew charitable Trust (2023)
Trade-off between model complexity & operational management advice.
Ecosystem model
Variance of policy indicator
MICE
'Sweet spot'
Model bias
Parameter uncertainty
Single spp
Model uncertainty
Complexity (number of parameters estimated)
Adapted from Collie et al., 2016; Plagányi et al., 2014
3

CEATTLE

Climate-**E**nhanced, **A**ge-based model with **T**emperature-specific **T**rophic **L**inkages and **E**nergetics

CEATTLE extends statistical catch-at-age models to **incorporate trophic interactions through diet proportions and bioenergetics**.

Key Feature: It splits Natural Mortality (M) into:

M1: Residual mortality (disease, senescence, non-modelled predators).

M2: Predation mortality by predators in the model.



We follow a cohort over time:

numbers → $N_{sp,a+1,y+1} = N_{sp,a,y}\, e^{-Z_{sp,a,y}}$ ← total mortality

$$Z_{sp,a,y} = M1_{sp,a} + M2_{sp,a,y} + F_{sp,a,y}$$

Residual mortality | Predation mortality | Fishing mortality

Predation mortality (M2)

Predation mortality (*M2*)

1. Suitability coefficient: prey- and age/size-preference
2. Predator abundance
3. Estimate of annual consumption:
   - Temperature-dependent consumption (Kitchell et al. 1977)
   - Consumption scales with body size (Francis 1983)

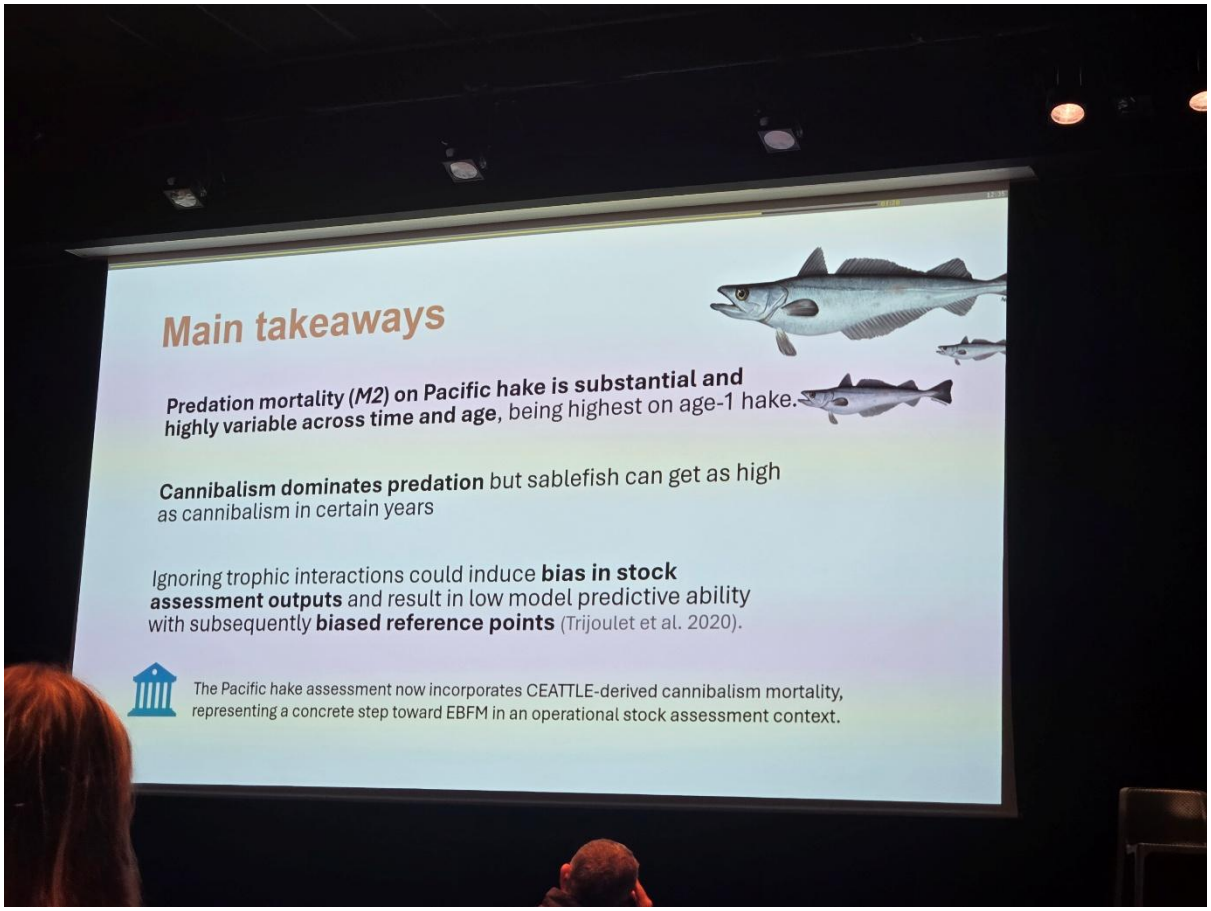
Consumption; Predator abundance; suitability

$$M2_{isay} = \sum_{pbj}\left(\frac{\bar{N}_{pbjy}\delta_{pbjy}\hat{S}_{pbjisa}}{\sum_{isa}\left(\hat{S}_{pbjisa}\bar{B}_{isay}\right) + B_p^{other}\left(1-\sum_{isa}\left(\hat{S}_{pbjisa}\right)\right)}\right)$$

Prey biomass; Other Biomass



For predators p of sex b, age j, and prey i of age a and sex s in year y



Considering Ecosystem Risk in the Management of New England Fisheries
Maxwell Grezlik

The New England Fishery Management Council (NEFMC) has approved and begun implementation of a Risk Policy Framework as a step toward Ecosystem-Based Fisheries Management. The framework is designed to incorporate ecosystem considerations into single-species management advice by explicitly accounting for environmental, ecological, and socioeconomic risk factors when setting Acceptable Biological Catch (ABC).
We present the development of climate- and ecosystem-informed indicators to support this framework, focusing on species-specific thermal habitat suitability as a measurable risk factor. Thermal tolerance ranges were derived from long-term bottom trawl survey observations and a comprehensive literature review . These tolerance estimates were paired with temperatures from an ocean reanalysis product to quantify temporal changes in realized thermal habitat for managed stocks.
For each species, we developed indicators that track the proportion of the stock's distribution occurring within, approaching, or exceeding thermal thresholds annually and seasonally. These indicators provide a standardized and transparent method to evaluate exposure to warming and potential shifts in productivity or distribution. By translating environmental change into stock-specific risk metrics, the approach allows climate signals to be considered in managers evaluation of risk alongside traditional assessment outputs.
Within the NEFMC Risk Policy Framework, a formal pathway exists for integrating environmental variability and long-term change into single-species management decisions. This integration occurs without replacing the existing assessment process, as adjustments to ABC control rules are made when risk is elevated.
Our work demonstrates a scalable and operational model for integrating climate and ecosystem risk into routine fisheries management while maintaining the structure of single-species assessment frameworks. This approach is transferable to other management bodies.



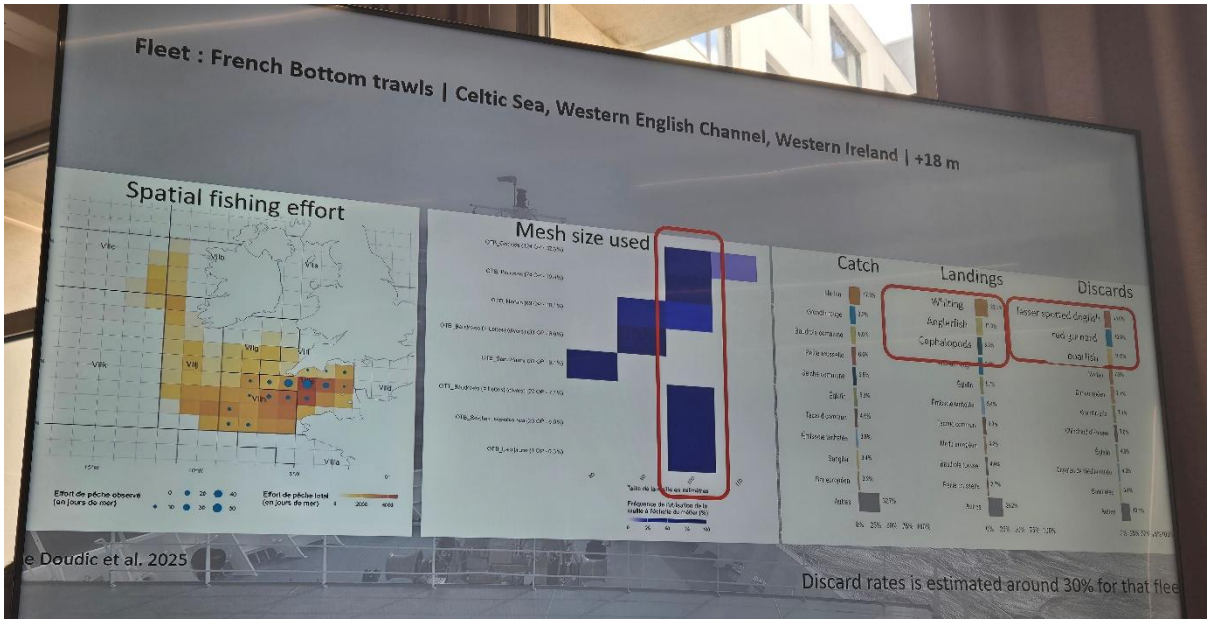


Fisher's experience with the 100 mm T90 mesh selective device in the Celtic Sea: high voluntary adoption in the monkfish and ray fisheries versus low uptake in the gadoid fisheries.
Marianne Robert

Reducing unwanted catches remains a key challenge for most European demersal trawl fisheries to improve fishing practices and ensure long-term yield. In the Celtic Sea, a recent assessment

of the absolute selectivity of the standard 100-mm diamond mesh codend and extension highlighted limited intra- and interspecific size selectivity. Several research programmes have investigated alternative gear configurations to enhance selectivity in the region. This study reports on the voluntary implementation of a 100-mm T90 mesh extension and codend as a bycatch reduction device (BRD) after scientific trials conducted under commercial conditions on twin trawlers. We demonstrated a marked reduction in catches of pelagic and schooling species, notably boarfish, for which these fisheries have strict quota restrictions. Owing to its low cost and ease of implementation, the device was rapidly and voluntarily adopted by vessels targeting monkfish and rays. A 2022 industry survey indicated that 13 vessels had implemented this gear modification. However, the 100-mm T90 configuration proved overly selective for roundfish species such as whiting and haddock, thereby constraining its uptake across other demersal trawl segments. Nevertheless, the mechanical characteristics of T90 mesh indicate potential to enhance multispecies selectivity, particularly for species subject to high discard rates, including gurnard and lesser-spotted dogfish. Experimental evidence suggests that reducing T90 mesh size to 80 mm may better align L50 values with the commercial sizes of gadoids. Indeed, successful voluntary uptake of an 80-mm T90 configuration has been documented on four vessels targeting finfish in the North Bay of Biscay. In the Celtic Sea, however, regulatory constraints currently hinder the implementation of an 80-mm T90 configuration. A shift towards a results-based management approach, rather than strict minimum mesh size regulation, could facilitate further testing of such BRDs in whitefish fisheries and promote the broader uptake of effective selectivity measures in the Celtic Sea.



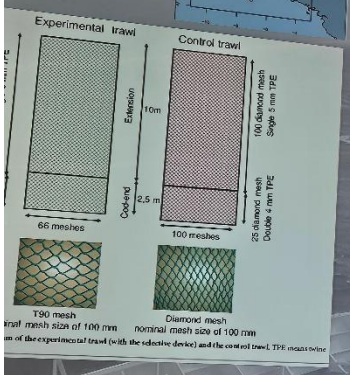


Toward elimination of unwanted catches using a 100mmT90 extension and codend in demersal mixed fisheries

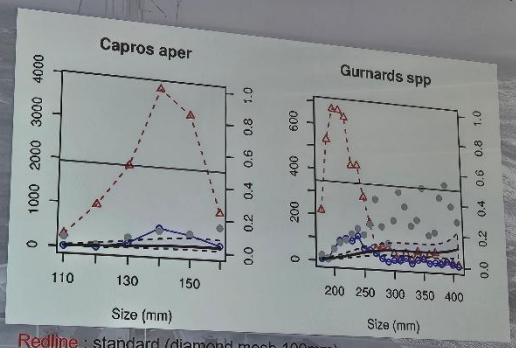
CELSELECT

Robert et al. 2020





Signifiant reduction of unwanted catches of Triglidae, and Caproidae



Redline : standard (diamond mesh 100mm)
Blue line : T90 100mm

Reduced protein waste

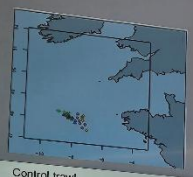
Reduced sorting time

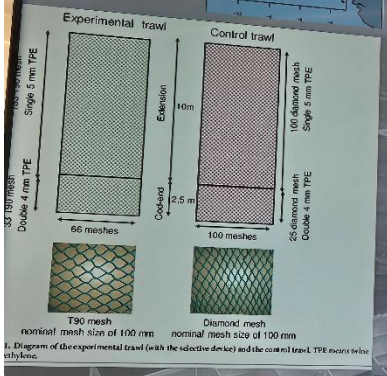
Improving the quality of catches

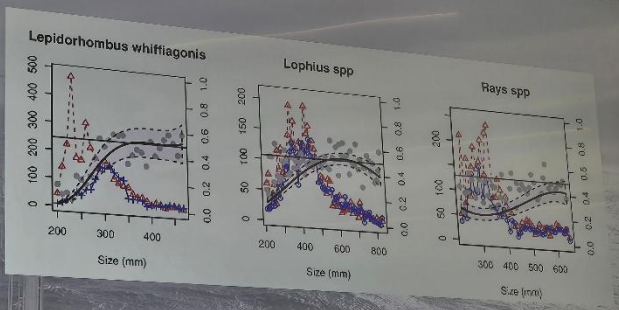
Toward elimination of unwanted catches using a 100mmT90 extension and codend in demersal mixed fisheries

CELSELECT

Robert et al. 2020







Increase escapement of small megrims, monkfish (and rays)

=> Low commercial losses (due to selective sorting practices)

Following the at-sea tests conducted as part of the project, **the T90 100 mm was adopted by certain vessels targeting monkfish and rays** in the western part of the area on a **voluntary basis**



Keys of the success :

Twin trawl experiment : Direct and visual comparison

Low-cost (same mesh as the one currently used)

Easy to handle during operations

Easily repairable (using the same mesh)

It was then included in the list of regulatory measures

Zone	Potential gear specification	Conditions
ZPMC = VIIf, VIIg, VIIh (north of latitude 49°30'N), VIIj (north of 49°30'N and east of 11°W)	Codend mesh size: 110 mm + SMP 120 mm	Bottom trawling or seine fishing (exempt if C < 1% COD)
ZPMC = VIIf, VIIg, VIIh (north of latitude 49°30'N), VIIj (north of 49°30'N and east of 11°W)	**T90 codend mesh size: 100 mm**	Bottom trawling or seine fishing (exempt if C < 1% COD)
ZPMC = VIIf, VIIg, VIIh (north of latitude 49°30'N), VIIj (north of 49°30'N and east of 11°W)	Codend mesh size: 120 mm	Bottom trawling or seine fishing (exempt if C < 1% COD)
VIIb, VIIc, VIId, VIIe, VIIf, VIIg, VIIh, VIIj, VIIk	Codend mesh size: 100 mm + SM P100 mm	Bottom trawling or seine fishing + C > 55% WHG or 55% MNZ, HAK, MEG
VIIb, VIIc, VIId, VIIe, VIIf, VIIg, VIIh, VIIj, VIIk	**T90 codend + 100 mm extension**	Bottom trawling or seine fishing + C > 55% WHG or 55% MNZ, HAK, MEG

Following sea trials, the T90 100 mm **was not adopted by vessels targeting gadoids** in the central Celtic Sea and the area south of the English Channel.

In these areas, fishermen can instead opted for installing SMPs in the extension and or increase diamond mesh size.

Zone	Potential gear specification	Conditions
ZPMC = VIIf, VIIg, VIIh (north of latitude 49°30'N), VIIj (north of 49°30'N and east of 11°W)	Codend mesh size: 110 mm + **SMP** 120 mm	Bottom trawling or seine fishing (exempt if C < 1% COD)
ZPMC = VIIf, VIIg, VIIh (north of latitude 49°30'N), VIIj (north of 49°30'N and east of 11°W)	T90 codend mesh size: 100 mm	Bottom trawling or seine fishing (exempt if C < 1% COD)
ZPMC = VIIf, VIIg, VIIh (north of latitude 49°30'N), VIIj (north of 49°30'N and east of 11°W)	**Codend mesh size: 120 mm**	Bottom trawling or seine fishing (exempt if C < 1% COD)
VIIb, VIIc, VIId, VIIe, VIIf, VIIg, VIIh, VIIj, VIIk	Codend mesh size: 100 mm + **SM** P100 mm	Bottom trawling or seine fishing + C > 55% WHG or 55% MNZ, HAK, MEG
VIIb, VIIc, VIId, VIIe, VIIf, VIIg, VIIh, VIIj, VIIk	T90 codend + 100 mm extension	Bottom trawling or seine fishing + C > 55% WHG or 55% MNZ, HAK, MEG

Discussion

One device does not fit all situations :

Regulation offers several options for improving the selectivity of fishing gear in the Celtic Sea

Advantage: flexibility provided to fishermen

Drawbacks: Monitoring the implementation of these selective devices—when and how—is difficult based on declarative regulatory data and is also poorly documented in scientific monitoring programs, such as at-sea observations.

The CAPS project in 2022 (interviews with fisherman) identified 12 vessels using T90 100mm

Consequently,

it is ***impossible to assess*** the actual effectiveness of these measures in improving stock exploitation profiles
Discard patterns and assumptions about selectivity in the stock assessment model

From Co-creation to Field Results: Lessons from the LIFE CIBBRiNA Bycatch Mitigation Case Studies

Martin Pastoors

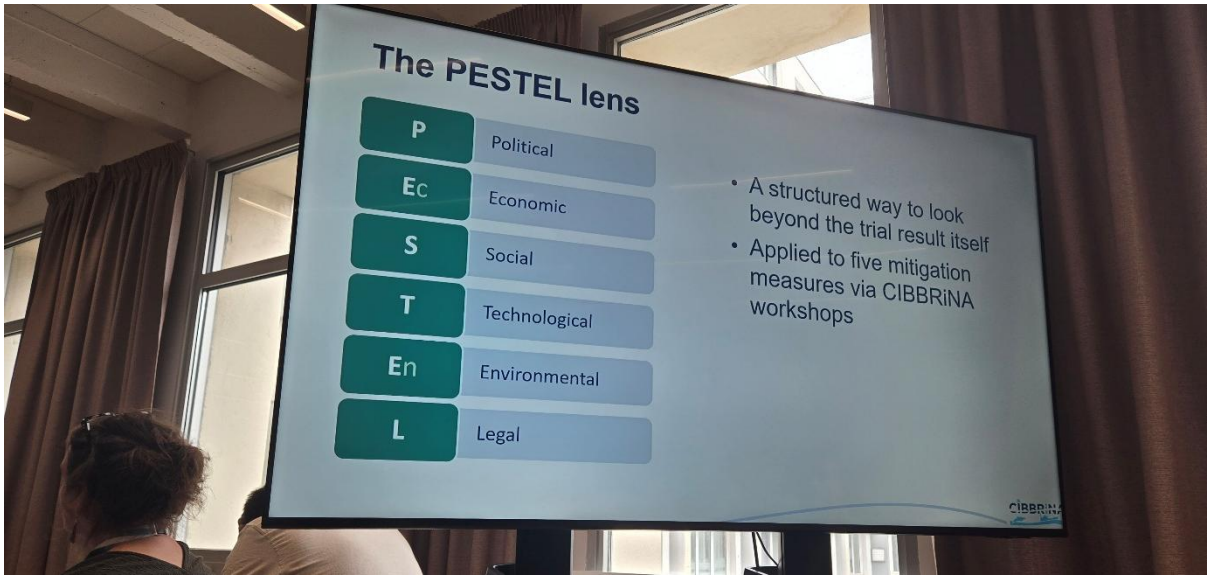
The LIFE CIBBRiNA project (2023–2029) implements bycatch mitigation trials across eight case studies covering gillnet, longline, pelagic trawl, and bottom trawl fisheries in thirteen European countries, focussed on endangered, threatened, and protected (ETP) species including marine mammals, sharks, rays and skates, seabirds and marine turtles.

Bycatch monitoring and mitigation technologies that are tested include pearl nets to avoid bycatch of cetaceans in gillnet fisheries, acoustic and electromagnetic deterrent devices of various types in both passive and active gears, bird scaring lines in UK longline fisheries, escape panels in pelagic trawl fisheries. Monitoring of the trials takes place with observers, remote electronic monitoring and self-reporting in different fisheries. Results are mixed but instructive: pearl nets show promise for reducing harbour porpoise bycatch in gillnet fisheries; bird scaring lines and offal disposal reduce seabird interactions under certain conditions in longline fisheries; and pinger trials reveal important context-dependent results, including potential 'dinner bell' effects for seals and bottlenose dolphins. A recurring challenge, for example in one of the gillnet case studies, is that mitigation trials can be conducted across hundreds of fishing sets without recording a single bycatch event either with or without the mitigation measure being deployed.

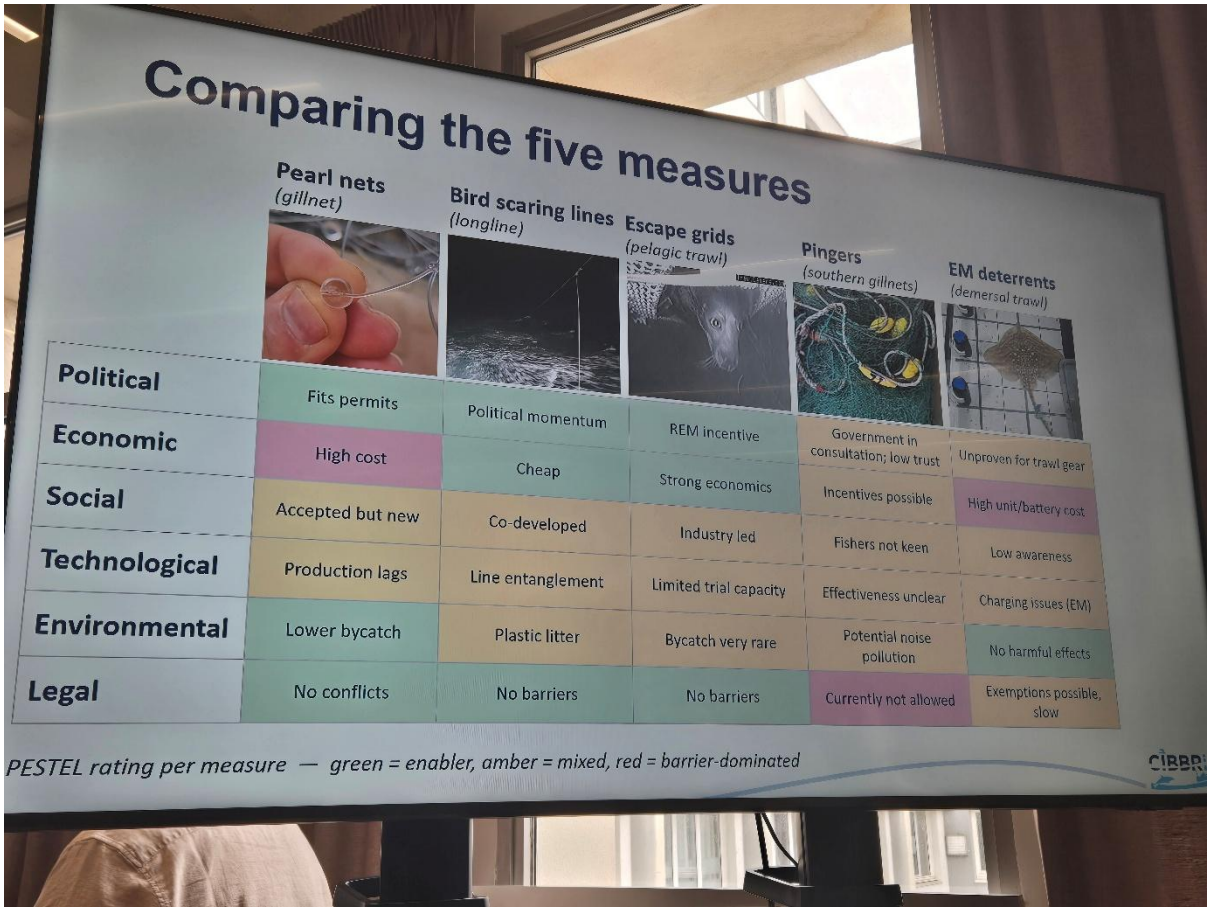
CIBBRiNA's co-creation model, in which fishers are active partners rather than research subjects, consistently underpins the trial design. Trust, transparency around data use, and timely feedback to participants are preconditions for sustained engagement, not afterthoughts. The co-creation model also lead to the raising of depredation of target species by e.g. bottlenose dolphins as a cross-cutting issue across multiple case studies. Addressing depredation concerns alongside conservation objectives has proven an important entry point for engaging the fishing industry, turning a shared problem into a shared motivation for participating in trials.

These lessons speak directly to the PESTEL framework (Political, Economic, Social, Technological, Environmental, Legal) that this session adopts to examine how innovation translates into real-world adoption: bycatch reduction technologies cannot be evaluated in isolation from the broader context in which they are deployed.




The PESTEL lens
P
Political
Ec
Economic
S
Social
T
Technological
En
Environmental
L
Legal
• A structured way to look beyond the trial result itself
• Applied to five mitigation measures via CIBBRiNA workshops


Five measures, five case studies
Pearl nets
(gillnet)
Early promise
Bird scaring lines
(longline)
Effective, but reduction in bycatch is not yet statistically significant
Escape grids
(pelagic trawl)
Working in some fisheries, redesign needed in others
Pingers
(southern gillnets)
Many trials but not proven effective against bycatch or depredation
Electro-magnetic deterrents
(demersal trawl)
Early, lab-based stage



Turning bycatch mitigation into practice: adaptive co-design in a bird-scaring line trial
Emily Roebuck

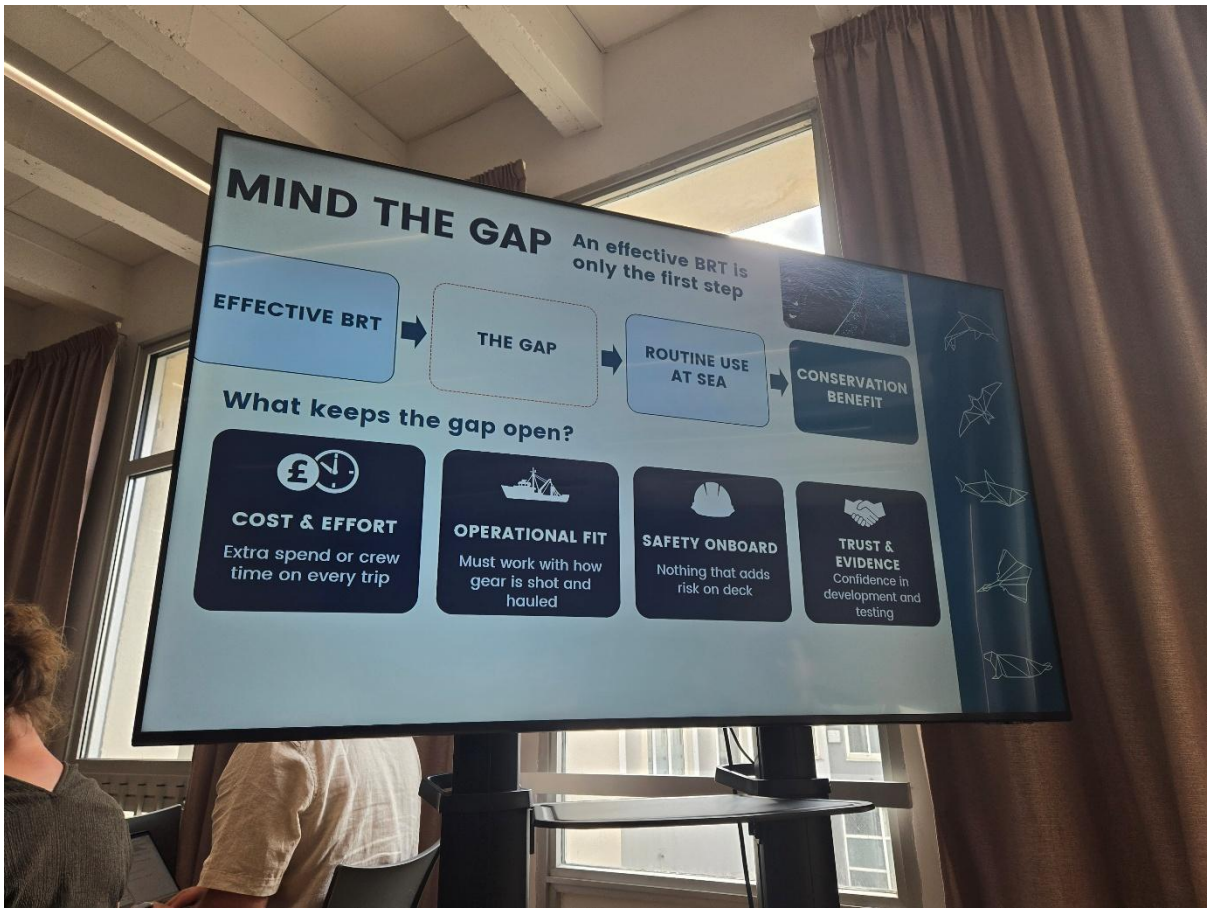
Bycatch remains a significant threat to sensitive marine species, including seabirds, cetaceans and elasmobranchs, despite the availability of bycatch reduction technologies (BRTs). Although many BRTs have demonstrated technical effectiveness, uptake within fisheries is often limited by operational, economic, social and governance challenges. Clean Catch seeks to address this implementation gap through a fishermen-led, co-designed approach to bycatch monitoring and mitigation in a North Sea trawl fishery, centred on a trial of bird-scaring lines (BSLs) to reduce seabird interactions and bycatch.

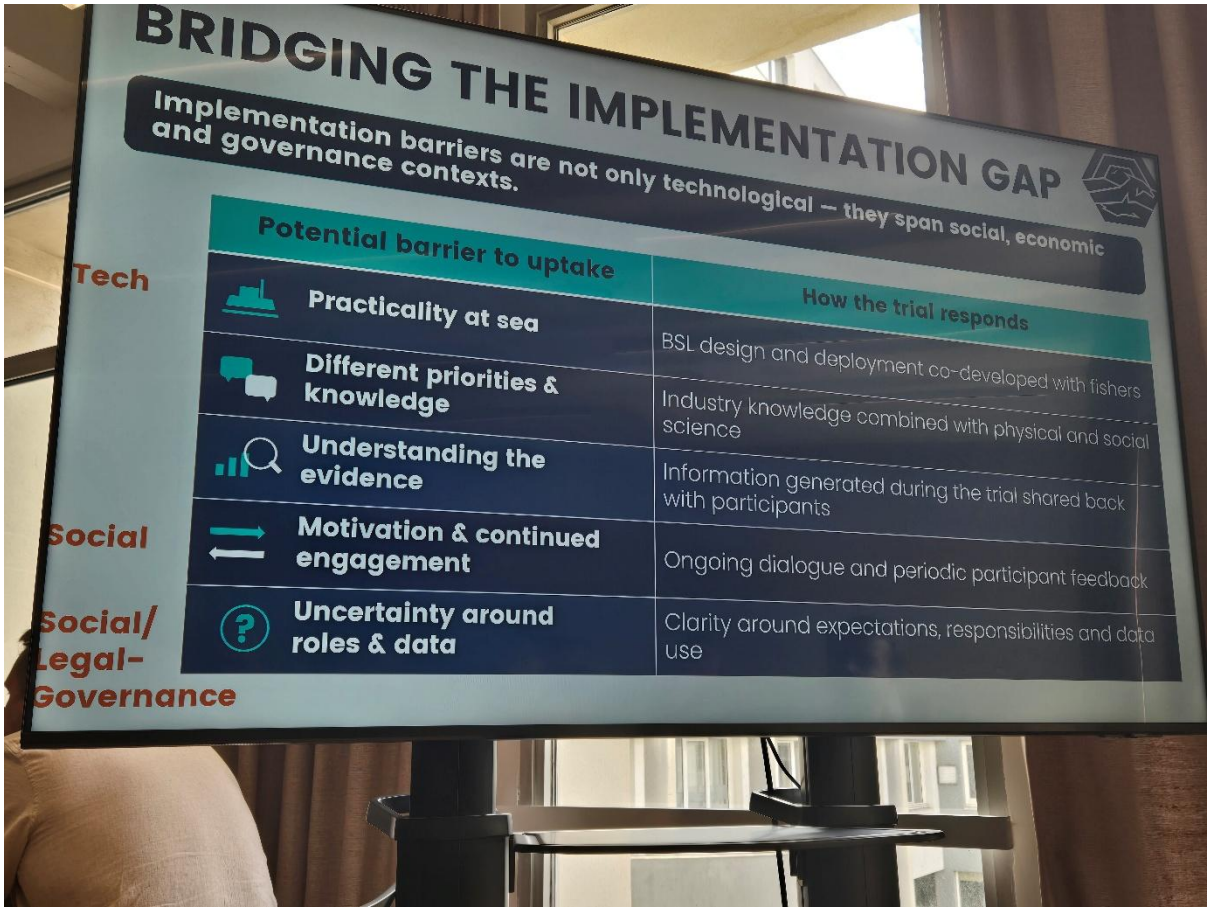
Vessel owners and skippers were involved from the outset, helping shape trial objectives and methods to ensure they reflected real fishing practices. Monitoring approaches were co-developed to balance scientific robustness with practicality at sea, combining remote electronic monitoring (REM) with skipper self-reporting to document seabird interactions with fishing gear, particularly warp cables, alongside observations of other sensitive species bycatch. Periodic questionnaires capture participant motivations, concerns and experiences throughout the trial, allowing the approach to evolve through an adaptive co-design process that brings together industry knowledge with physical and social science evidence.

Following an initial three-month baseline monitoring phase, bird-scaring lines were introduced using configurations developed jointly with participating skippers and vessel owners. Information gathered throughout the trial, including insights from observer trips, was shared with participants in an accessible and appropriate format, supporting informed decisions about trial progression and providing clarity around roles, expectations and data use. Rather than viewing implementation as a fixed endpoint, Clean Catch adopts an adaptive learning approach based on ongoing communication, knowledge exchange and adjustments informed by participant feedback to maintain engagement and operational feasibility.

This trial shows how a co-designed approach, supported by ongoing communication, structured feedback and shared decision-making, can help address persistent barriers to BRT uptake by aligning mitigation measures with industry motivations and working practices. The approach offers transferable lessons for translating bycatch mitigation technologies from trials into practical, scalable solutions that support ecosystem-based fisheries management.







The development and implementation of a tunnel Excluder in small-meshed North Sea trawl fisheries

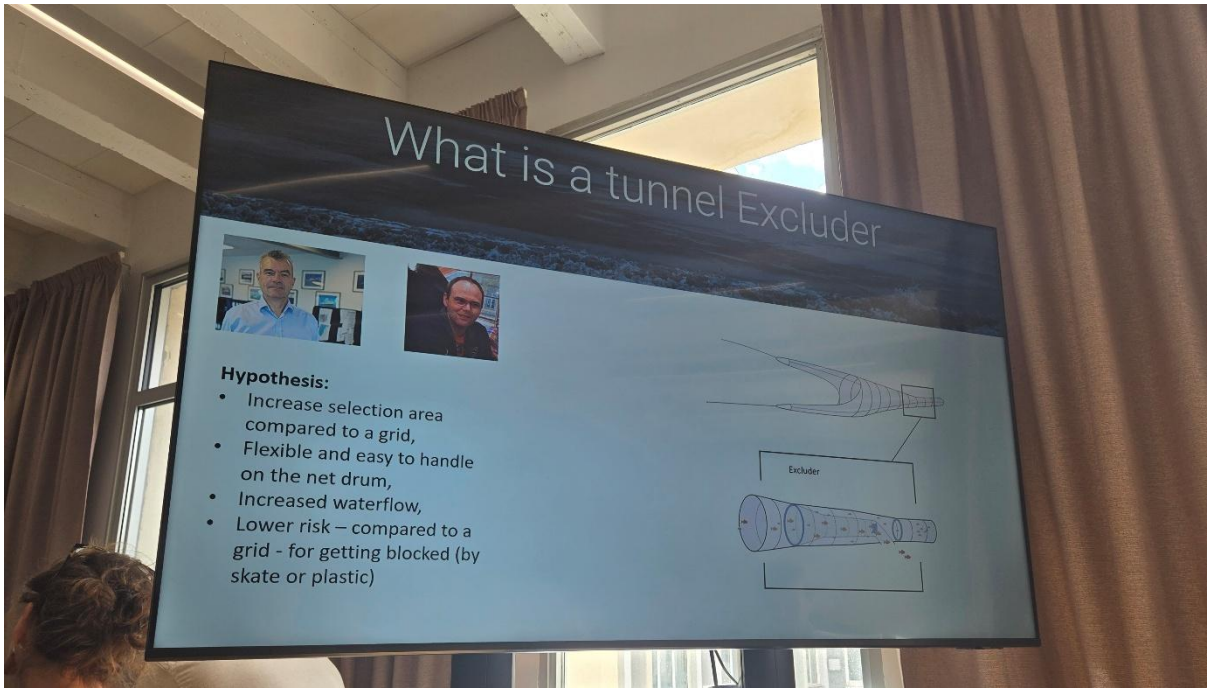
Claus Sparrevohn

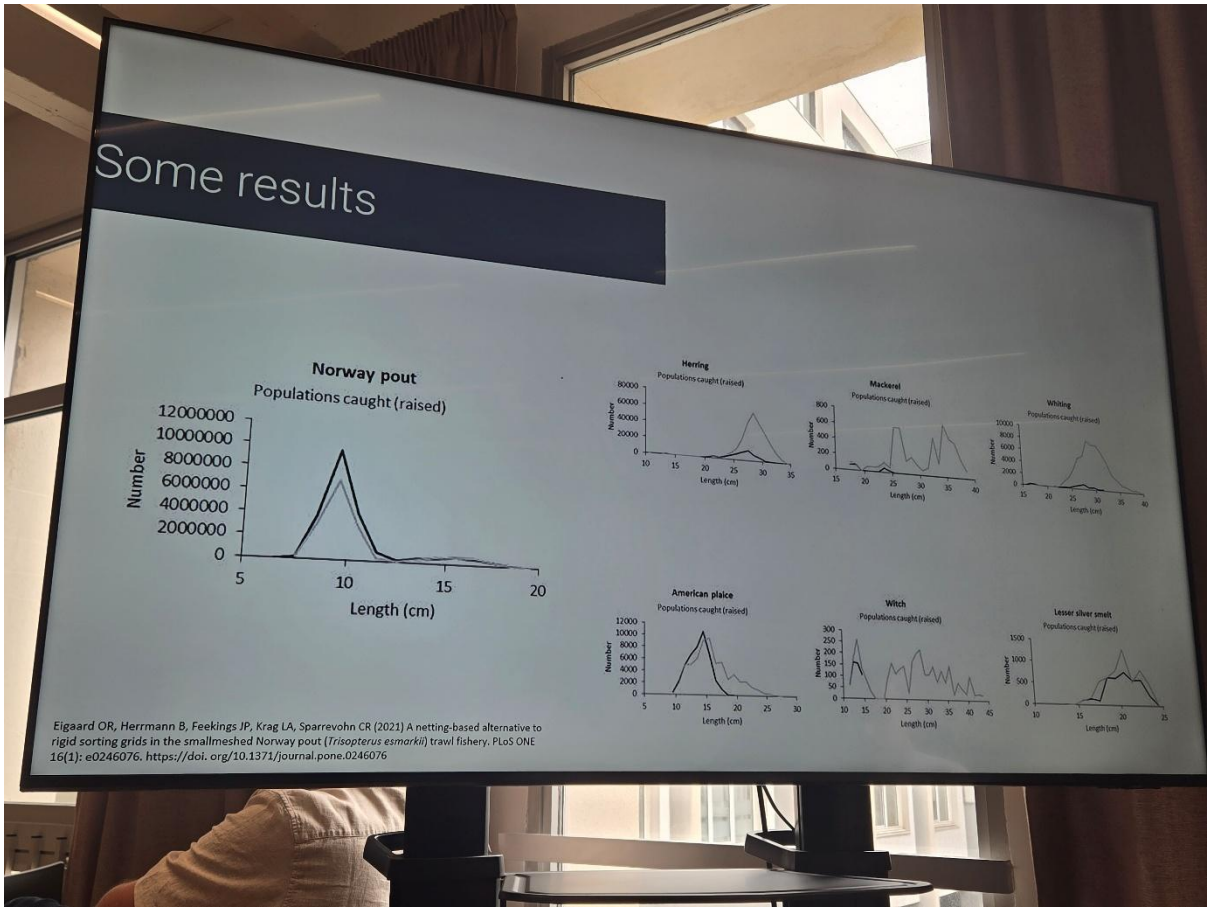
A challenge often encountered in small-meshed trawling for forage fish is bycatch of adult and juvenile non-target species. To mitigate this, top-down regulation with multiple regulatory and technical measures has been implemented for many of the fisheries taken place in the Norths Sea, but with varying success.

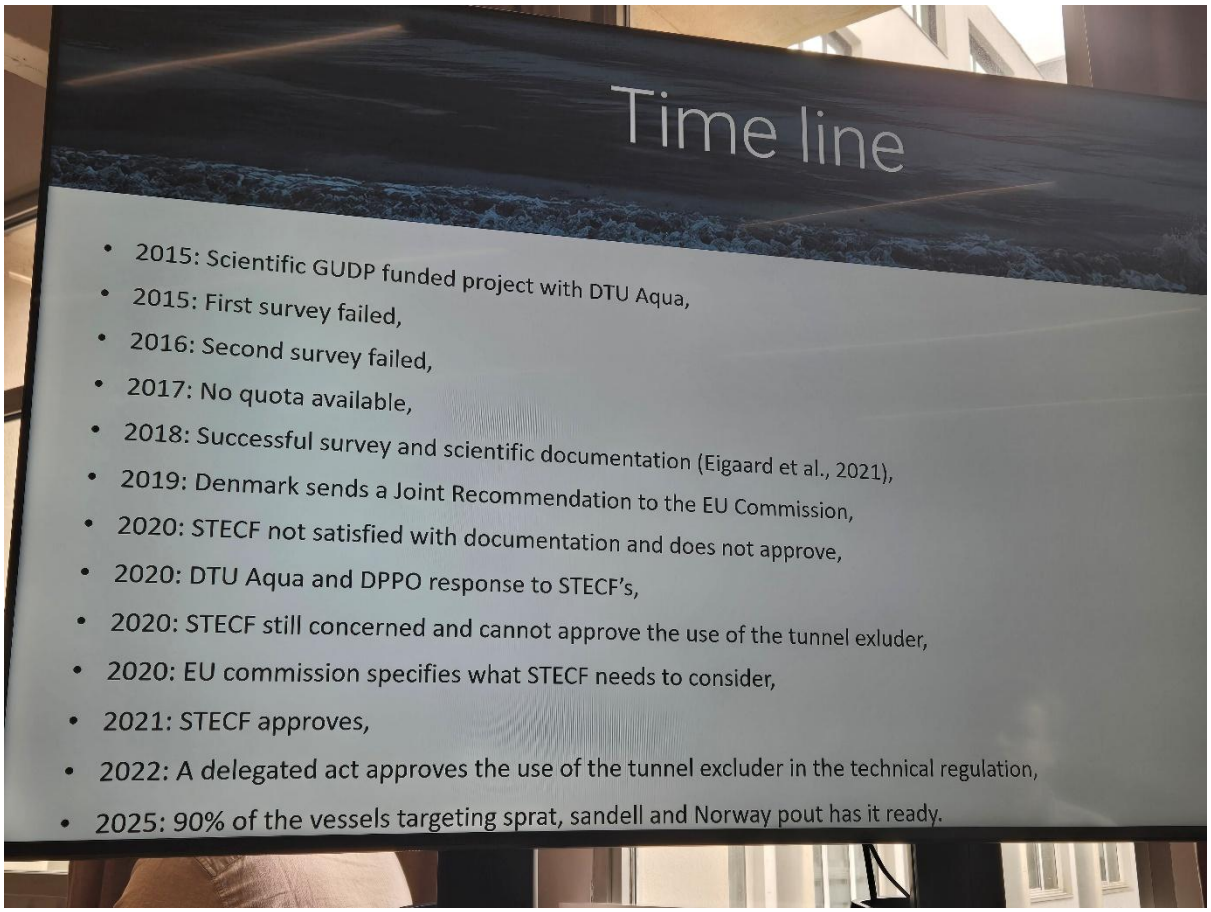
A bottom-up driven process where fishers and trawl manufacturers started developing an Excluder tunnel was started in 2015. The project setup was such that most of the development of the gear and testing lay within the responsibility of the fishery and net manufacturers, while the scientific proofs of concept and documentation was done by DTU Aqua. The tunnel Excluder has proven successful and is now being used voluntary by most of the vessels in North Sea fisheries for Norway pout (*Trisopterus esmarkii*), sandeel (*Ammodytes* spp.) and sprat (*Sprattus sprattus*). The journey from ideas to final implementation in EU legislation and broad acceptance within the fishery has not been without bumps. In this presentation we tell the story focusing on aspects fundamental for the successful implementation of the gear, such as target species efficiency, motivation within the fishery and a bottom-up industry driven process with a strong consortium.


DPPO
CIBBRINA
The development and implementation of a tunnel Excluder in small-meshed North Sea trawl fishery


DANISH PELAGIC PO
OUR FISHERY:
11 members
1/3 of the turnover in Danish fishery
Catch around 350.000 tons of fish per year
Large pelagic RSW vessels
Diversity in 13 different species / stocks

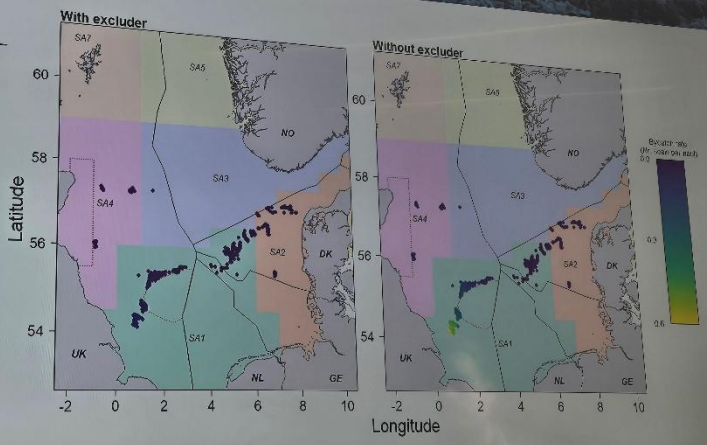

What is a tunnel Excluder
Hypothesis:
Increase selection area compared to a grid,
Flexible and easy to handle on the net drum,
Increased waterflow,
Lower risk – compared to a grid - for getting blocked (by skate or plastic)
Excluder


Some results
Norway pout
Populations caught (raised)
Number
Length (cm)
Herring
Mackerel
Whiting
American plaice
Witch
Lesser silver smelt
Eigaard OR, Herrmann B, Feekings JP, Krag LA, Sparrevohn CR (2021) A netting-based alternative to rigid sorting grids in the smallmeshed Norway pout (Trisopterus esmarkii) trawl fishery. PLoS ONE 16(1): e0246076. https://doi. org/10.1371/journal.pone.0246076


Time line
2015: Scientific GUDP funded project with DTU Aqua,
2015: First survey failed,
2016: Second survey failed,
2017: No quota available,
2018: Successful survey and scientific documentation (Eigaard et al., 2021),
2019: Denmark sends a Joint Recommendation to the EU Commission,
2020: STECF not satisfied with documentation and does not approve,
2020: DTU Aqua and DPPO response to STECF's,
2020: STECF still concerned and cannot approve the use of the tunnel exluder,
2020: EU commission specifies what STECF needs to consider,
2021: STECF approves,
2022: A delegated act approves the use of the tunnel excluder in the technical regulation,
2025: 90% of the vessels targeting sprat, sandell and Norway pout has it ready.

Next step – ETP species

Seals in sandeel



Industry-led mitigation of seal bycatch in North Sea pelagic trawl fisheries: Evaluating excluder device effectiveness and policy implications. van der Reijden et al., In press

Thanks

Ole R. Eigaard, Ludvig A. Kragh, Bent Herrmann, Karin van der Reijden, Emil Bundgaard, Jordan Freekings, Jesper Hjermitslev, Karsten Hjelm, Lynn Selboe, Mollie Brooks, Niels Hintzen, Mathias Søgaard, Lotte Kindt-Larsen,

Bridging the Implementation Gap: Best Practices to Promote the Uptake of Selectivity Measures in EU Fisheries

Laurence Fauconnet

The implementation of the EU Landing Obligation (LO) created a strong incentive to improve selectivity in EU fisheries. To assess progress and remaining challenges, an overview of the current state of play in selectivity developments in the wake of the LO was requested by the European Parliament, along with the identification of best practices from projects that have successfully improved selectivity and could be replicated across Member States. The review of existing selectivity measures and recent research revealed a clear pattern: while extensive experimental and technical work has been conducted over the past decade to test gear modifications and other selectivity measures, their uptake in commercial fisheries has often lagged behind. This implementation gap highlights persistent technical, economic, and social barriers. Best practices were identified through a literature review and an analysis of EU and national initiatives. The most consistent driver of successful uptake was close collaboration with fishers, grounded in trust, transparency, and long-term engagement. Bottom-up initiatives proved particularly effective in fostering ownership and innovation, provided that appropriate incentives were in place. While financial incentives can support adoption, enhancing the public image and recognition of fishers engaging in selective practices also emerged as a powerful lever. Successful initiatives typically developed solutions tailored to local fisheries and operational realities, emphasizing practicality and "fisher-friendly" designs. Striking the right balance between simplicity and technical sophistication was also key to promoting adoption. Strategic testing pathways - screening promising measures, conducting rigorous validation under commercial conditions, and ensuring wide and accessible communication of results -helped accelerate both regulatory acceptance and industry uptake. Finally, advancing knowledge on species behaviour, gear-species interactions, and ecosystem processes, combined with international data sharing and integrated evaluation frameworks, strengthened the evidence base for effective selectivity improvements. These findings highlight that technological innovation alone is insufficient: overcoming barriers to implementation requires co-development, targeted incentives, effective communication, and integration of ecological, technical, and socio-economic dimensions.







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

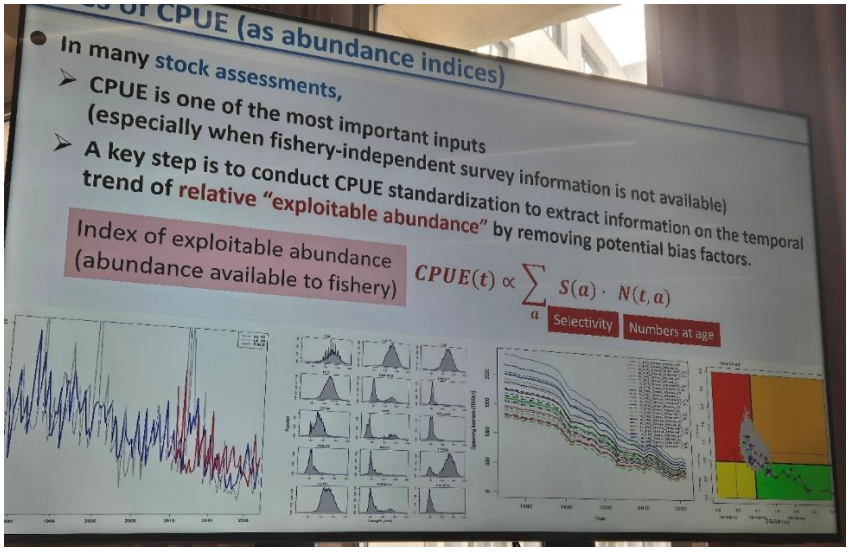
actions such as total allowable catch. CPUE standardization aims to extract temporal trends in exploitable abundance by removing bias due to vessel characteristics, gear configuration, targeting practices, and spatial distribution. However, climate-driven shifts in species distribution and differences 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.





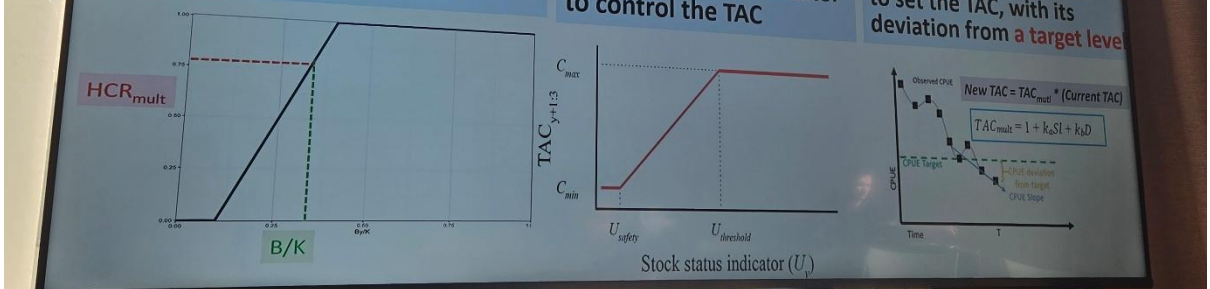
Currently adopted management procedures in IOTC

	Bigeye (adopted in 2022)	Skipjack (adopted in 2024)	Swordfish (adopted in 2025)
MP type	Model-based (production model with catch & **CPUE series**)	Data-based (based on **CPUE level**)	Data-based (based on **recent CPUE trend**)
Index	**Joint Longline std-CPUE**	**Averaged over std-CPUE series for two fisheries**	**Japanese Longline std-CPUE**

CPUE series is used in an internal simple assessment to control fishing intensity via an HCR

CPUE level is used directly as a stock status indicator to control the TAC

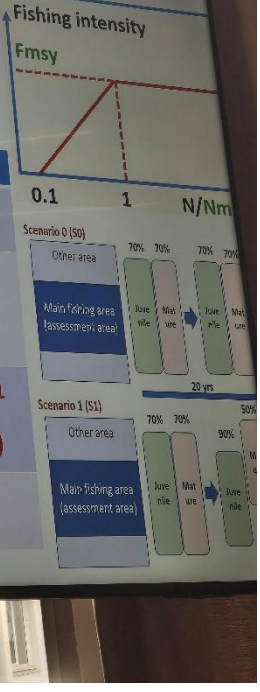
Recent CPUE trend is used to set the TAC, with its deviation from a target level

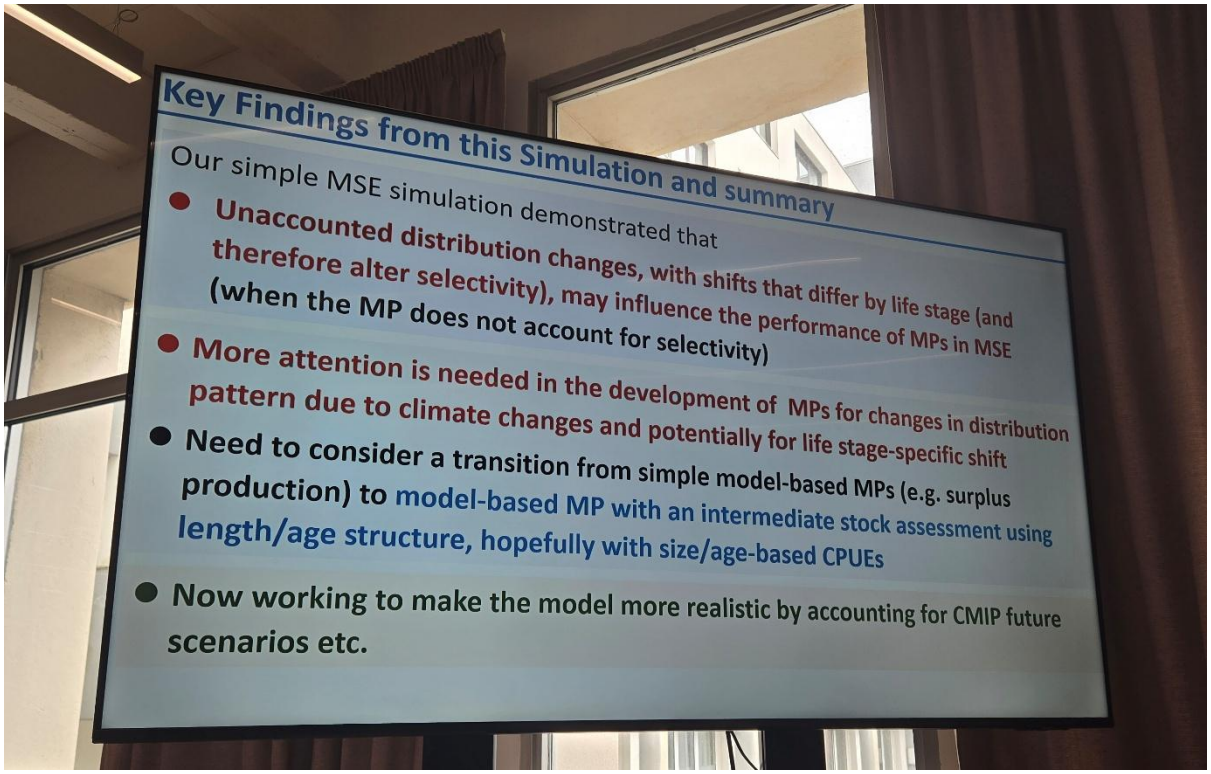


Management procedures in MSE simulation

- Annual CPUE (number) available from a fixed "assessment area"
- CPUE series as inputs in a simple model-based MP with an HCR (=>)
- Assume Reference Points (RPs) estimated in MPs cannot easily reflect to the distribution shift, keeping original RPs in HCR except for Run 4

	Run 1	Run 2	Run 3	Run 4
Distribution scenario	S0 (no shift)	S1 (shift)	S1 (shift)	S1 (shift)
CPUE in MP	Naïve std-CPUE	Naïve std-CPUE (overestimated)	Correcting CPUE for spatial availability	Correcting CPUE for spatial availability
RPs in HCR Fmsy Nmsy)	Based on S0 (constant selectivity)	Based on S0 (constant selectivity)	Based on S0 (constant selectivity)	Based on S1 (changing selectivity)
Expected outcome	Should work!	Stock status overestimated	Still not by appropriate RPs	Should work!

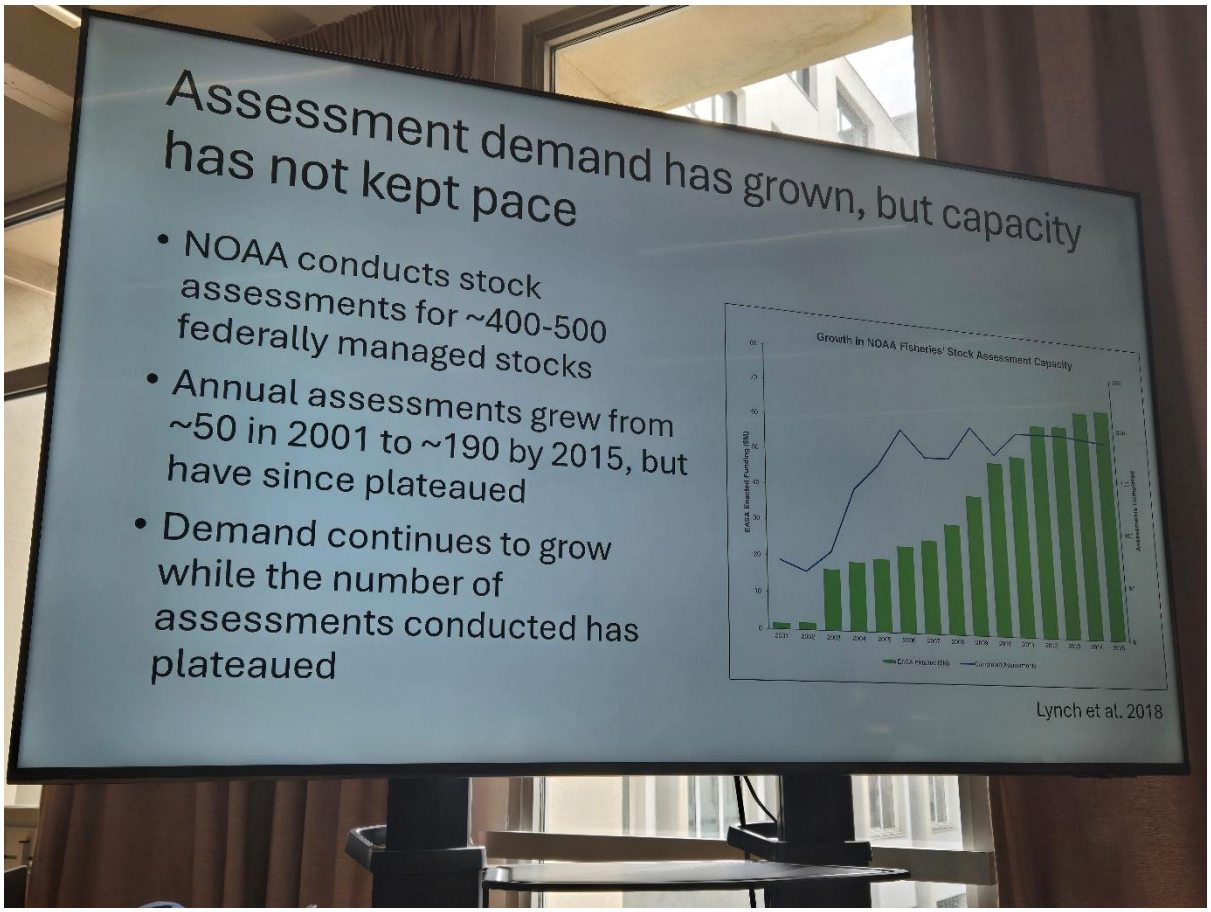




The SPoRC stock assessment package: A generalized next-generation platform to assess spatial, age, and sex-structured populations
Matt Cheng

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.



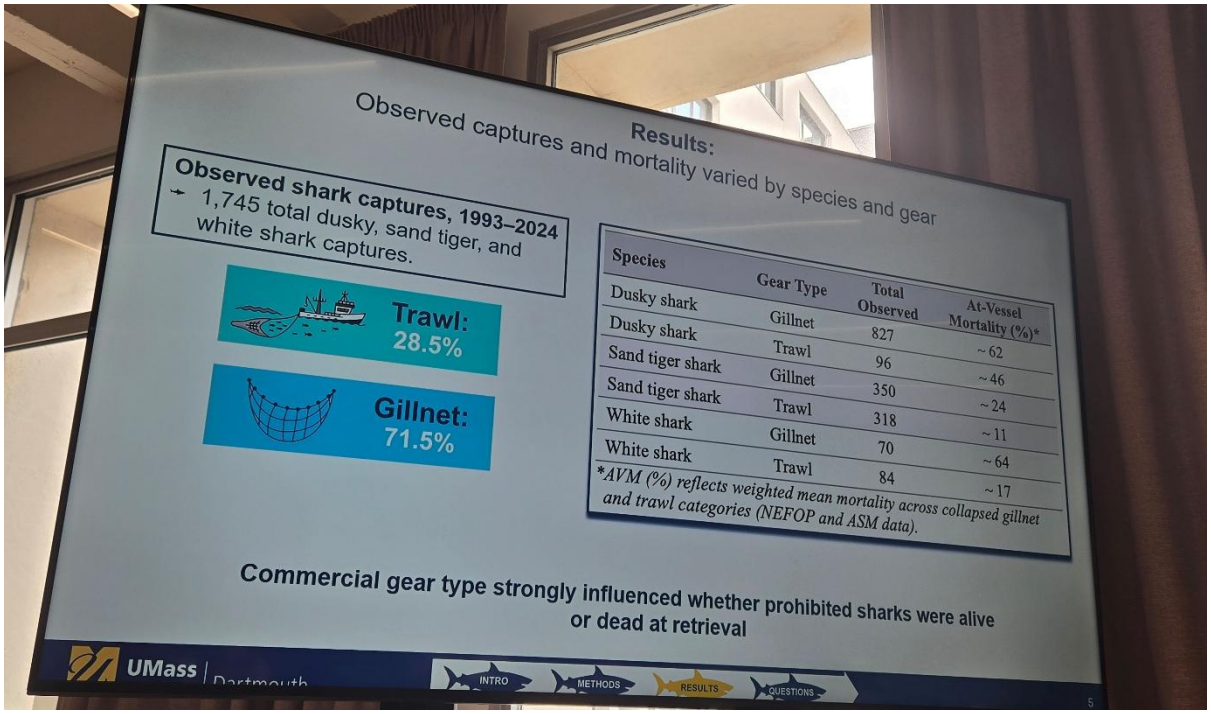


Bycatch and Mortality of Three Prohibited Shark Species in the Northeast U.S.
Lindsay Graff

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 ± 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.



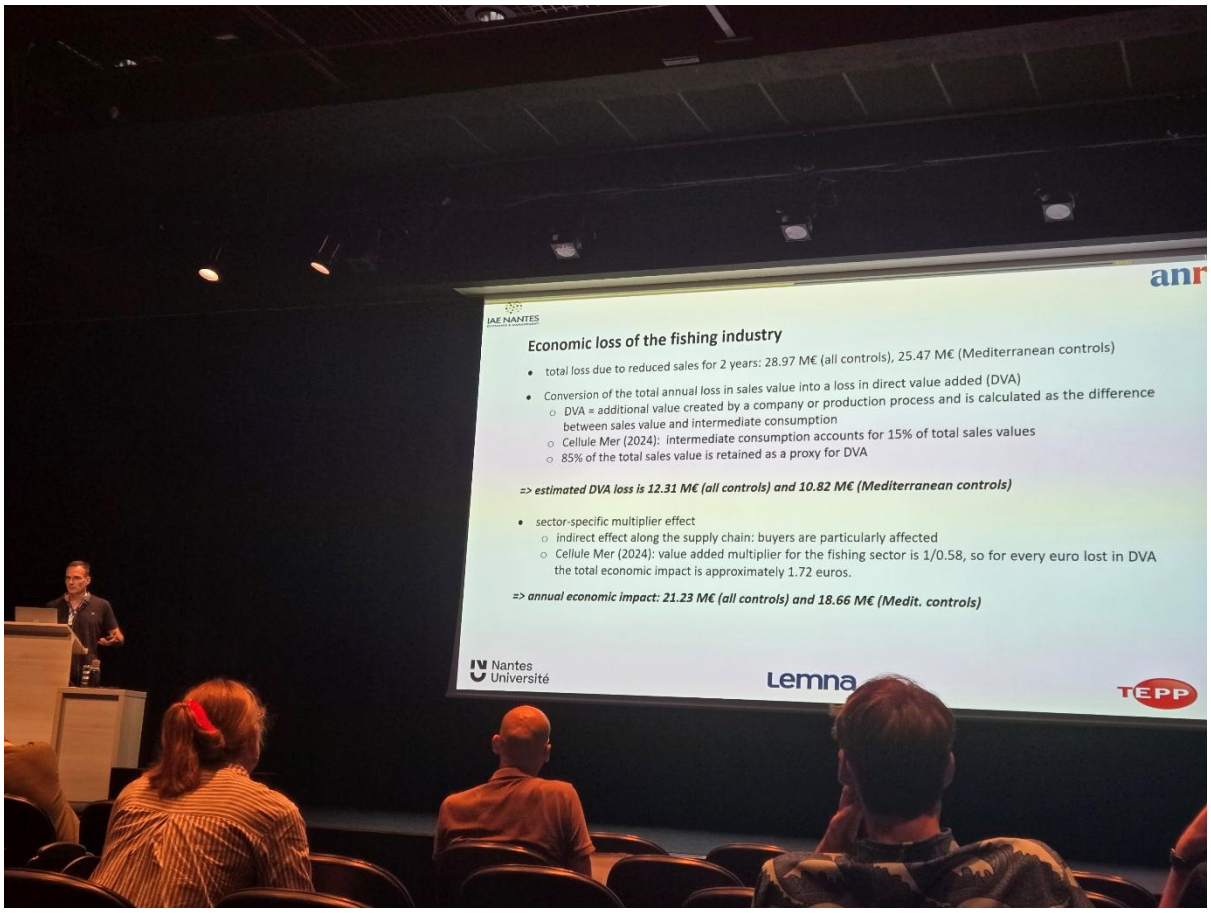
How valuable is a dolphin? Evidence from the French Bay of Biscay closure
Francois-Charles Wolff

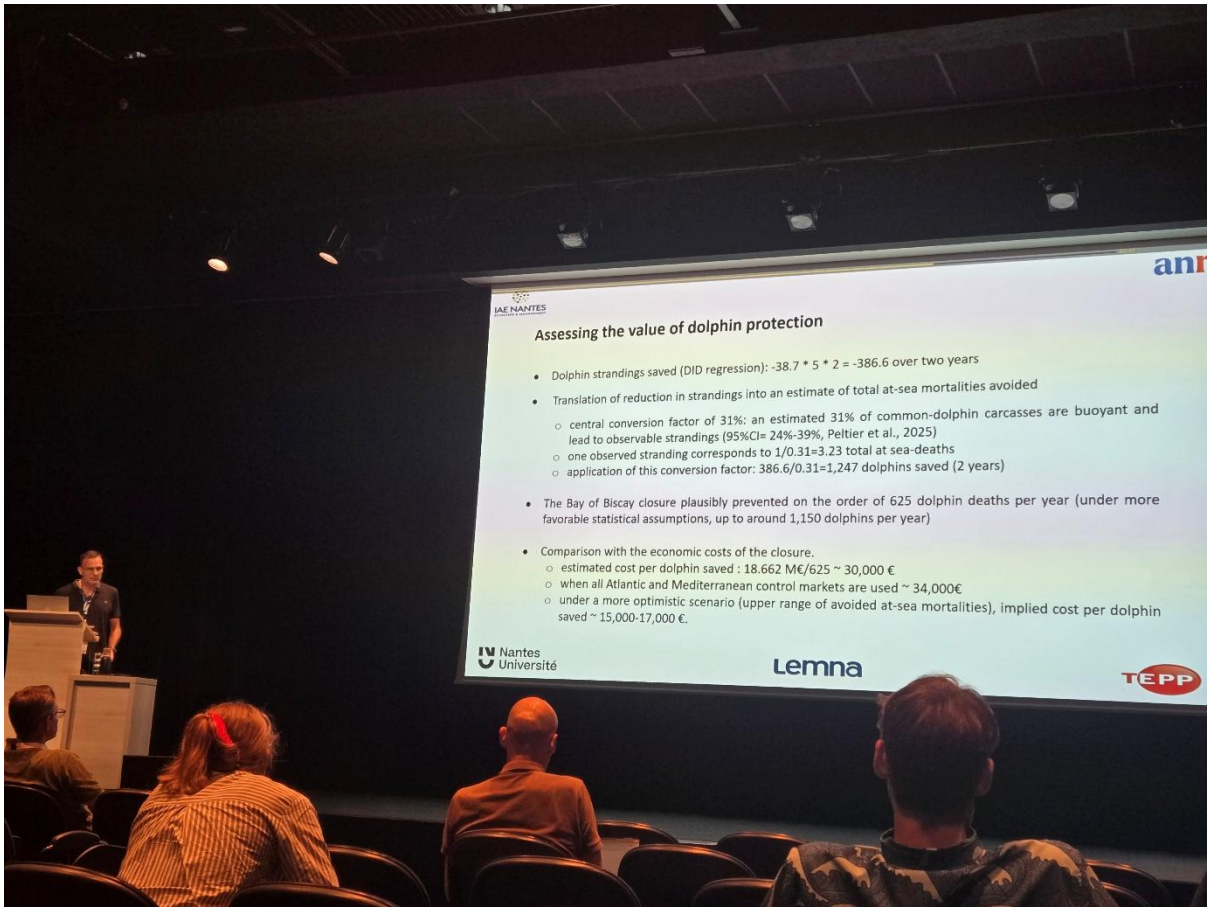
This paper provides a comprehensive economic and conservation evaluation of a large-scale spatio-temporal fishing closure implemented in the Bay of Biscay in 2024 and 2025 to reduce incidental bycatch of common dolphins. Mandated under judicial and regulatory pressure following scientific advice, the policy represents one of the most extensive fishery closures ever adopted in European waters for marine mammal protection. We exploit this intervention as a natural experiment to quantify both its economic costs to the fishing sector and its benefits in terms of avoided cetacean mortality.

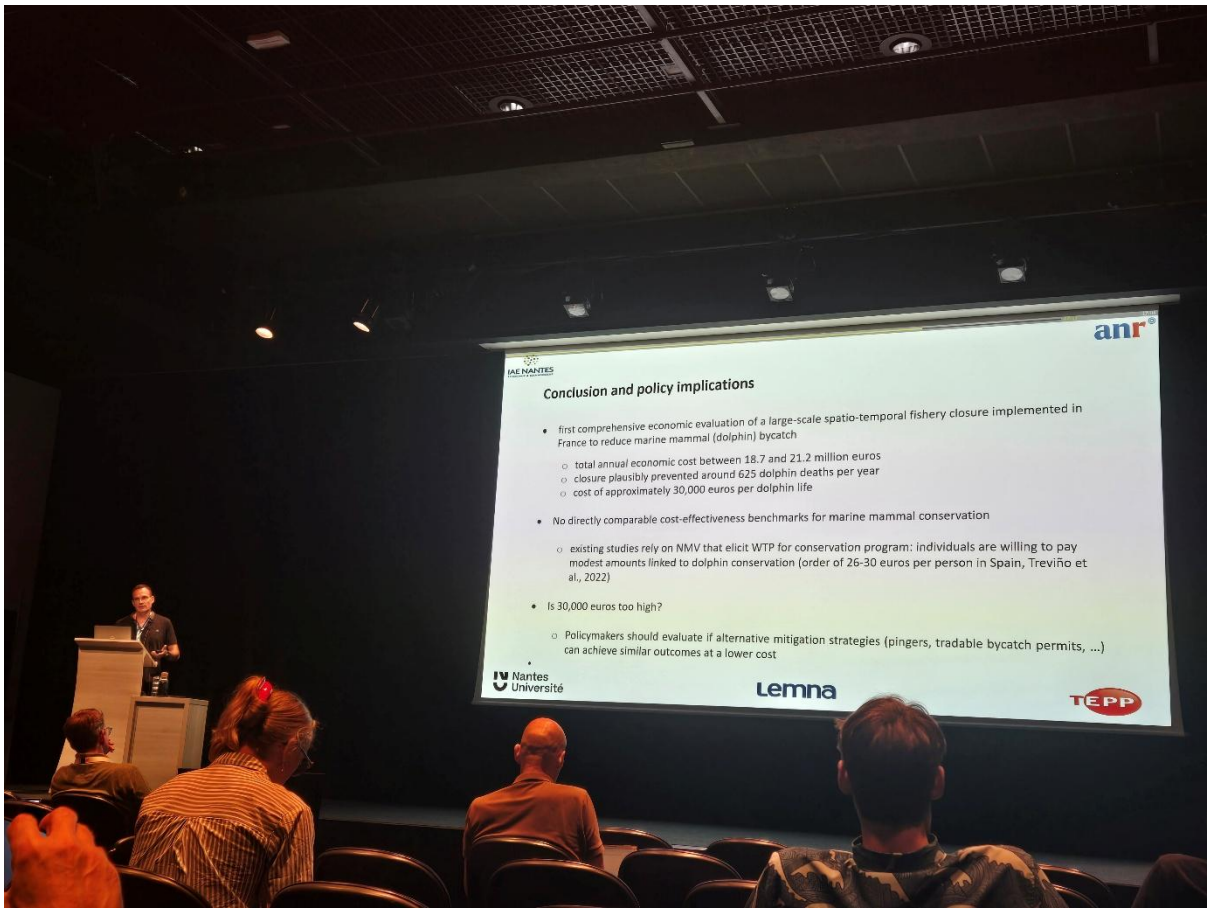
Our analysis combines highly granular transaction-level data from all French fish auction markets over the period 2016–2025 with detailed records of dolphin strandings along the French Atlantic coastline. To identify causal effects, we implement imputation-based difference-in-differences estimators that accommodate strong heterogeneity across markets, unbalanced panels, and unobserved time-varying confounders. This approach allows us to construct credible counterfactual outcomes for affected markets and to assess pre-treatment dynamics and placebo effects.

We find that the closure reduced daily auction sales in treated markets by approximately 36,000-41,000 euros per market during the one-month closure window. After accounting for auction days lost due to insufficient supply and applying sector-specific value-added multipliers, the resulting annual economic cost is estimated to range between 18.7 million euros and 21.2 million euros. In parallel, a spatial difference-in-differences analysis of dolphin strandings indicates a statistically significant reduction in strandings south of the closure boundary relative to northern control areas. Translating strandings into at-sea mortalities using empirically grounded carcass buoyancy estimates suggests that the closure plausibly prevented around 625 common dolphin deaths per year under central assumptions, with substantial uncertainty bounds.

Combining these estimates yields a cost-effectiveness measure of roughly 30,000 euros per dolphin life saved, with lower values under more favorable assumptions regarding mortality reduction. While interpretation is complicated by uncertainty in stranding-to-mortality conversion and the presence of concurrent mitigation measures, the results offer a rare transaction-level benchmark for evaluating trade-offs between fisheries livelihoods and marine mammal conservation. More broadly, the paper illustrates how integrating administrative market data with ecological indicators and modern causal inference methods can inform the design, comparison, and targeting of bycatch mitigation policies.




IAE NANTES
Assessing the value of dolphin protection
Dolphin strandings saved (DID regression): -38.7 * 5 * 2 = -386.6 over two years
Translation of reduction in strandings into an estimate of total at-sea mortalities avoided
central conversion factor of 31%: an estimated 31% of common-dolphin carcasses are buoyant and lead to observable strandings (95%CI= 24%-39%, Peltier et al., 2025)
one observed stranding corresponds to 1/0.31=3.23 total at sea-deaths
application of this conversion factor: 386.6/0.31=1,247 dolphins saved (2 years)
The Bay of Biscay closure plausibly prevented on the order of 625 dolphin deaths per year (under more favorable statistical assumptions, up to around 1,150 dolphins per year)
Comparison with the economic costs of the closure.
estimated cost per dolphin saved : 18.662 M€/625 ~ 30,000 €
when all Atlantic and Mediterranean control markets are used ~ 34,000€
under a more optimistic scenario (upper range of avoided at-sea mortalities), implied cost per dolphin saved ~ 15,000-17,000 €.
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TEPP


IAE NANTES
Conclusion and policy implications
first comprehensive economic evaluation of a large-scale spatio-temporal fishery closure implemented in France to reduce marine mammal (dolphin) bycatch
total annual economic cost between 18.7 and 21.2 million euros
closure plausibly prevented around 625 dolphin deaths per year
cost of approximately 30,000 euros per dolphin life
No directly comparable cost-effectiveness benchmarks for marine mammal conservation
existing studies rely on NMV that elicit WTP for conservation program: individuals are willing to pay modest amounts linked to dolphin conservation (order of 26-30 euros per person in Spain, Treviño et al., 2022)
Is 30,000 euros too high?
Policymakers should evaluate if alternative mitigation strategies (pingers, tradable bycatch permits, ...) can achieve similar outcomes at a lower cost
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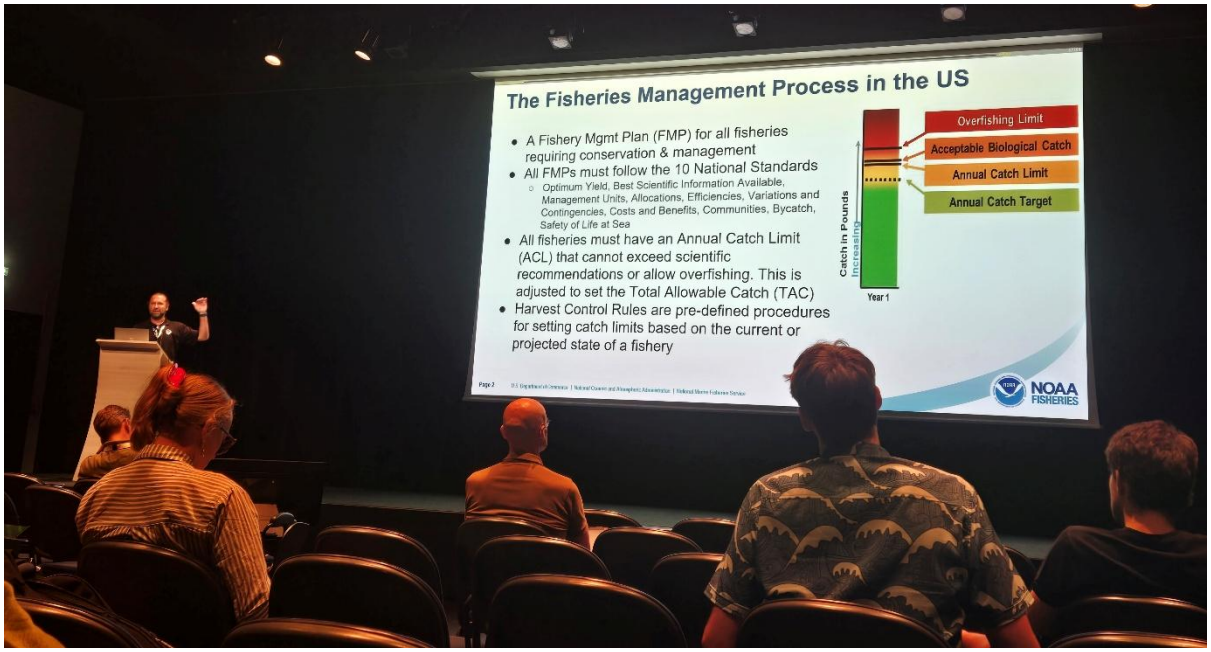
Many Branching Paths: The multitude of ways we use ecosystem information in fisheries management

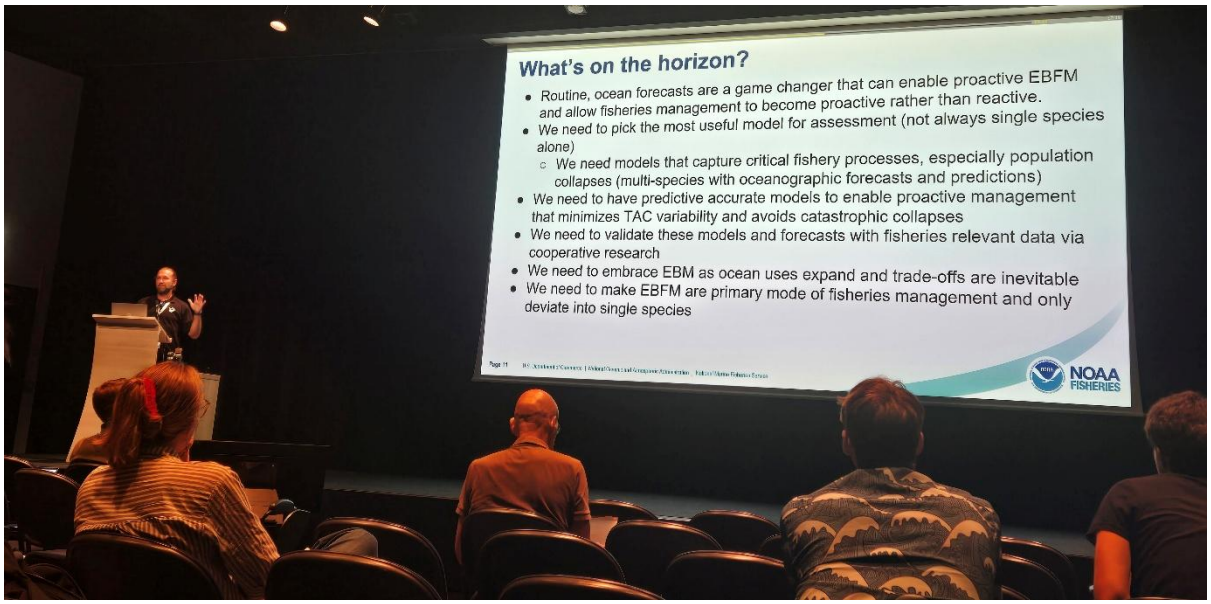
Chris Kelble

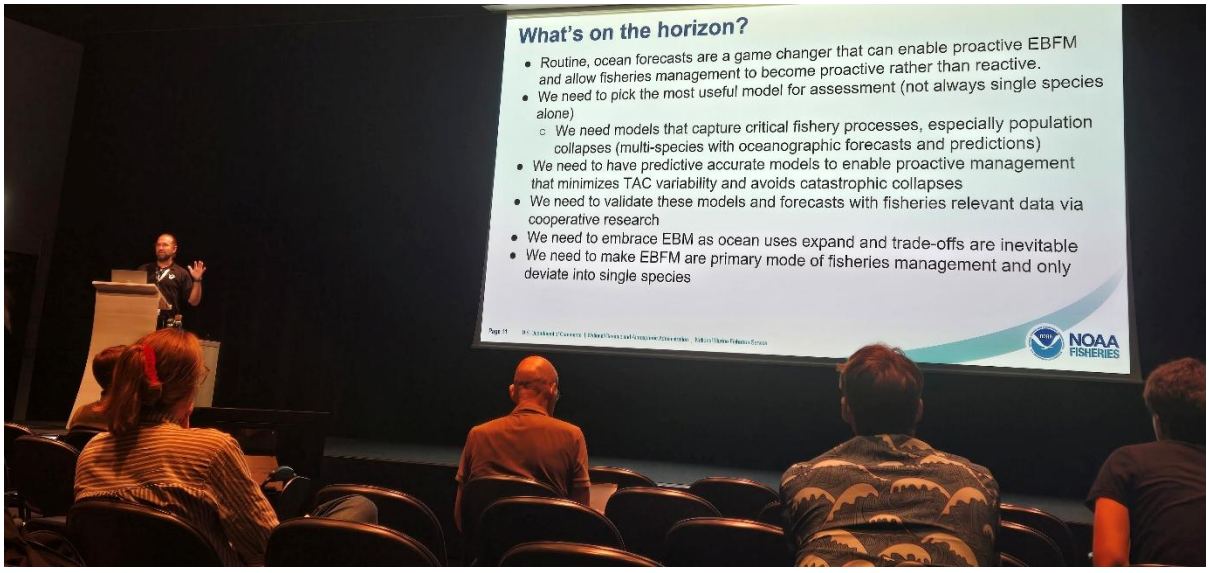
There has been an established scientific understanding of the need to implement Ecosystem Based Fisheries Management (EBFM) for decades. Among the most compelling rationales for EBFM is that our oceans are changing in ways that are affecting the productivity and distributions of many important fishery species. Thus, we need to incorporate ecosystem information in the scientific advice we are providing to fisheries management. Over the past 2 decades there have been numerous attempts to include environmental information in the fisheries management decision-making process and progress towards EBFM has been substantial. This includes multiple case studies where ecosystem information was critical to informing management decisions that prevented overfishing. However, ecosystem information is not comprehensively or routinely incorporated into our scientific advice for the majority of our fisheries.

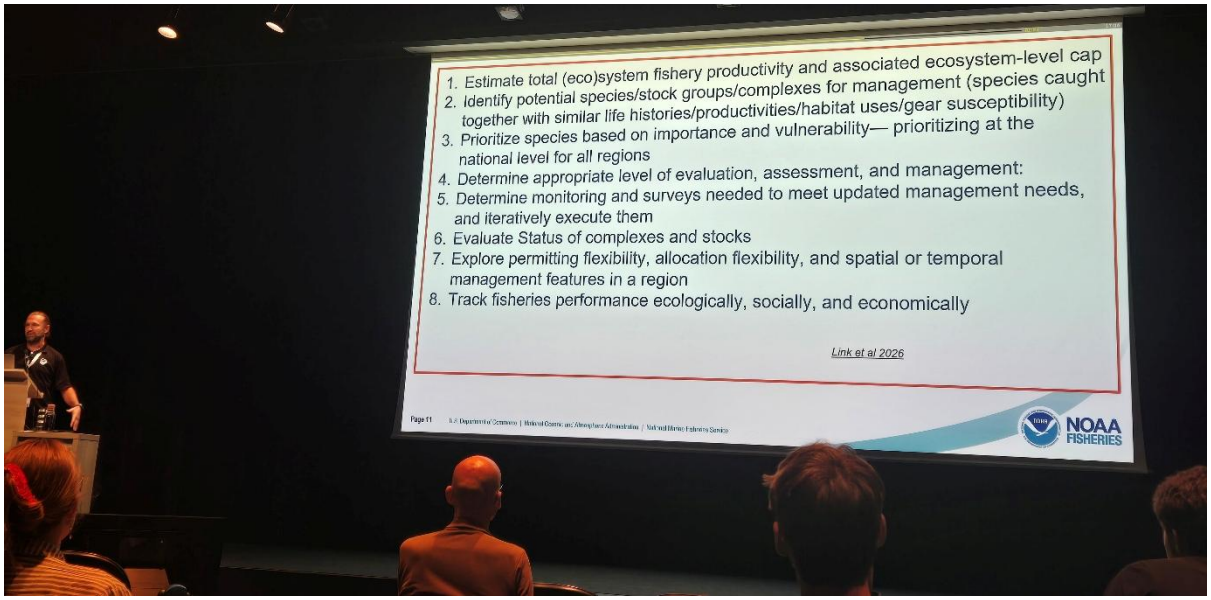
In the USA, we have attempted to incorporate ecosystem information into fisheries management advice via a variety of pathways ranging from direct inclusion in stock assessment models to presenting ecosystem status reports that set the context for fisheries management decision-making. A recent review of stock assessment models in the USA from 2003-2023 found that just over 2% had an assessment parameter directly linked to an ecosystem factor. Ecosystem information has also been incorporated into the fisheries management advice process via ecosystem status reports (indicator assessment of the overall ecosystem condition), ecosystem and socioeconomic profiles (a synthesis report of stock-specific ecosystem indicator trends), risk tables (evaluate unanticipated ecosystem and environmental impacts on the stock), risk assessments (quantify the probability of undesirable events along with their consequences), and dynamic ocean management tools (use satellite data and species distribution models to predict bycatch potential). In this talk, we will review the various pathways for ecosystem information to be incorporated into the scientific advice provided to the fisheries management community and suggest some ways forward to increase the uptake of ecosystem information into fisheries management.




The Fisheries Management Process in the US
A Fishery Mgmt Plan (FMP) for all fisheries requiring conservation & management
All FMPs must follow the 10 National Standards
Optimum Yield, Best Scientific Information Available, Management Units, Allocations, Efficiencies, Variations and Contingencies, Costs and Benefits, Communities, Bycatch, Safety of Life at Sea
All fisheries must have an Annual Catch Limit (ACL) that cannot exceed scientific recommendations or allow overfishing. This is adjusted to set the Total Allowable Catch (TAC)
Harvest Control Rules are pre-defined procedures for setting catch limits based on the current or projected state of a fishery
Overfishing Limit
Acceptable Biological Catch
Annual Catch Limit
Annual Catch Target
Catch in Pounds
Increasing
Year 1
NOAA FISHERIES


What's on the horizon?
Routine, ocean forecasts are a game changer that can enable proactive EBFM and allow fisheries management to become proactive rather than reactive.
We need to pick the most useful model for assessment (not always single species alone)
We need models that capture critical fishery processes, especially population collapses (multi-species with oceanographic forecasts and predictions)
We need to have predictive accurate models to enable proactive management that minimizes TAC variability and avoids catastrophic collapses
We need to validate these models and forecasts with fisheries relevant data via cooperative research
We need to embrace EBM as ocean uses expand and trade-offs are inevitable
We need to make EBFM are primary mode of fisheries management and only deviate into single species
NOAA FISHERIES


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NOAA FISHERIES



Incorporating ecosystem indicators into a single stock assessment framework: a case study using anadromous Dolly Varden

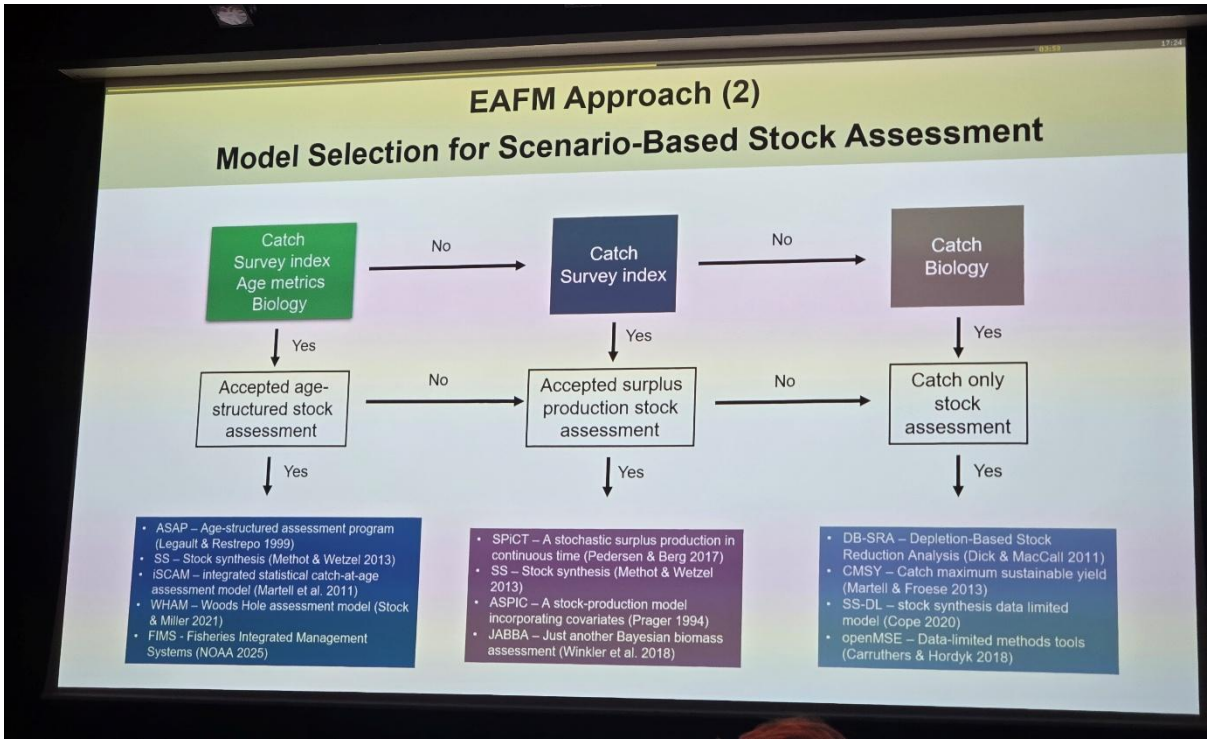
Xinhua Zhu

A warming climate in the western Canadian Arctic has affected river discharge, which provides important habitat for anadromous salmonids. Strong seasonal variations in weather and hydroclimatic conditions have been identified as environmental drivers of the timing of seasonal migrations of anadromous fish populations.

Subsistence fisheries in the western Canadian Arctic rely on stocks of anadromous Arctic Char and Dolly Varden to ensure food security and transmit cultural practices. In response to a decline in the abundance of anadromous Dolly Varden in the Rat River, Northwest Territories, an annual fisheries-dependent community-based monitoring program was initiated in 1995. Experienced Gwich'in harvesters implemented this program to collect fisheries data, including catch-effort and biological information, during the upstream migration (late-July to mid-September). Additionally, several qualitative categorical variables regarding water level, debris, and water clarity were recorded to track the temporal changes in the environmental conditions and link them to the relative abundance index of migrating Dolly Varden. The assessment of temporal changes in weather and hydrometric indicators may contribute to a better understanding of impacts on the seasonal migration timing and population dynamics, although the qualitative environmental information is difficult to directly apply to quantitative stock assessment.

To incorporate the ecosystem indicators recorded by the harvesters into a stock assessment, our EAFM approach was to i) establish scenario-based causal models linking catch-per-unit-effort of Dolly Varden with the qualitative and quantitative ecosystem indicators, ii) estimate population dynamics parameters using a Bayesian state-space surplus production model, and iii) develop fisheries reference points delineating the historical and current stock status of the population among scenarios. The modelling indicated that the stock is currently in a healthy state. The outcomes will promote an integrated assessment plan for the stock that incorporates environmental considerations.

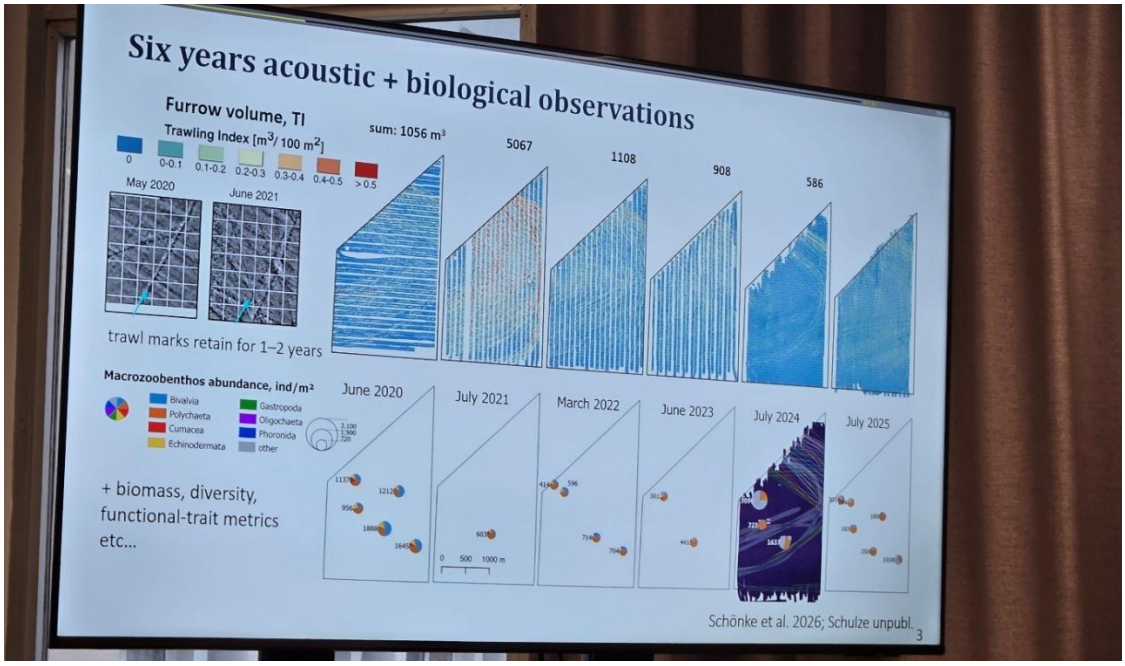


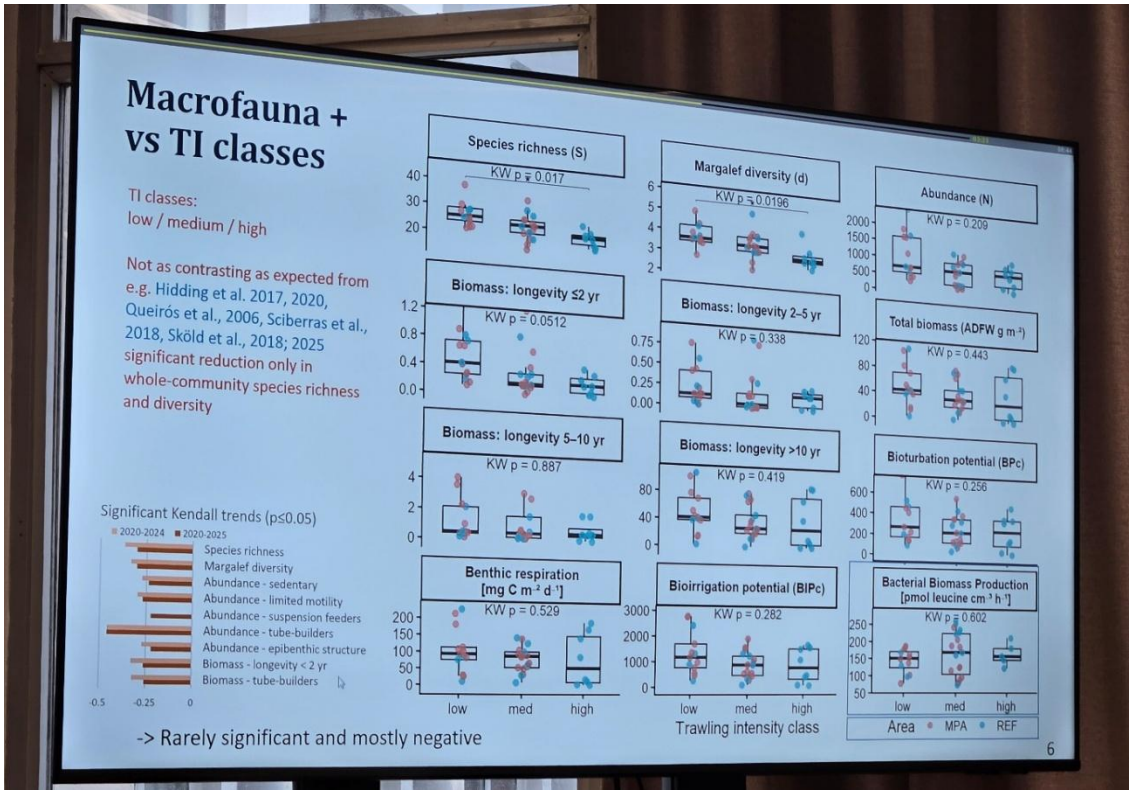


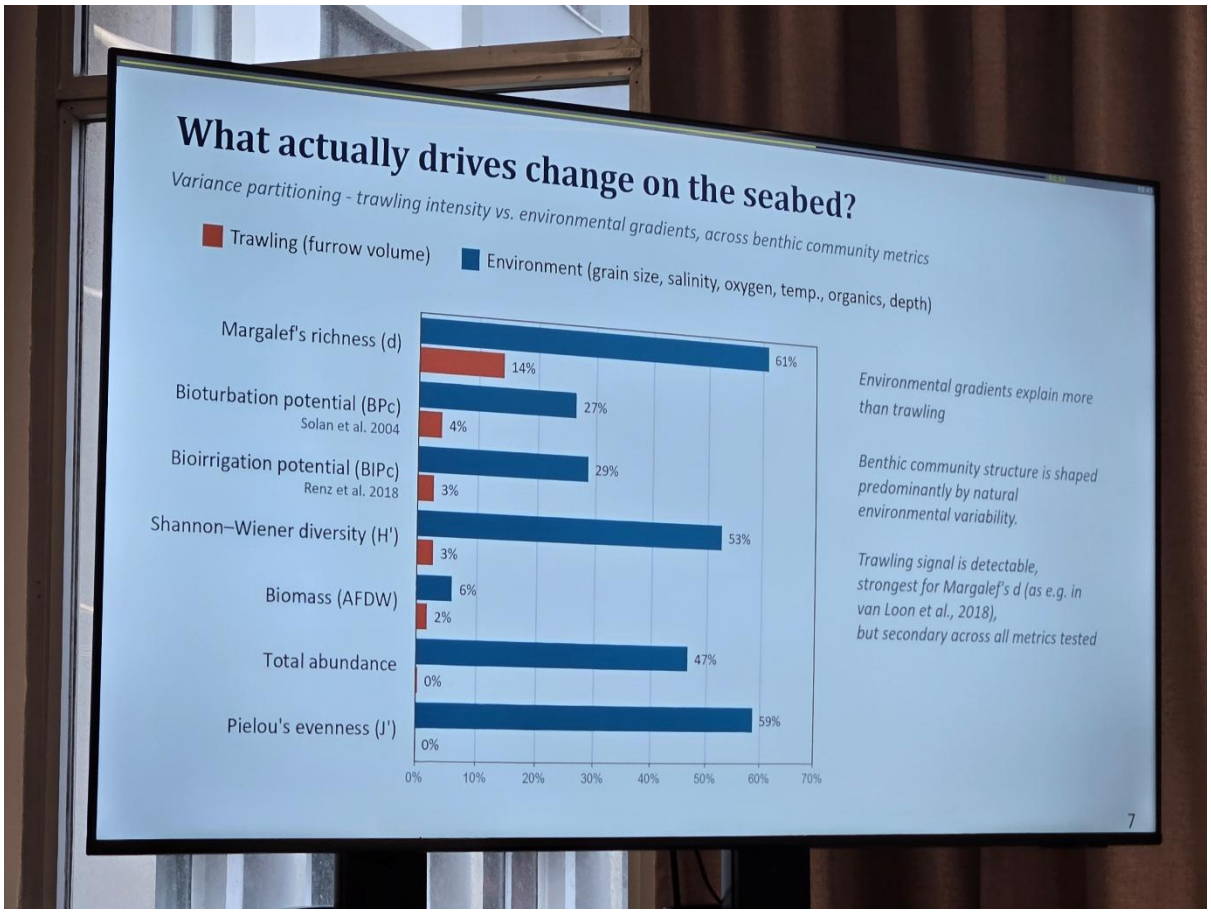
Furrows and benthos: linking acoustic trawling signatures to macrofauna
Mayya Gogina

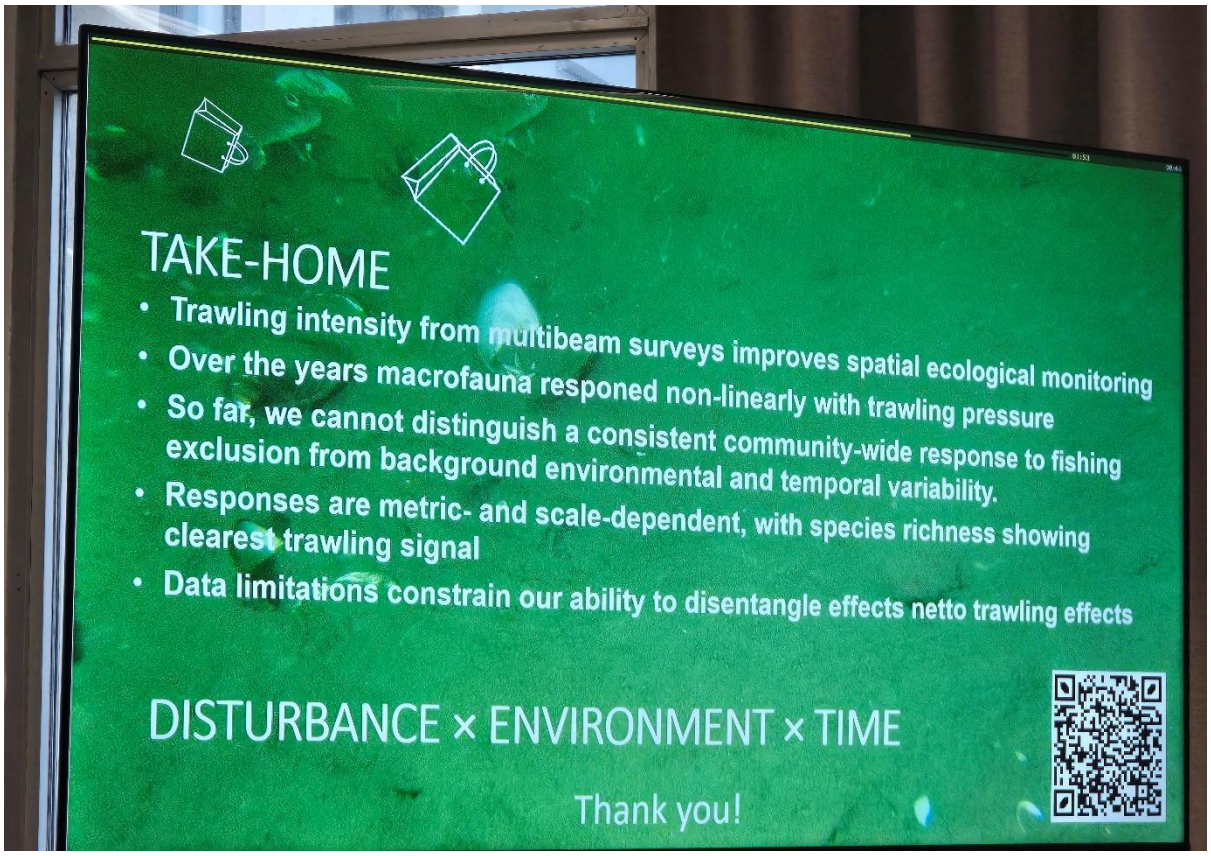
Seafloor disturbance by demersal fishing is a major anthropogenic pressure on marine benthic ecosystems, yet natural environmental gradients and temporal variability mask or interact with fishing effects, and quantifying its ecological impact remains challenging. It requires both precise disturbance metrics and explicit consideration of temporal alignment and environmental variability.
We combine multi-year hydroacoustic mapping with macrozoobenthos sampling to disentangle the ecological signal of bottom trawling fishing from background environmental variability in the Fehmarn Belt (southern Baltic Sea), including muddy habitat plots in marine protected area (MPA) and adjacent reference area. This fine-scale study integrates six years (2020–2025) of multibeam echosounder (MBES) hydroacoustic surveys and biological sampling, combining the derived

trawling-induced seafloor furrow volume (Trawling Index TI) with macrofauna (MZB) abundance, biomass, diversity, and functional traits metrics.
The analysis demonstrates that benthic macrofaunal communities respond nonlinearly to cumulative trawling pressure, with stronger impacts on total abundance than biomass. Variance-partitioning models incorporating environmental drivers showed that the unique contribution of TI to changes of these community-level variables was generally negligible to modest. It was slightly higher for bioturbation and bioirrigation potential indices. In line with previous studies, Margalef's richness emerged as the most sensitive diversity metric, showing a consistent statistically significant negative relationship with TI. In contrast, environmental variability, factors such as sediment grain size, salinity, and organic content, explain more variance in macrofauna than trawling in this naturally dynamic system.



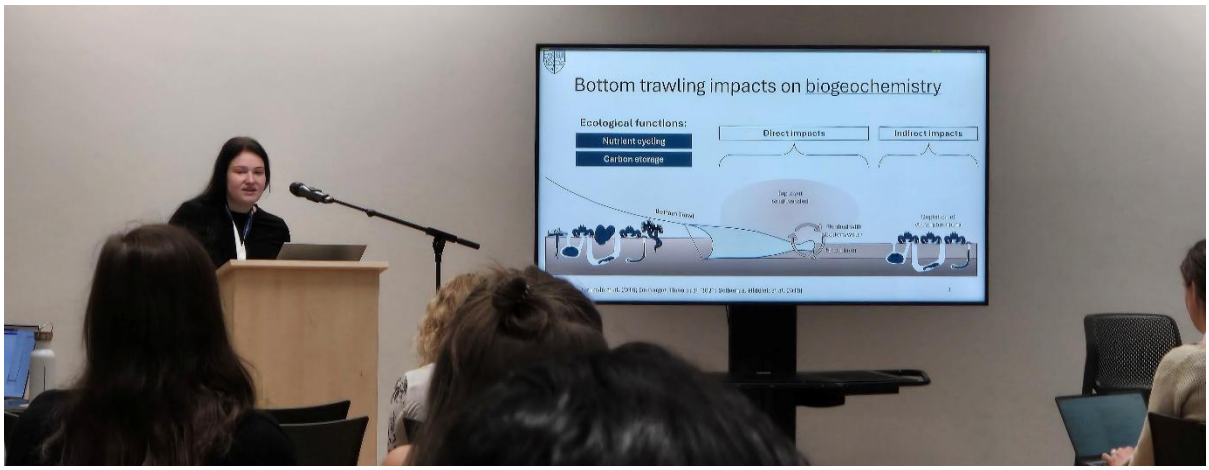


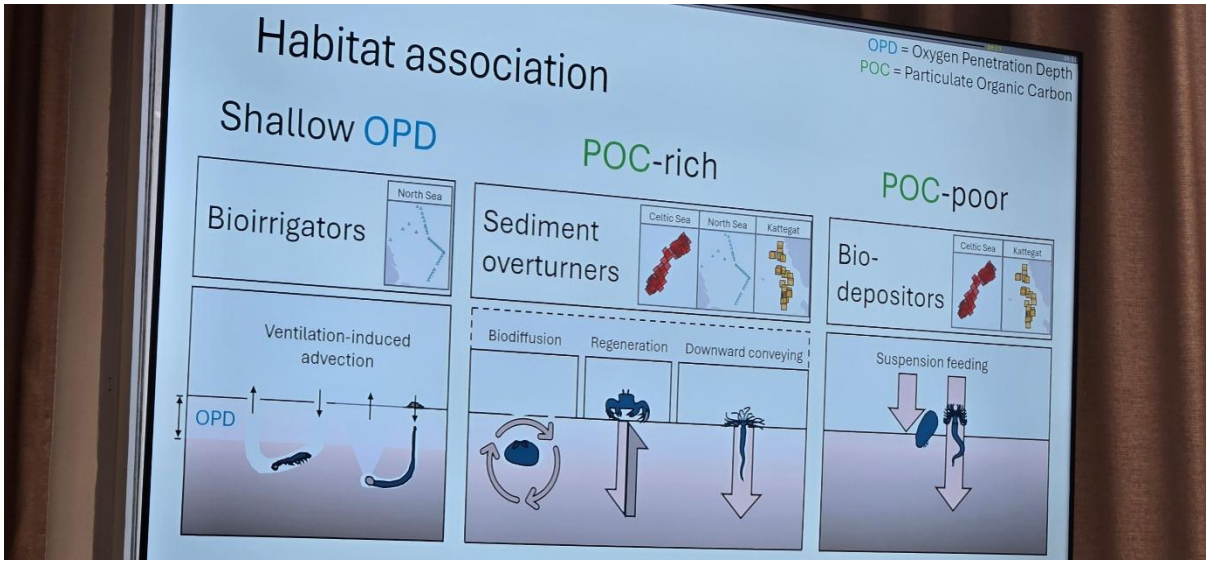

What actually drives change on the seabed?
Variance partitioning - trawling intensity vs. environmental gradients, across benthic community metrics
Trawling (furrow volume)
Environment (grain size, salinity, oxygen, temp., organics, depth)
Margalef's richness (d)
14%
61%
Bioturbation potential (BPc)
Solan et al. 2004
4%
27%
Bioirrigation potential (BIPc)
Renz et al. 2018
3%
29%
Shannon–Wiener diversity (H')
3%
53%
Biomass (AFDW)
2%
6%
Total abundance
0%
47%
Pielou's evenness (J')
0%
59%
0%
10%
20%
30%
40%
50%
60%
70%
Environmental gradients explain more than trawling
Benthic community structure is shaped predominantly by natural environmental variability.
Trawling signal is detectable, strongest for Margalef's d (as e.g. in van Loon et al., 2018), but secondary across all metrics tested
7

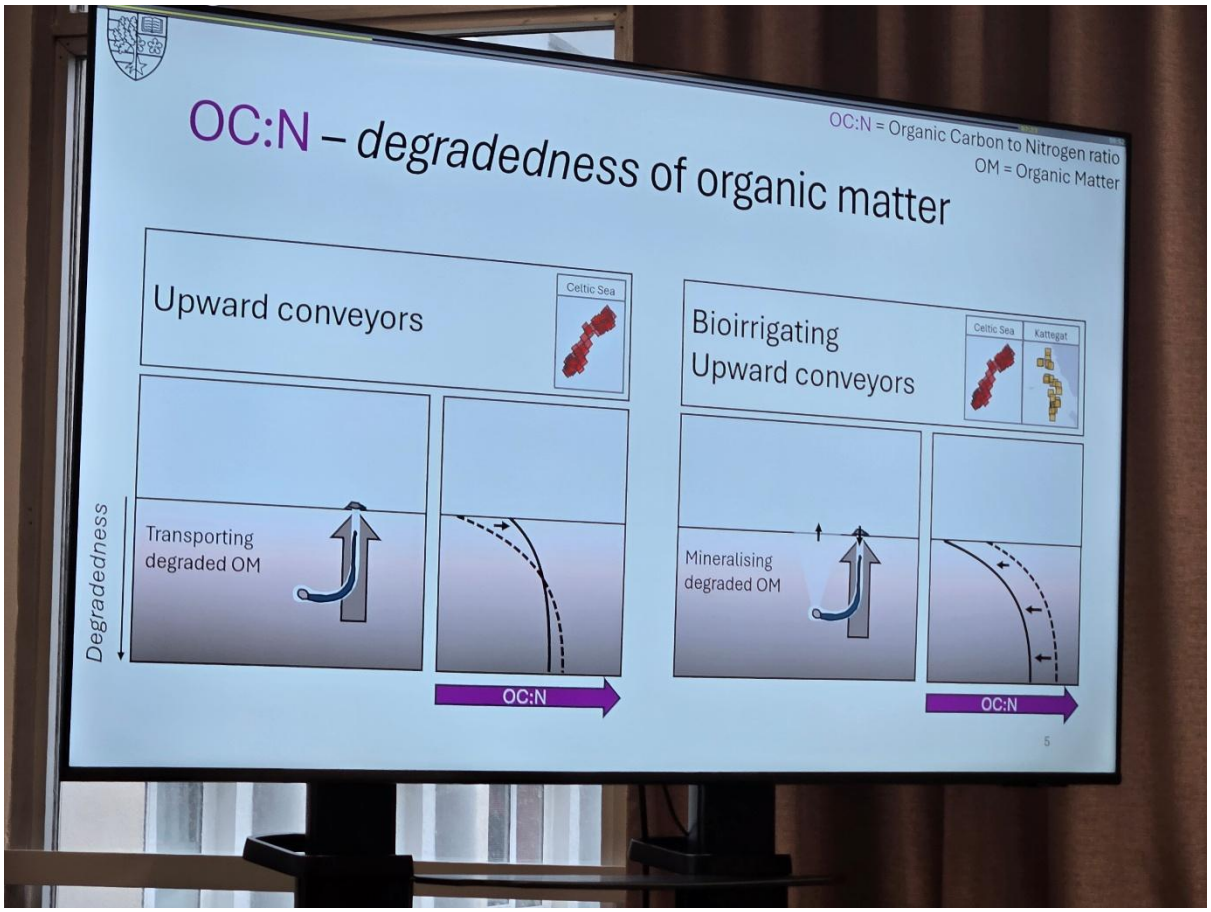

TAKE-HOME
Trawling intensity from multibeam surveys improves spatial ecological monitoring
Over the years macrofauna responed non-linearly with trawling pressure
So far, we cannot distinguish a consistent community-wide response to fishing exclusion from background environmental and temporal variability.
Responses are metric- and scale-dependent, with species richness showing clearest trawling signal
Data limitations constrain our ability to disentangle effects netto trawling effects
DISTURBANCE × ENVIRONMENT × TIME
Thank you!

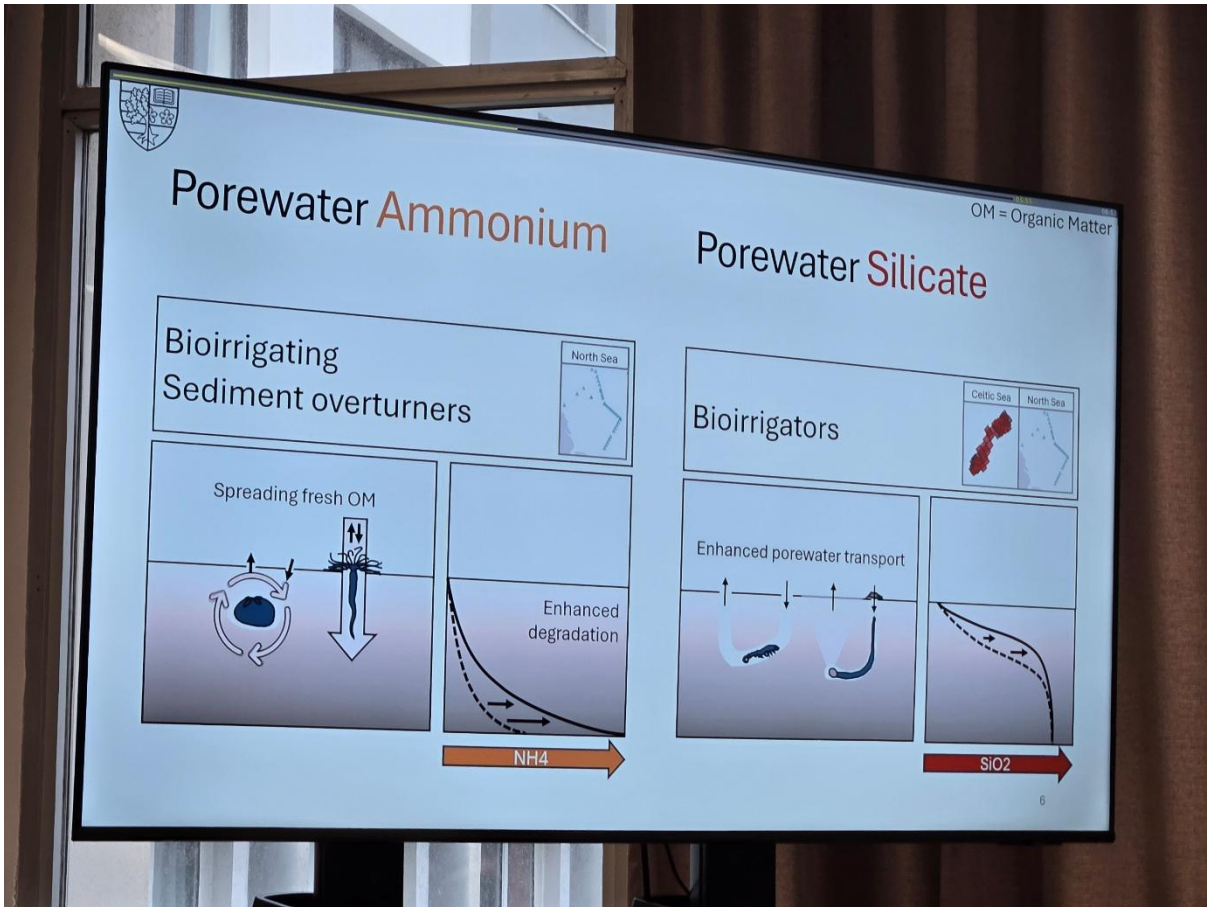
Fauna-biogeochemistry relationships under bottom trawling
Amrei Gruender

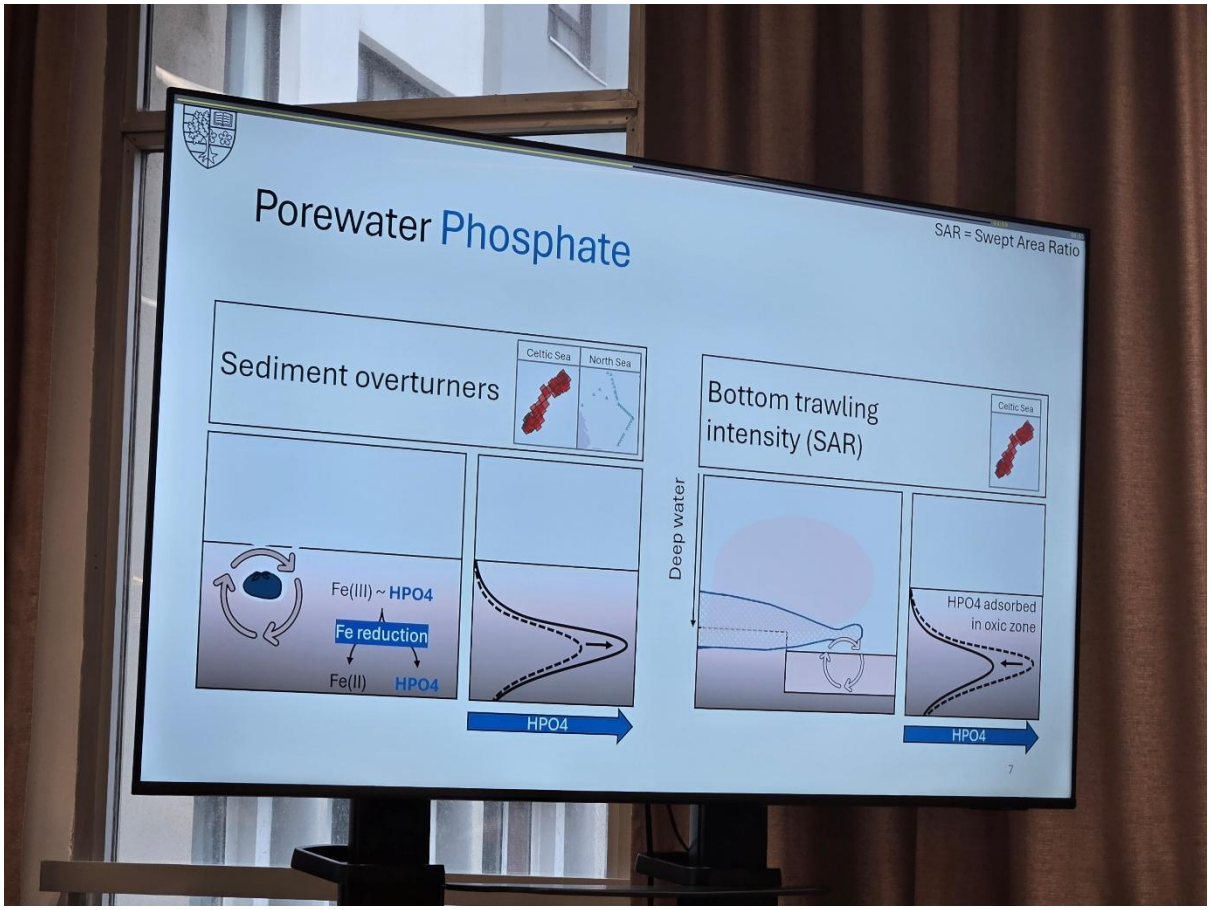
Sediment biogeochemistry can be influenced by bottom trawling directly, through resuspending and mixing the sediment, or indirectly, by depleting vulnerable fauna. Faunal activity can be an important driver of biogeochemical processes. Biodepositors and bioturbators locally enhance organic matter input, mechanically rework the sediment, and increase oxygen availability around ventilated burrows. Studies on bottom trawling have so far focused on the direct impacts on fauna or on sediment biogeochemistry. In this study, impacts on biogeochemistry as mediated through faunal composition change is addressed. Case studies are analysed to identify relationships between sediment biogeochemistry and the trait composition of benthic macroinvertebrates over a gradient of trawling pressures. Organic carbon and pore water nutrients were explained in the framework of statistical modelling in surface and subsurface depth slices and as fluxes across the sediment-water interface. Relevant environmental factors (like sediment type), fishing pressure, and biomass of functional groups were tested as explanatory variables. Species were assigned to functional groups by combined expression of trait modalities biodeposition, bioirrigation, sediment reworking, and upward conveying. The influence of environment and fishing pressure on the distribution of functional groups was investigated through multivariate analysis. This study aims to establish quantifiable fauna-biogeochemistry relationships and assess the impact of faunal composition change induced by chronic trawling on nutrient cycling and carbon mineralisation.

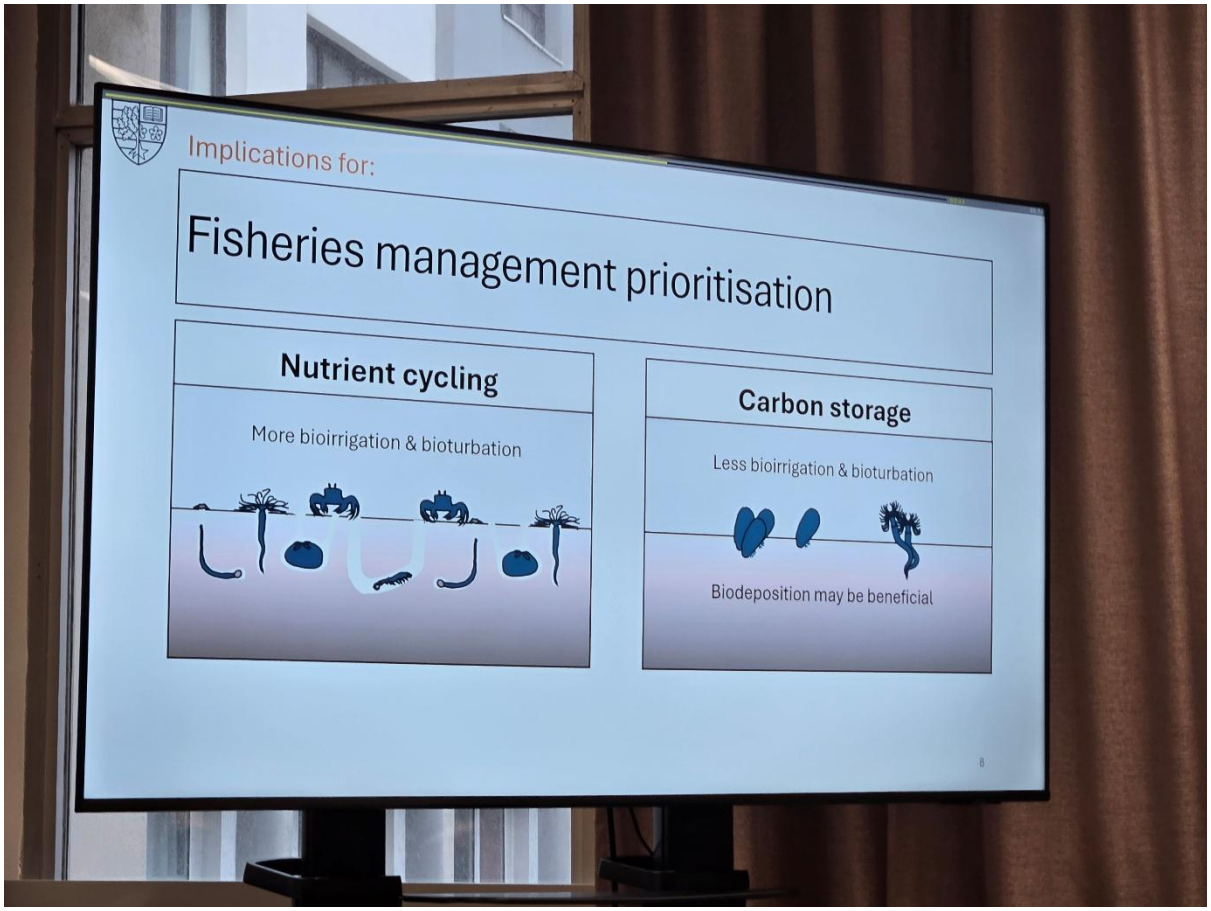





OC:N – degradedness of organic matter
OC:N = Organic Carbon to Nitrogen ratio
OM = Organic Matter
Upward conveyors
Celtic Sea
Bioirrigating
Upward conveyors
Celtic Sea
Kattegat
Degradedness
Transporting
degraded OM
Mineralising
degraded OM
OC:N
OC:N
5


Porewater Ammonium
Porewater Silicate
OM = Organic Matter
Bioirrigating
Sediment overturners
North Sea
Bioirrigators
Celtic Sea
North Sea
Spreading fresh OM
Enhanced
degradation
Enhanced porewater transport
NH4
SiO2
6


Porewater Phosphate
SAR = Swept Area Ratio
Sediment overturners
Celtic Sea
North Sea
Fe(III) ~ HPO4
Fe reduction
Fe(II)
HPO4
HPO4
Bottom trawling intensity (SAR)
Celtic Sea
Deep water
HPO4 adsorbed in oxic zone
HPO4
7

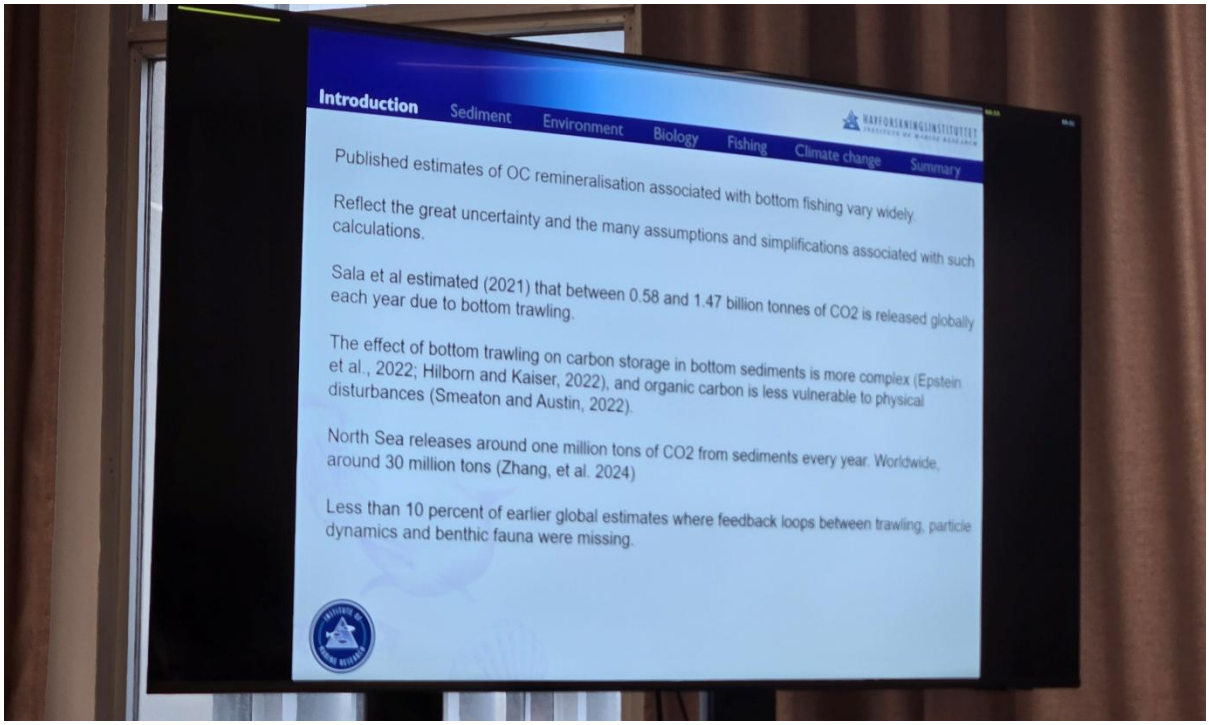

Implications for:
Fisheries management prioritisation
Nutrient cycling
More bioirrigation & bioturbation
Carbon storage
Less bioirrigation & bioturbation
Biodeposition may be beneficial
8

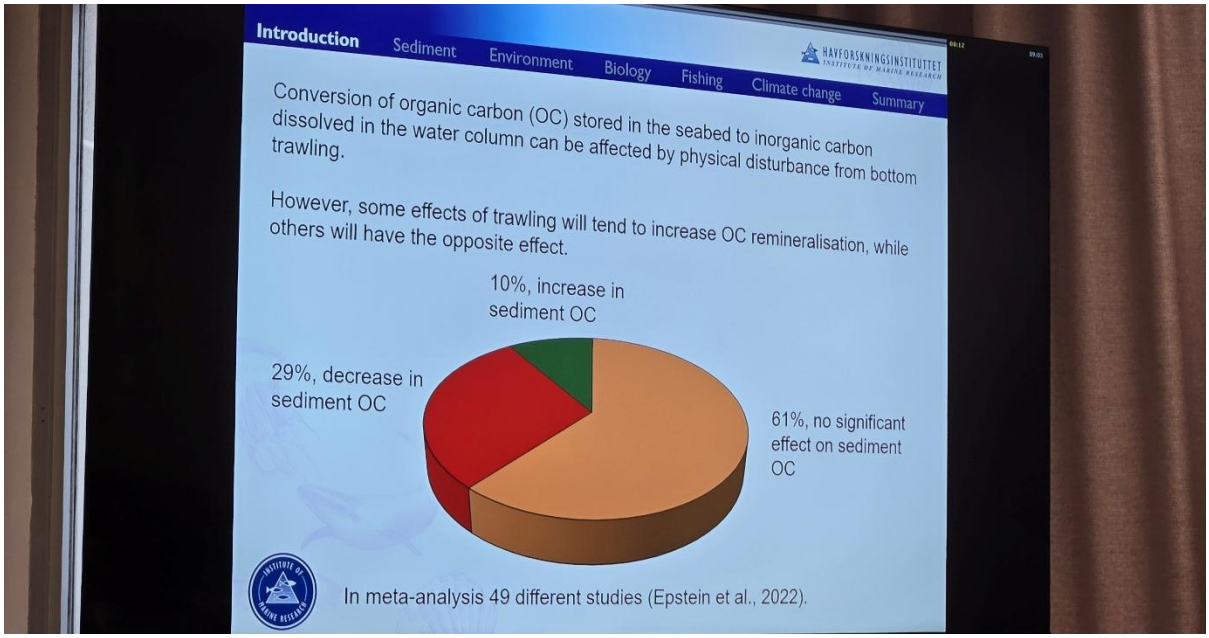


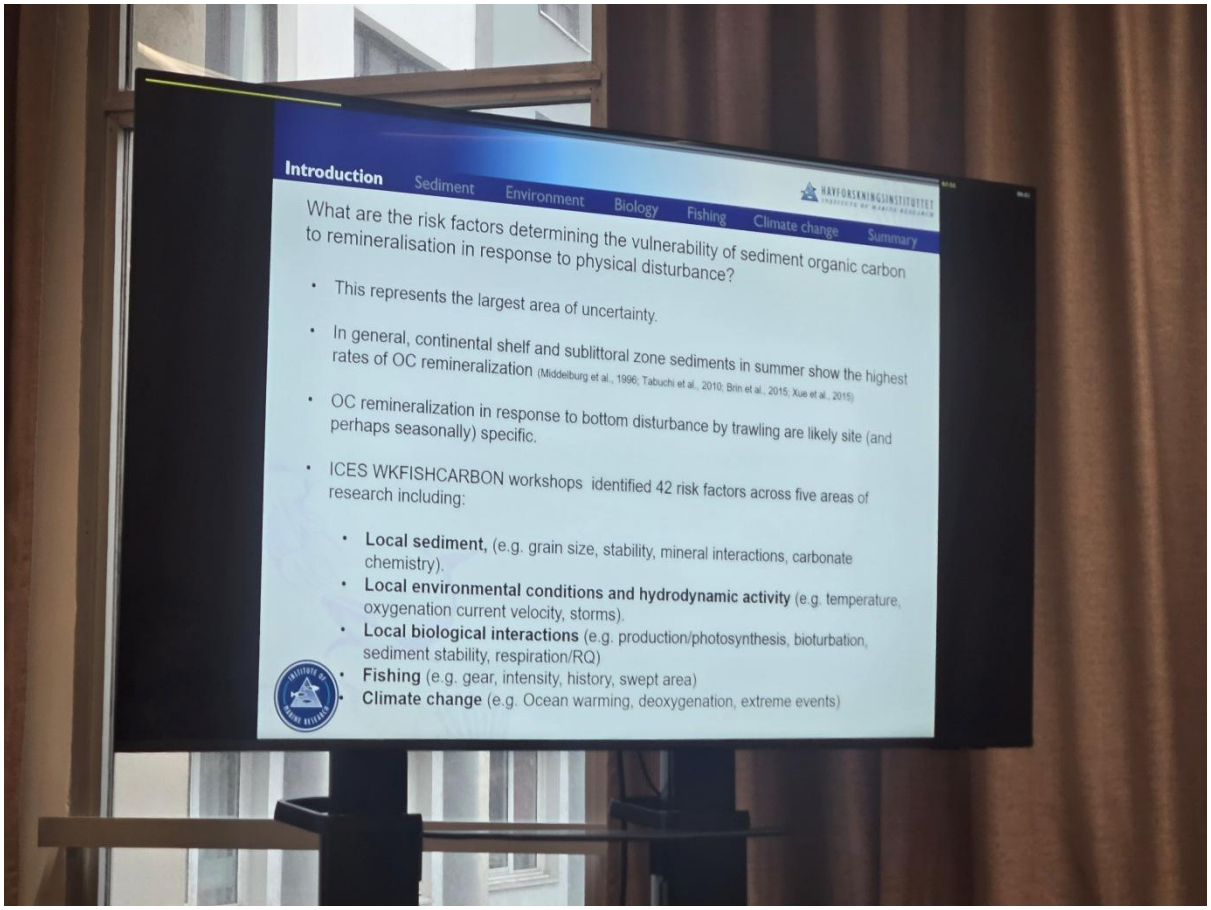
Risk factors determining the vulnerability of sediment organic carbon to remineralisation in response to physical disturbance.
Samuel Rastrick

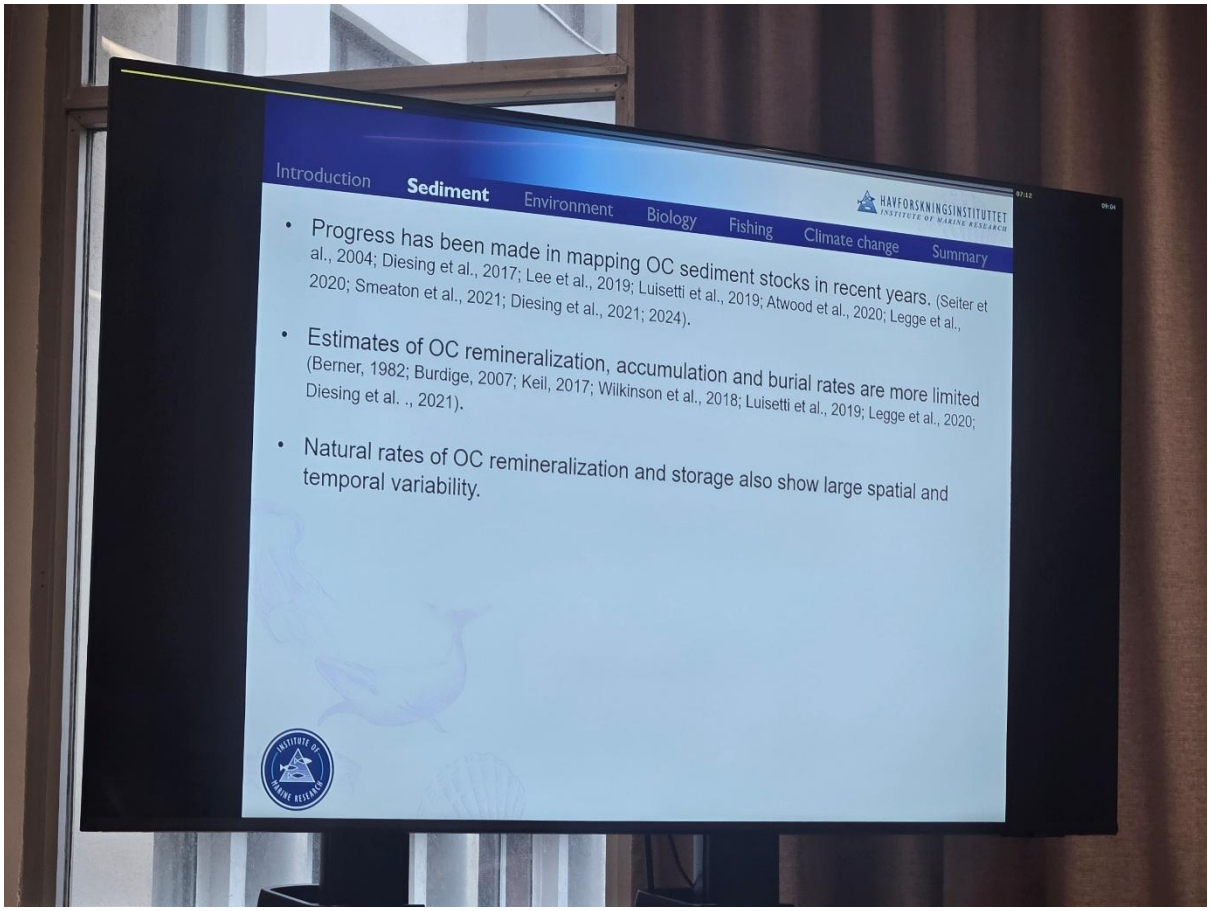
The conversion of organic carbon (OC) stored in the seabed to inorganic carbon dissolved in the water column can be affected by mobile bottom fishing and other marine industry. However, some effects of bottom disturbance will tend to increase OC remineralisation, while others will have the opposite effect. Published estimates of OC remineralisation associated with bottom fishing also vary widely, reflecting the great uncertainty and the many assumptions and simplifications associated with such calculations. The vulnerability of sediment OC to remineralisation in response to physical disturbance is dependent on the complex interactions between local sediment (e.g. grain size, OC content, lability and source), local environmental conditions (e.g. temperature) and hydrodynamics (e.g. turbulence, currents), local biological communities (e.g. production and bioturbation), local benthic fishing methods (e.g. gear penetration depth, Swept area, Intensity / history) and climate change (e.g. warming, deoxygenation). Here we discuss work from the ICES FISHCARBON workshops, reviewing local drivers of OC accumulation and remineralisation to develop a list of risk factors that can be used by managers to assess the local vulnerability of sediment OC to remineralisation in response to physical disturbance.

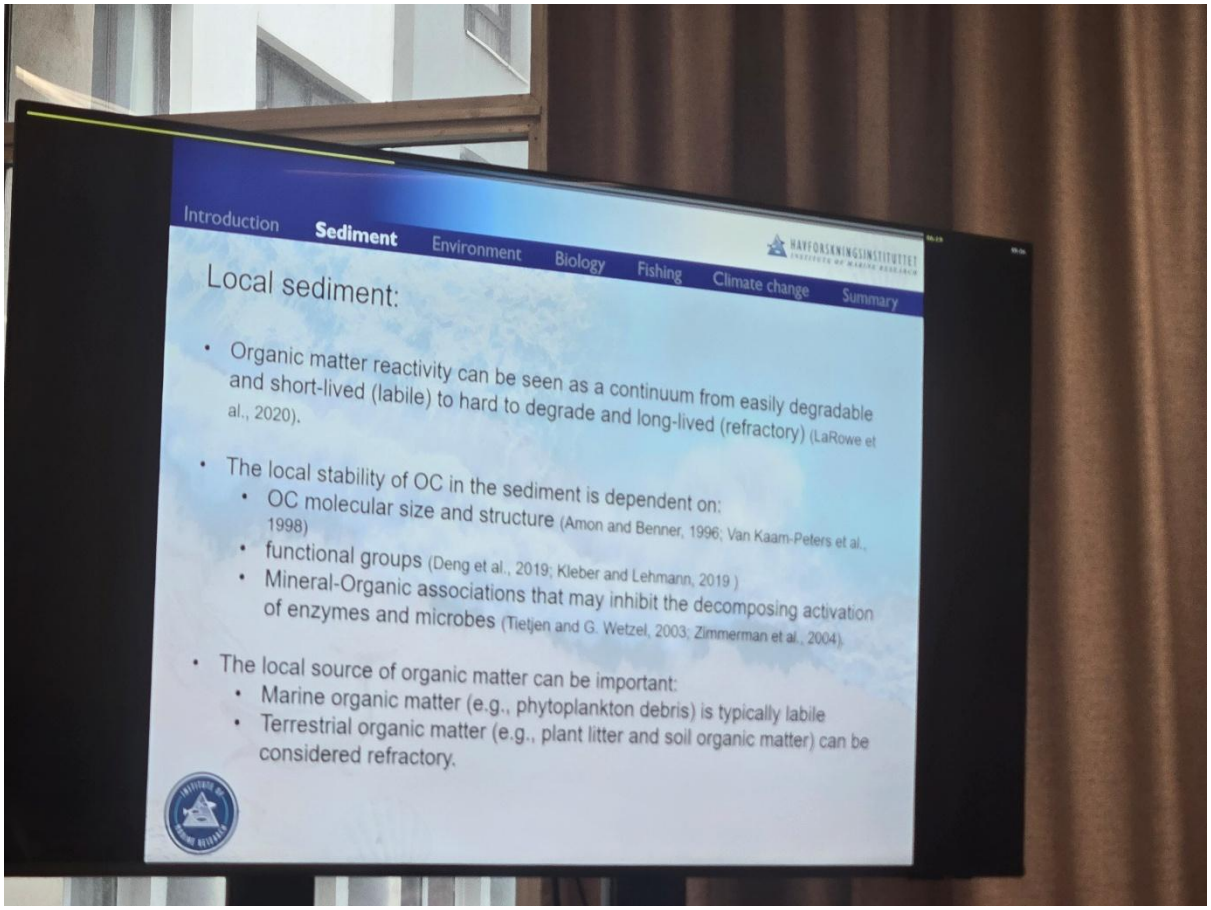


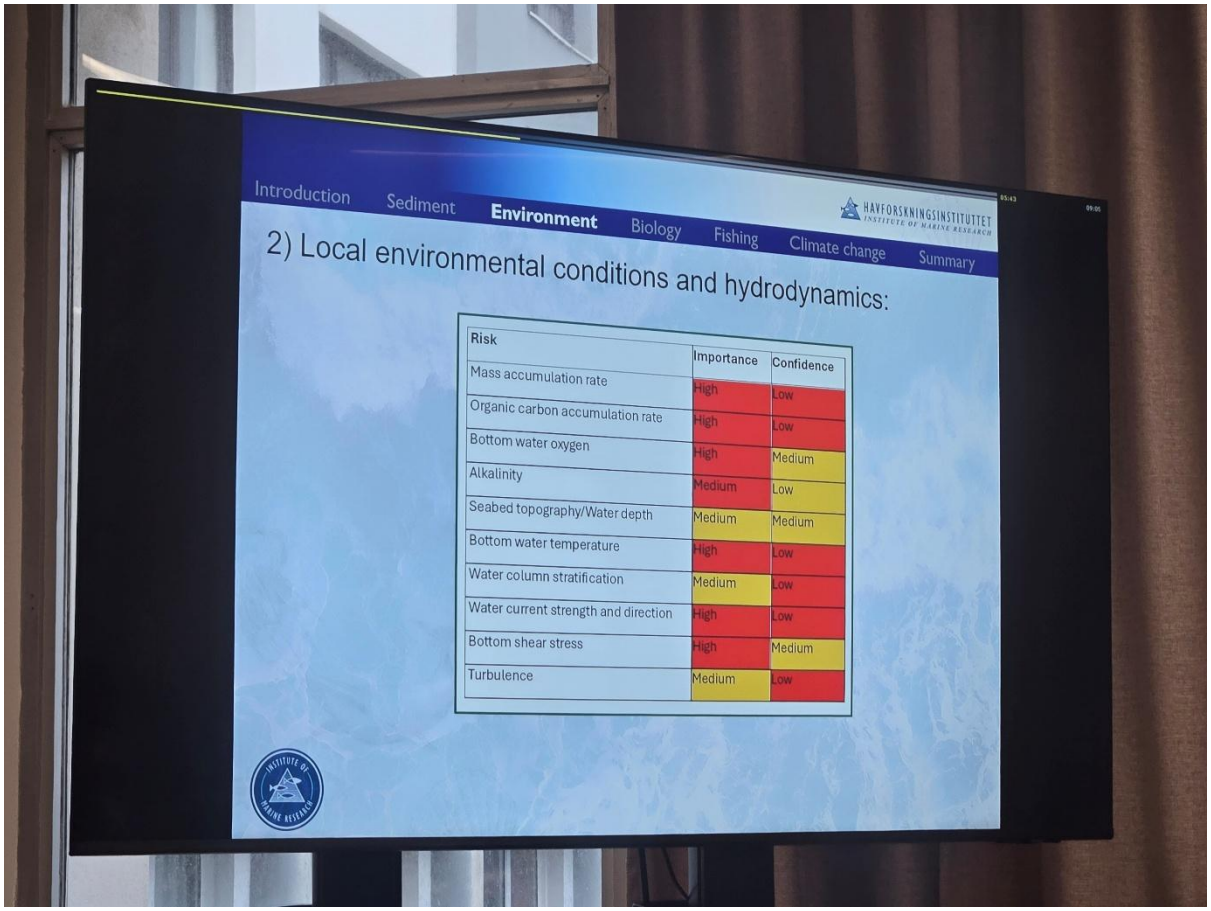

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Published estimates of OC remineralisation associated with bottom fishing vary widely.
Reflect the great uncertainty and the many assumptions and simplifications associated with such calculations.
Sala et al estimated (2021) that between 0.58 and 1.47 billion tonnes of CO2 is released globally each year due to bottom trawling.
The effect of bottom trawling on carbon storage in bottom sediments is more complex (Epstein et al., 2022; Hilborn and Kaiser, 2022), and organic carbon is less vulnerable to physical disturbances (Smeaton and Austin, 2022).
North Sea releases around one million tons of CO2 from sediments every year. Worldwide, around 30 million tons (Zhang, et al. 2024)
Less than 10 percent of earlier global estimates where feedback loops between trawling, particle dynamics and benthic fauna were missing.

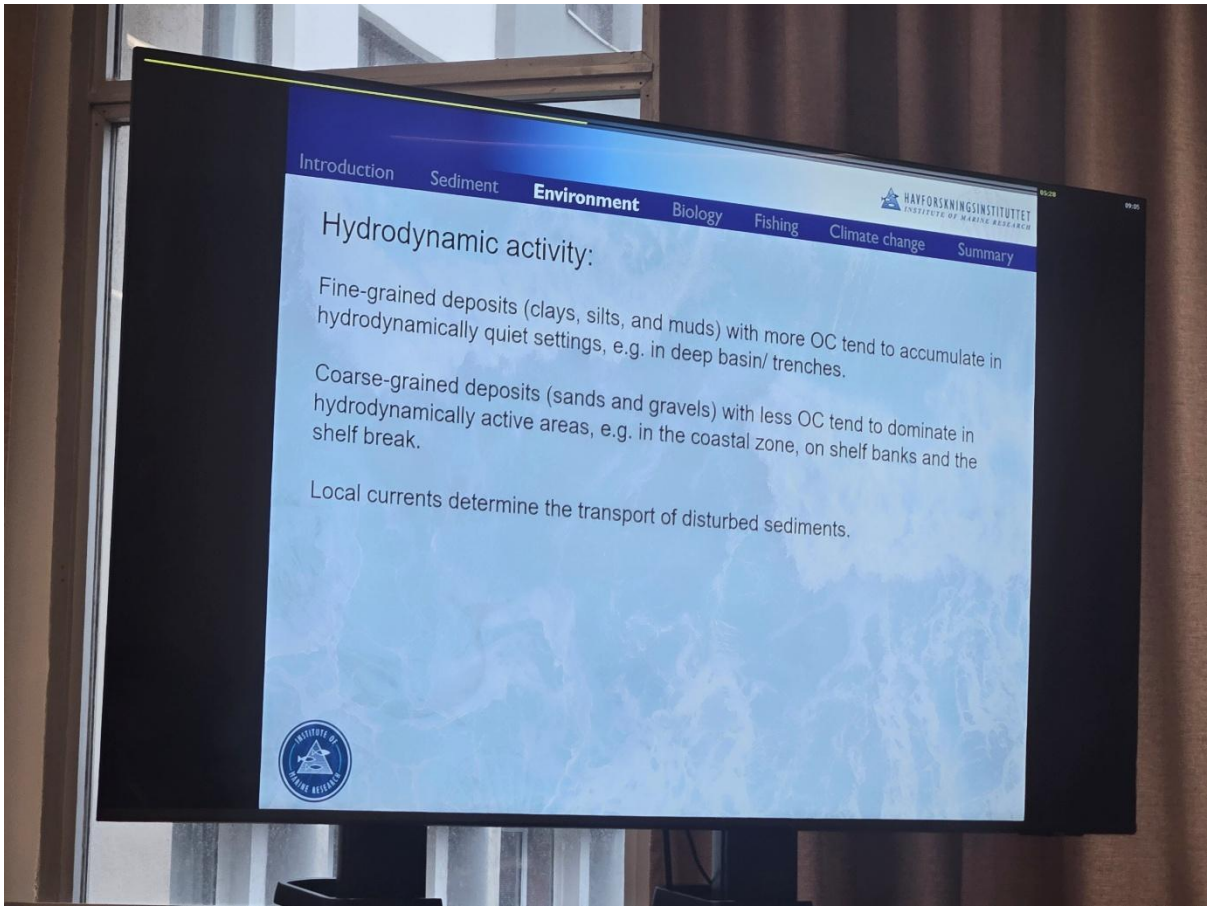

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Conversion of organic carbon (OC) stored in the seabed to inorganic carbon dissolved in the water column can be affected by physical disturbance from bottom trawling.
However, some effects of trawling will tend to increase OC remineralisation, while others will have the opposite effect.
10%, increase in sediment OC
29%, decrease in sediment OC
61%, no significant effect on sediment OC
In meta-analysis 49 different studies (Epstein et al., 2022).

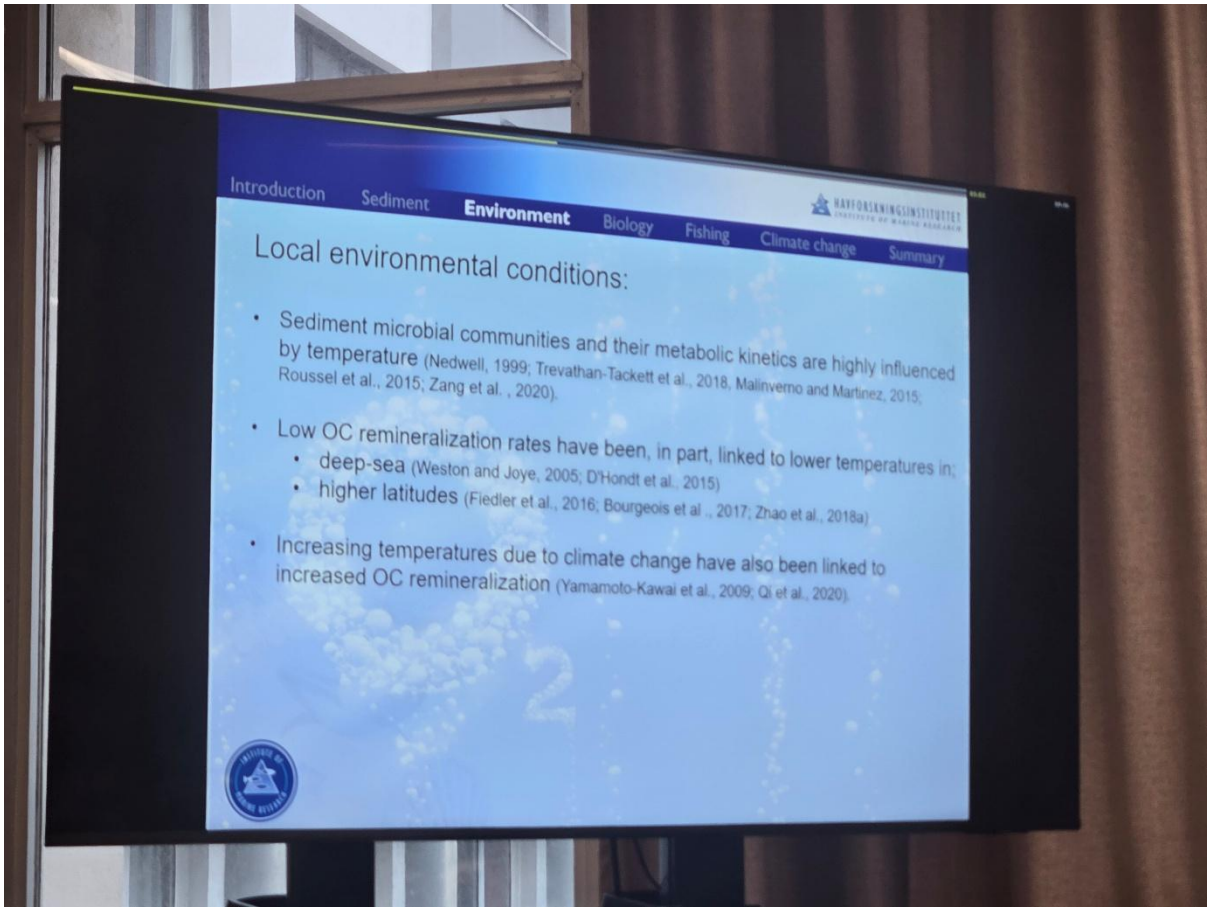

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What are the risk factors determining the vulnerability of sediment organic carbon to remineralisation in response to physical disturbance?
This represents the largest area of uncertainty.
In general, continental shelf and sublittoral zone sediments in summer show the highest rates of OC remineralization (Middelburg et al., 1996; Tabuchi et al., 2010; Brin et al., 2015; Xue et al., 2015)
OC remineralization in response to bottom disturbance by trawling are likely site (and perhaps seasonally) specific.
ICES WKFISHCARBON workshops identified 42 risk factors across five areas of research including:
Local sediment, (e.g. grain size, stability, mineral interactions, carbonate chemistry).
Local environmental conditions and hydrodynamic activity (e.g. temperature, oxygenation current velocity, storms).
Local biological interactions (e.g. production/photosynthesis, bioturbation, sediment stability, respiration/RQ)
Fishing (e.g. gear, intensity, history, swept area)
Climate change (e.g. Ocean warming, deoxygenation, extreme events)

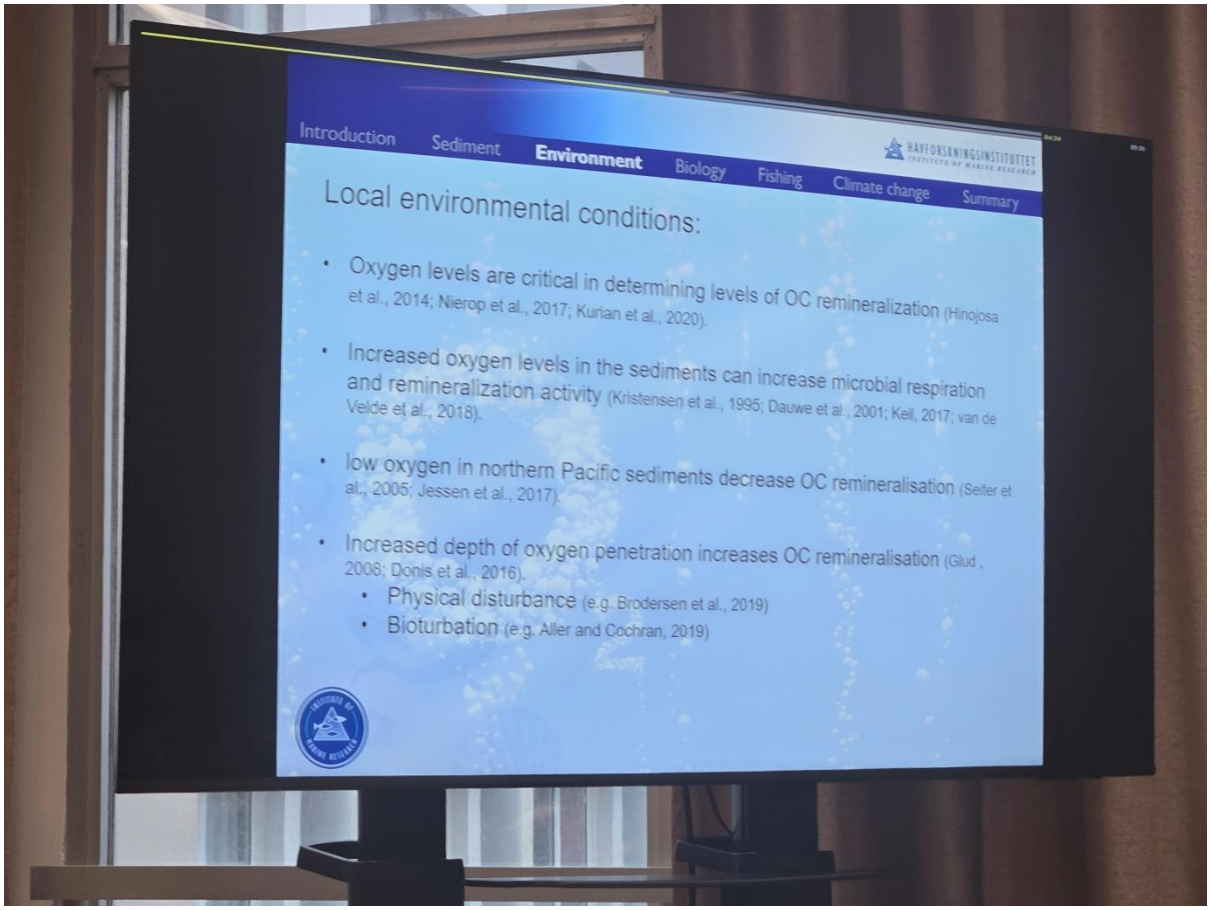

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Progress has been made in mapping OC sediment stocks in recent years. (Seiter et al., 2004; Diesing et al., 2017; Lee et al., 2019; Luisetti et al., 2019; Atwood et al., 2020; Legge et al., 2020; Smeaton et al., 2021; Diesing et al., 2021; 2024).
Estimates of OC remineralization, accumulation and burial rates are more limited (Berner, 1982; Burdige, 2007; Keil, 2017; Wilkinson et al., 2018; Luisetti et al., 2019; Legge et al., 2020; Diesing et al. ., 2021).
Natural rates of OC remineralization and storage also show large spatial and temporal variability.

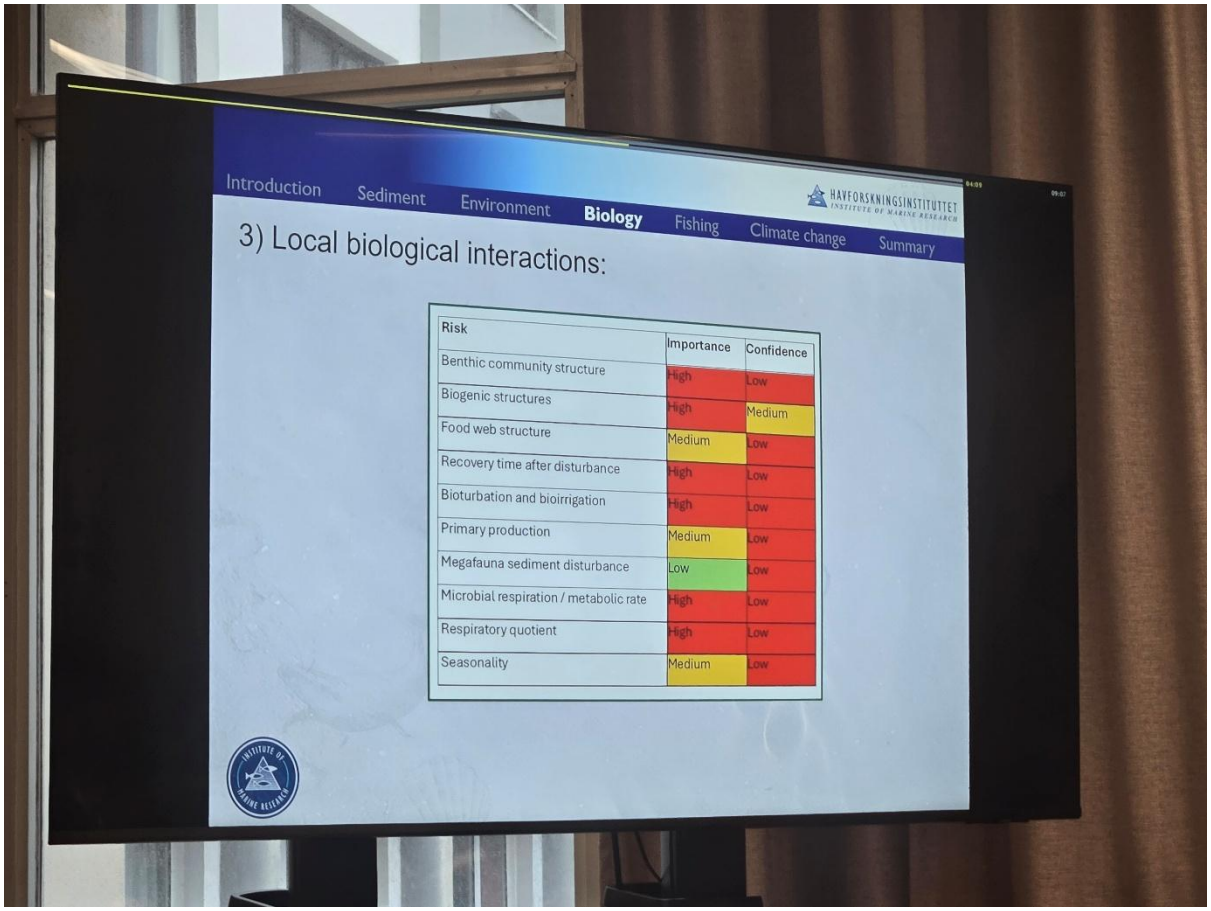

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Local sediment:
• Organic matter reactivity can be seen as a continuum from easily degradable and short-lived (labile) to hard to degrade and long-lived (refractory) (LaRowe et al., 2020).
• The local stability of OC in the sediment is dependent on:
• OC molecular size and structure (Amon and Benner, 1996; Van Kaam-Peters et al., 1998)
• functional groups (Deng et al., 2019; Kleber and Lehmann, 2019)
• Mineral-Organic associations that may inhibit the decomposing activation of enzymes and microbes (Tietjen and G. Wetzel, 2003; Zimmerman et al., 2004).
• The local source of organic matter can be important:
• Marine organic matter (e.g., phytoplankton debris) is typically labile
• Terrestrial organic matter (e.g., plant litter and soil organic matter) can be considered refractory.

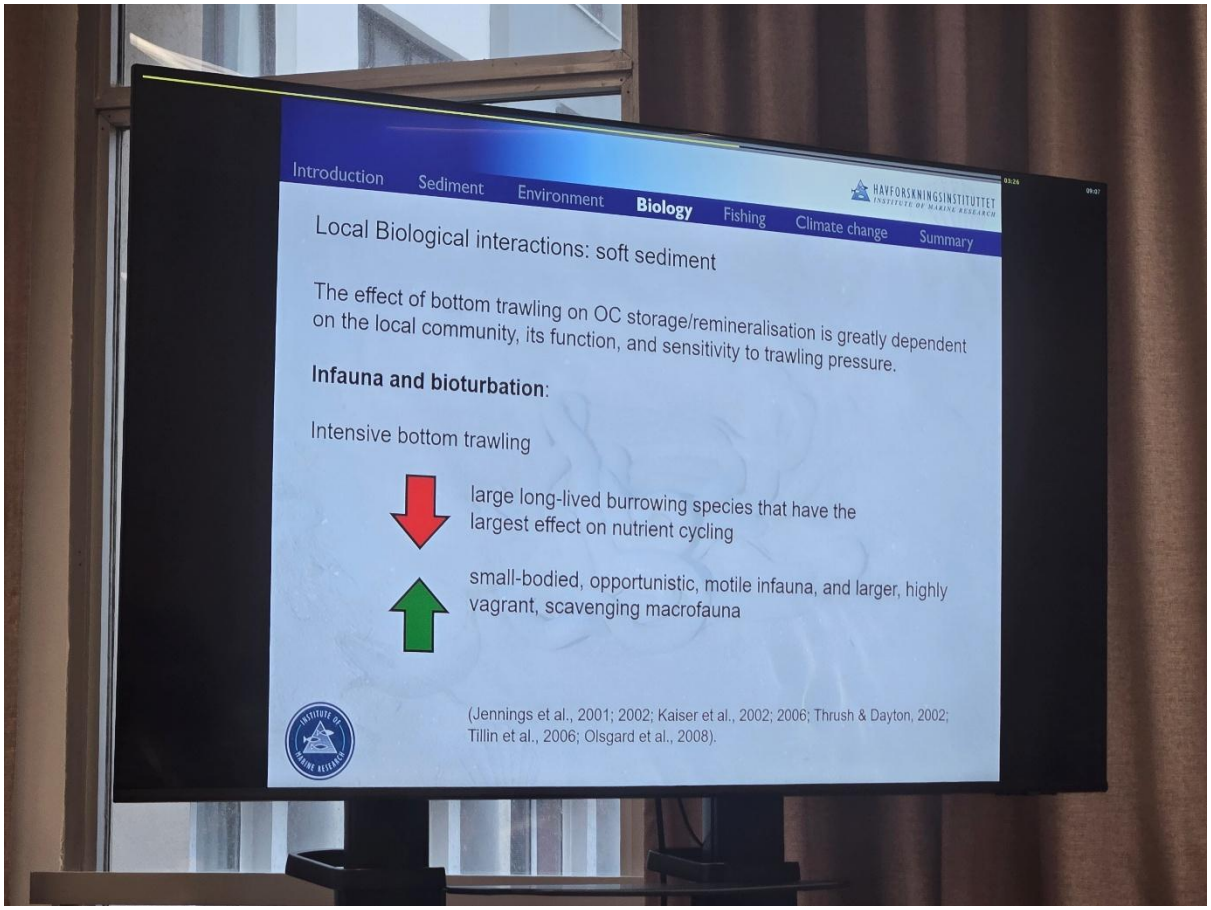

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2) Local environmental conditions and hydrodynamics:
Risk
Importance
Confidence
Mass accumulation rate
High
Low
Organic carbon accumulation rate
High
Low
Bottom water oxygen
High
Medium
Alkalinity
Medium
Low
Seabed topography/Water depth
Medium
Medium
Bottom water temperature
High
Low
Water column stratification
Medium
Low
Water current strength and direction
High
Low
Bottom shear stress
High
Medium
Turbulence
Medium
Low

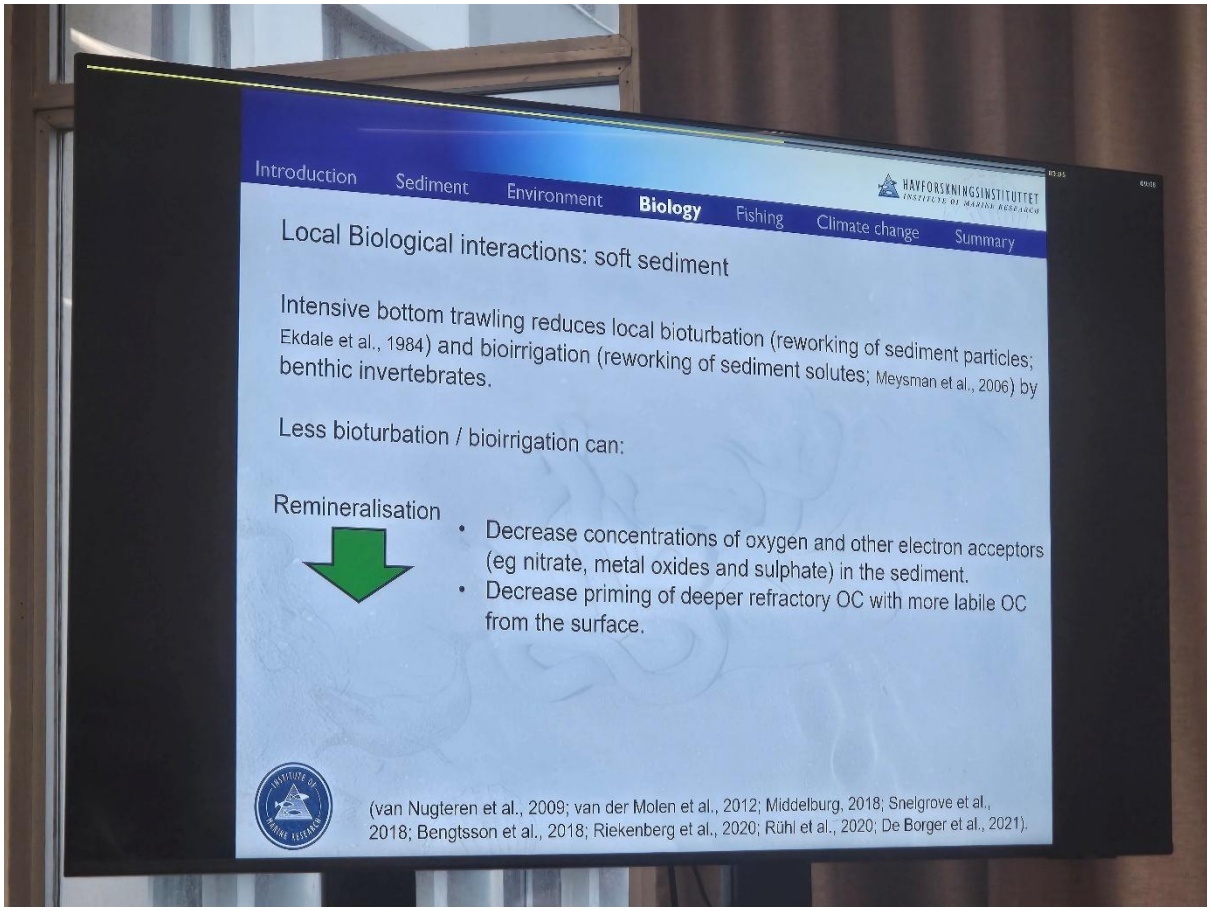

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Hydrodynamic activity:
Fine-grained deposits (clays, silts, and muds) with more OC tend to accumulate in hydrodynamically quiet settings, e.g. in deep basin/ trenches.
Coarse-grained deposits (sands and gravels) with less OC tend to dominate in hydrodynamically active areas, e.g. in the coastal zone, on shelf banks and the shelf break.
Local currents determine the transport of disturbed sediments.

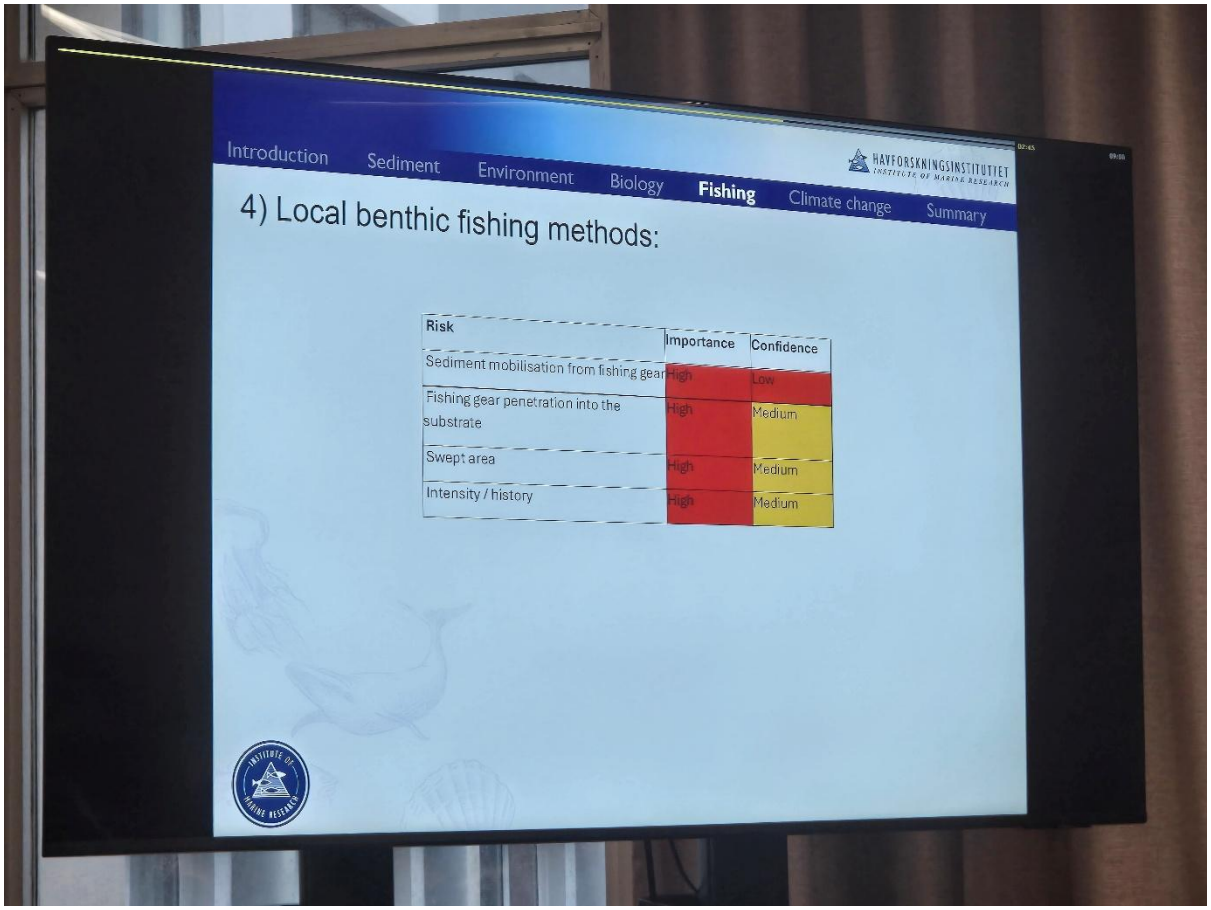

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Local environmental conditions:
Sediment microbial communities and their metabolic kinetics are highly influenced by temperature (Nedwell, 1999; Trevathan-Tackett et al., 2018, Malinverno and Martinez, 2015; Roussel et al., 2015; Zang et al. , 2020).
Low OC remineralization rates have been, in part, linked to lower temperatures in:
deep-sea (Weston and Joye, 2005; D'Hondt et al., 2015)
higher latitudes (Fiedler et al., 2016; Bourgeois et al ., 2017; Zhao et al., 2018a)
Increasing temperatures due to climate change have also been linked to increased OC remineralization (Yamamoto-Kawai et al., 2009; Qi et al., 2020).

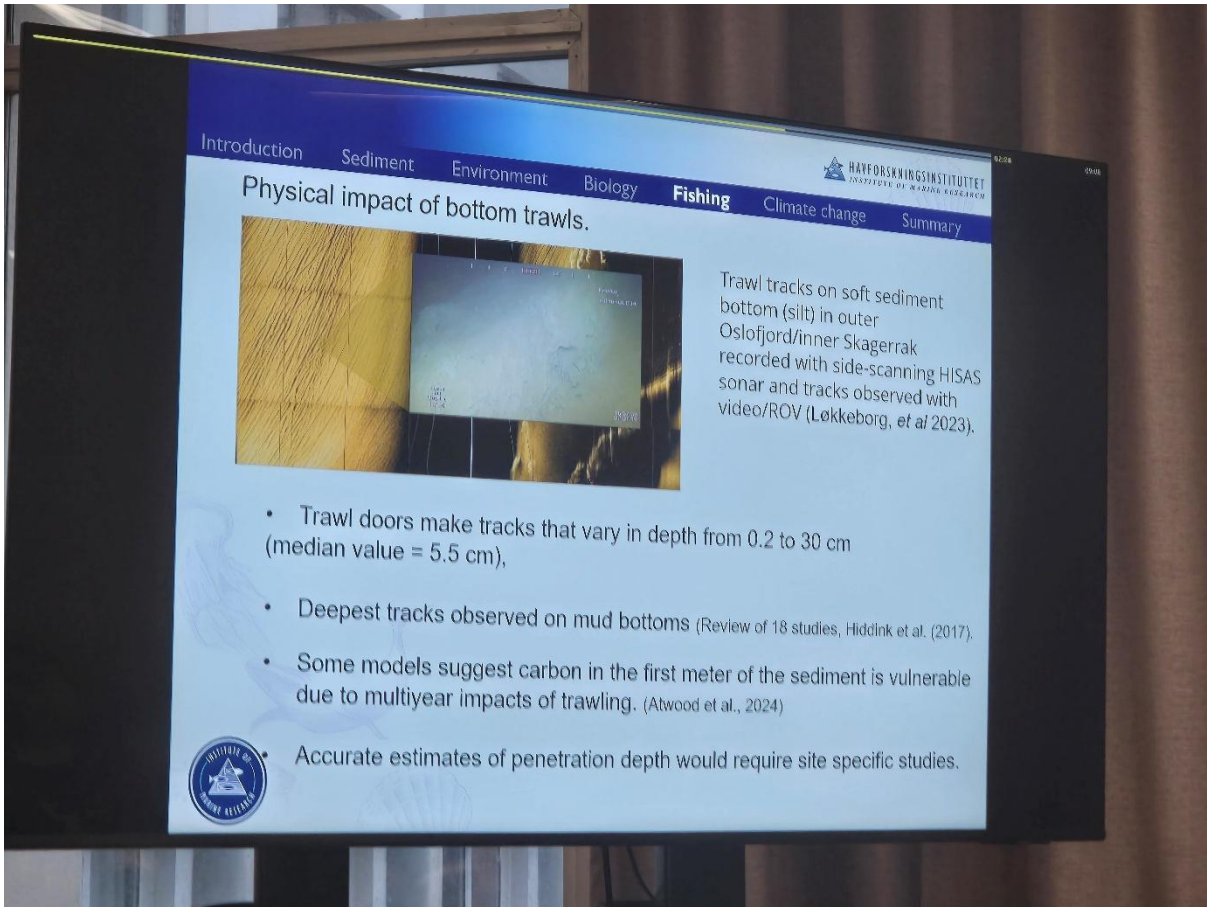

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Local environmental conditions:
• Oxygen levels are critical in determining levels of OC remineralization (Hinojosa et al., 2014; Nierop et al., 2017; Kurian et al., 2020).
• Increased oxygen levels in the sediments can increase microbial respiration and remineralization activity (Kristensen et al., 1995; Dauwe et al., 2001; Keil, 2017; van de Velde et al., 2018).
• low oxygen in northern Pacific sediments decrease OC remineralisation (Seiter et al., 2005; Jessen et al., 2017).
• Increased depth of oxygen penetration increases OC remineralisation (Glud , 2008; Donis et al., 2016).
• Physical disturbance (e.g. Brodersen et al., 2019)
• Bioturbation (e.g. Aller and Cochran, 2019)

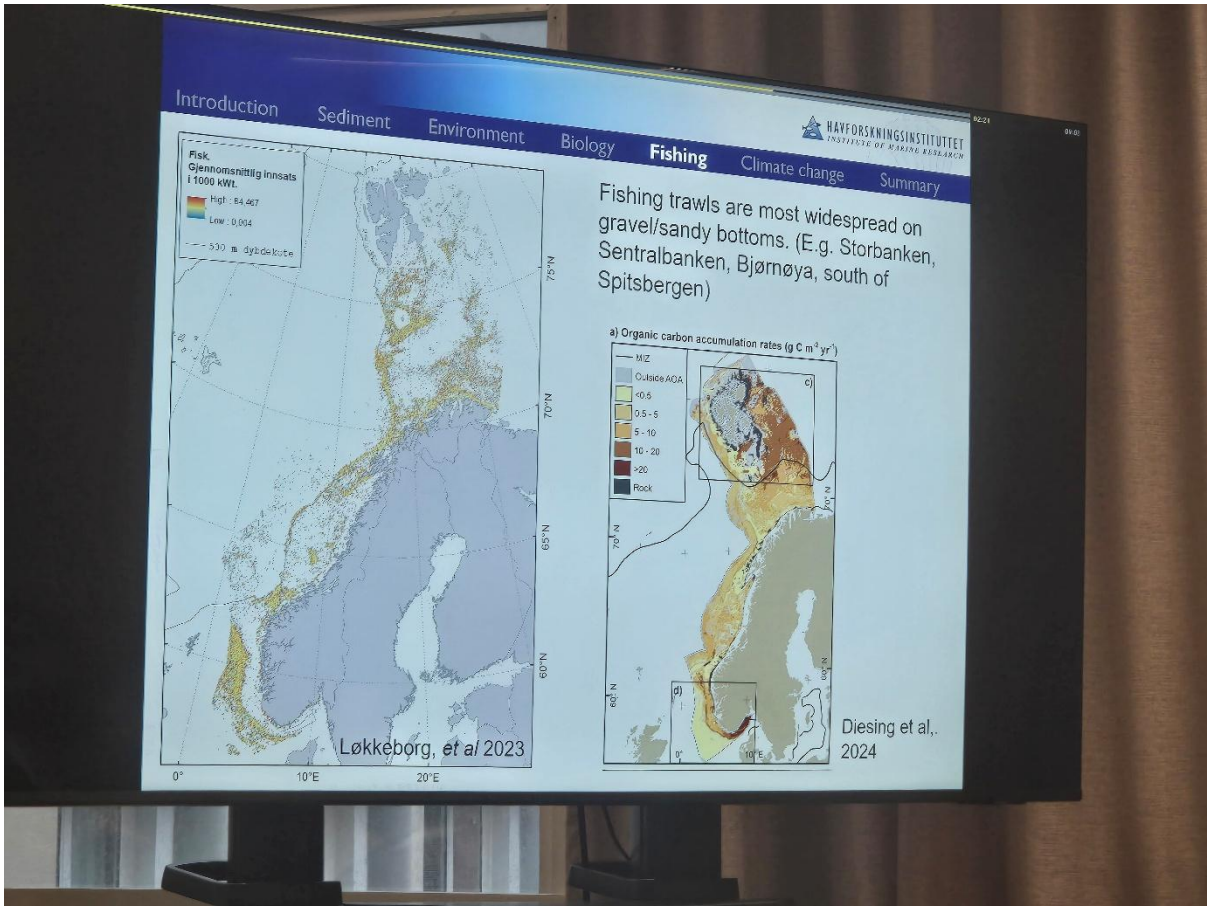

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3) Local biological interactions:
Risk | Importance | Confidence
Benthic community structure | High | Low
Biogenic structures | High | Medium
Food web structure | Medium | Low
Recovery time after disturbance | High | Low
Bioturbation and bioirrigation | High | Low
Primary production | Medium | Low
Megafauna sediment disturbance | Low | Low
Microbial respiration / metabolic rate | High | Low
Respiratory quotient | High | Low
Seasonality | Medium | Low

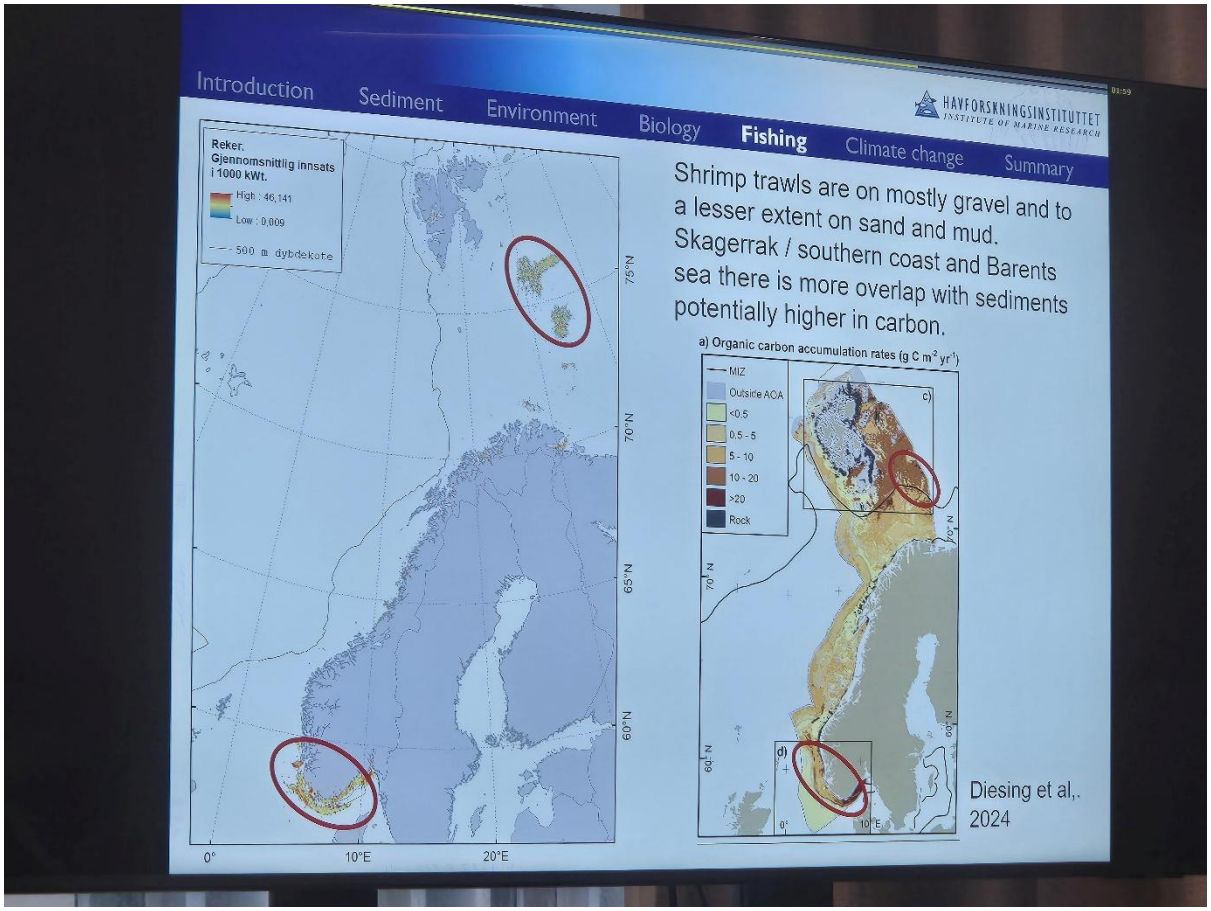

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Local Biological interactions: soft sediment
The effect of bottom trawling on OC storage/remineralisation is greatly dependent on the local community, its function, and sensitivity to trawling pressure.
Infauna and bioturbation:
Intensive bottom trawling
large long-lived burrowing species that have the largest effect on nutrient cycling
small-bodied, opportunistic, motile infauna, and larger, highly vagrant, scavenging macrofauna
(Jennings et al., 2001; 2002; Kaiser et al., 2002; 2006; Thrush & Dayton, 2002; Tillin et al., 2006; Olsgard et al., 2008).

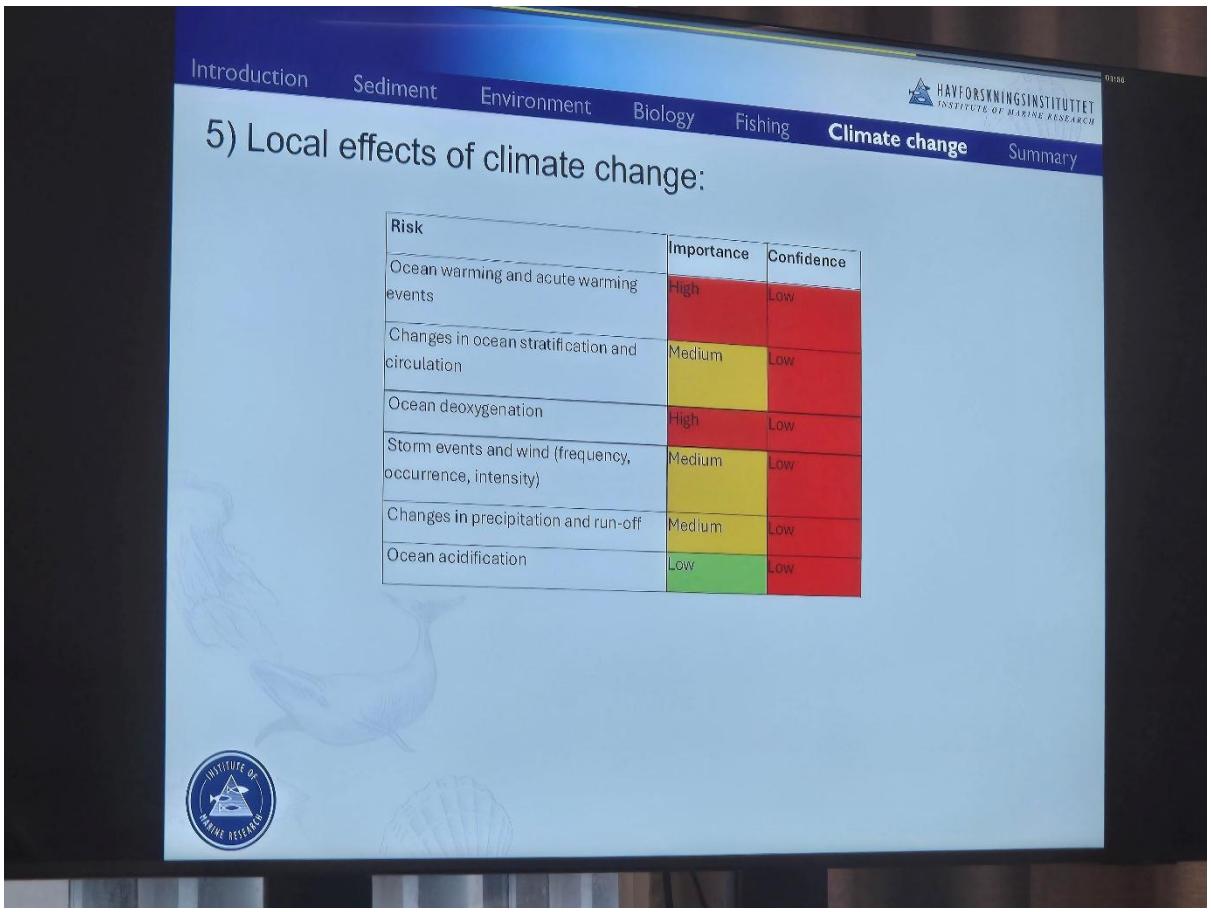

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Local Biological interactions: soft sediment
Intensive bottom trawling reduces local bioturbation (reworking of sediment particles; Ekdale et al., 1984) and bioirrigation (reworking of sediment solutes; Meysman et al., 2006) by benthic invertebrates.
Less bioturbation / bioirrigation can:
Remineralisation
Decrease concentrations of oxygen and other electron acceptors (eg nitrate, metal oxides and sulphate) in the sediment.
Decrease priming of deeper refractory OC with more labile OC from the surface.
(van Nugteren et al., 2009; van der Molen et al., 2012; Middelburg, 2018; Snelgrove et al., 2018; Bengtsson et al., 2018; Riekenberg et al., 2020; Rühl et al., 2020; De Borger et al., 2021).


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HAVFORSKNINGSINSTITUTTET
4) Local benthic fishing methods:
Risk
Importance
Confidence
Sediment mobilisation from fishing gear
High
Low
Fishing gear penetration into the substrate
High
Medium
Swept area
High
Medium
Intensity / history
High
Medium


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Physical impact of bottom trawls.
Trawl tracks on soft sediment bottom (silt) in outer Oslofjord/inner Skagerrak recorded with side-scanning HISAS sonar and tracks observed with video/ROV (Løkkeborg, et al 2023).
• Trawl doors make tracks that vary in depth from 0.2 to 30 cm (median value = 5.5 cm),
• Deepest tracks observed on mud bottoms (Review of 18 studies, Hiddink et al. (2017).
• Some models suggest carbon in the first meter of the sediment is vulnerable due to multiyear impacts of trawling. (Atwood et al., 2024)
• Accurate estimates of penetration depth would require site specific studies.

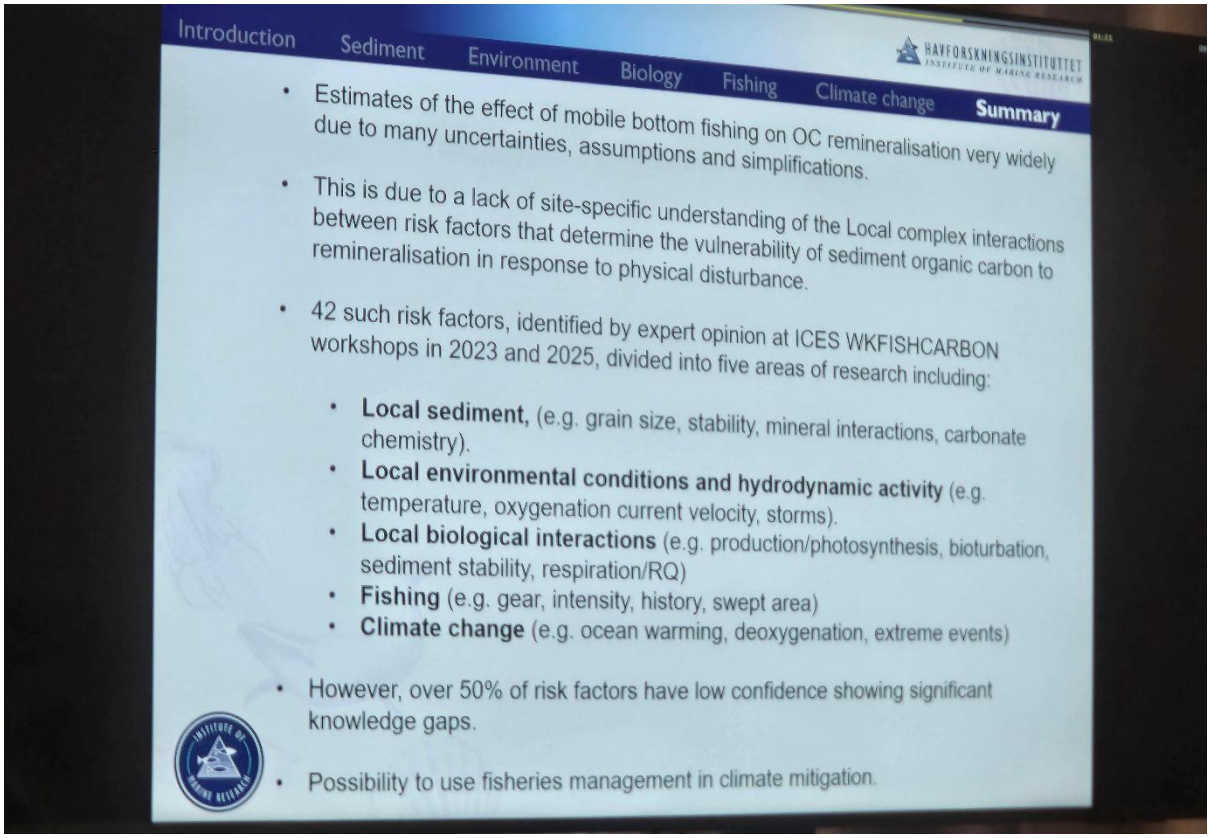

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HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH
Fisk.
Gjennomsnittlig innsats i 1000 kWt.
High : 84,467
Low : 0,004
500 m dybdekote
Fishing trawls are most widespread on gravel/sandy bottoms. (E.g. Storbanken, Sentralbanken, Bjørnøya, south of Spitsbergen)
a) Organic carbon accumulation rates (g C m-2 yr-1)
MIZ
Outside AOA
<0.5
0.5 - 5
5 - 10
10 - 20
>20
Rock
Løkkeborg, et al 2023
Diesing et al,. 2024


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HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH
Reker.
Gjennomsnittlig innsats i 1000 kWt.
High : 46,141
Low : 0,009
500 m dybdekote
Shrimp trawls are on mostly gravel and to a lesser extent on sand and mud. Skagerrak / southern coast and Barents sea there is more overlap with sediments potentially higher in carbon.
a) Organic carbon accumulation rates (g C m-2 yr-1)
MIZ
Outside AOA
<0.5
0.5 - 5
5 - 10
10 - 20
>20
Rock
Diesing et al,. 2024

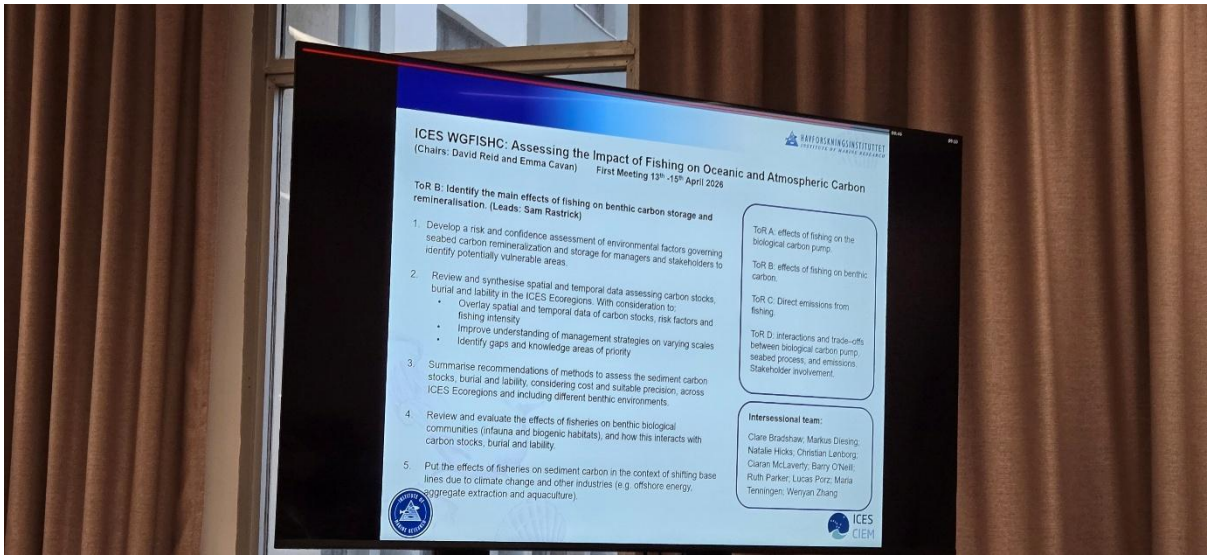


5) Local effects of climate change:

Risk	Importance	Confidence
Ocean warming and acute warming events	High	Low
Changes in ocean stratification and circulation	Medium	Low
Ocean deoxygenation	High	Low
Storm events and wind (frequency, occurrence, intensity)	Medium	Low
Changes in precipitation and run-off	Medium	Low
Ocean acidification	Low	Low



- Estimates of the effect of mobile bottom fishing on OC remineralisation very widely due to many uncertainties, assumptions and simplifications.
- This is due to a lack of site-specific understanding of the Local complex interactions between risk factors that determine the vulnerability of sediment organic carbon to remineralisation in response to physical disturbance.
- 42 such risk factors, identified by expert opinion at ICES WKFISHCARBON workshops in 2023 and 2025, divided into five areas of research including:
  - **Local sediment,** (e.g. grain size, stability, mineral interactions, carbonate chemistry).
  - **Local environmental conditions and hydrodynamic activity** (e.g. temperature, oxygenation current velocity, storms).
  - **Local biological interactions** (e.g. production/photosynthesis, bioturbation, sediment stability, respiration/RQ)
  - **Fishing** (e.g. gear, intensity, history, swept area)
  - **Climate change** (e.g. ocean warming, deoxygenation, extreme events)
- However, over 50% of risk factors have low confidence showing significant knowledge gaps.
- Possibility to use fisheries management in climate mitigation.



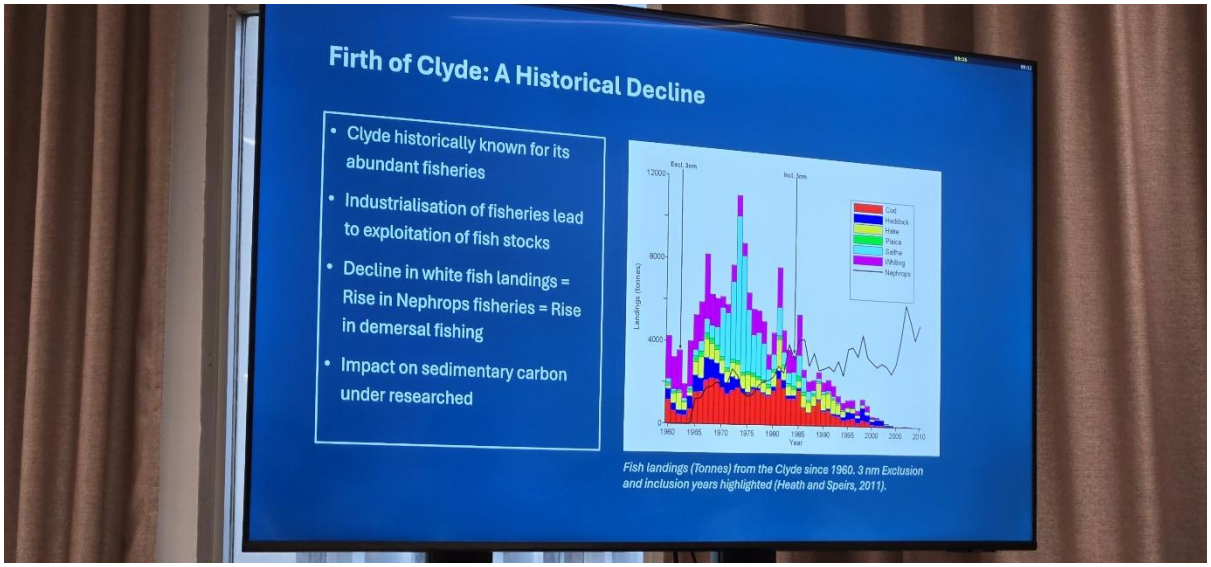
Assessing the vulnerability of marine sedimentary Organic Carbon to anthropogenic pressure in Scotland's coastal waters.
James Johnson

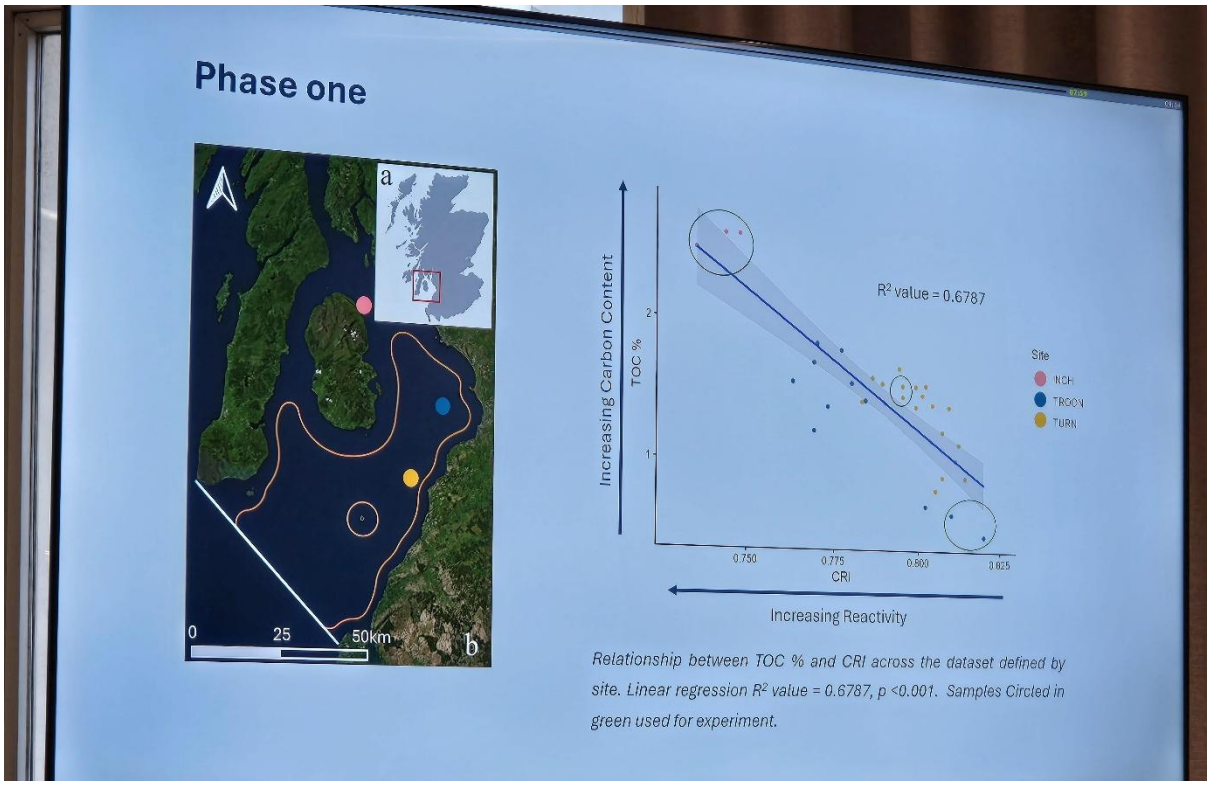
Coastal and shelf sediments store vast quantities of Organic Carbon (OC), supporting benthic ecosystems and wider climate regulation. Recent research has identified these sediments as carbon burial hotspots, a valuable function of marine habitats. However, stored OC is becoming increasingly exposed to anthropogenic disturbance as human interactions with benthic sediments have intensified. Whilst the impacts of physical disturbance (e.g., bottom trawling) on benthic ecosystems have been widely studied, little is known about the vulnerability of sedimentary OC under increased anthropogenic pressure. Bottom trawling resuspends sedimentary OC, removing it from long-term storage in the seabed. When disturbed, these sediments are vulnerable to remineralisation, causing previously stored carbon to be reemitted as carbon dioxide (CO2). At a global scale, these potentially avoidable greenhouse gas emissions are likely to be enhancing global warming.

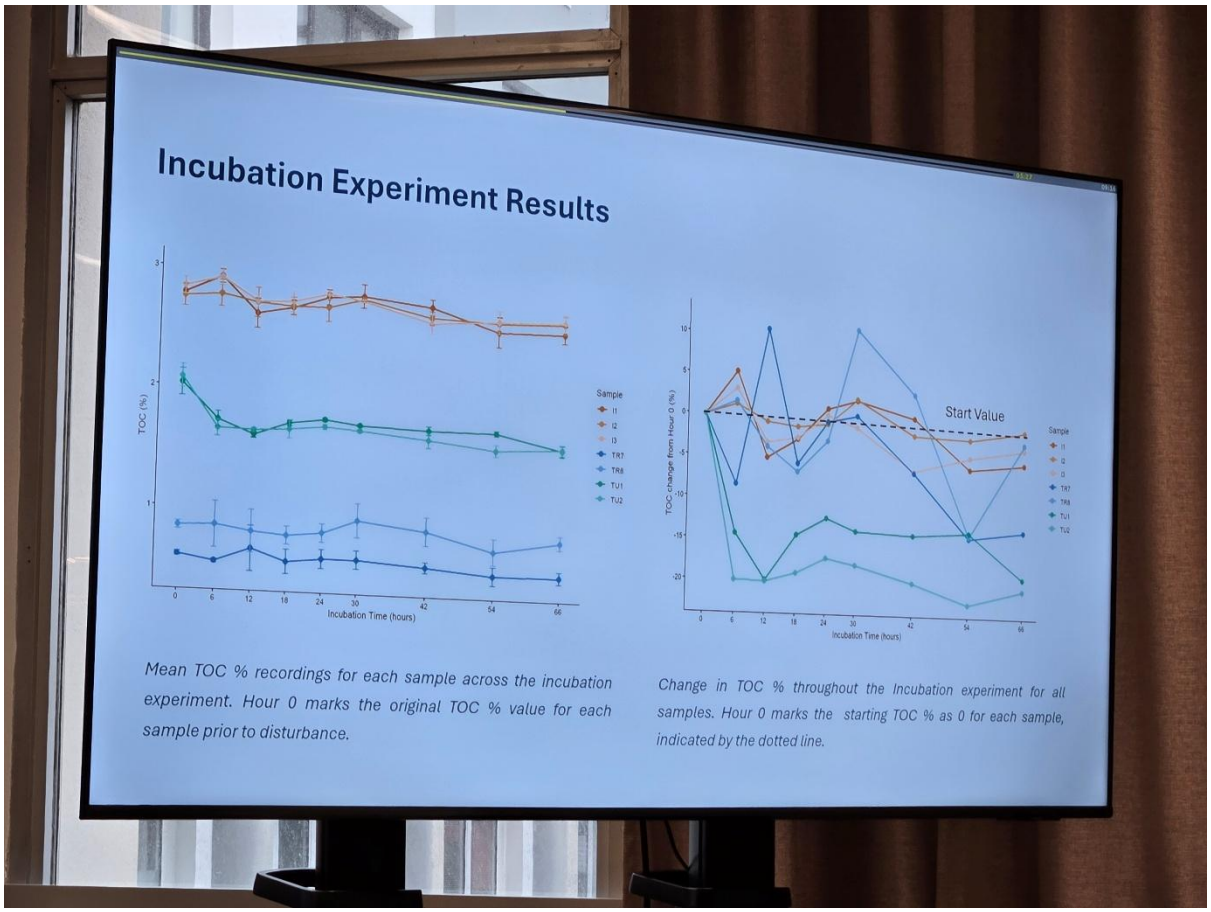
This study assesses the vulnerability of marine sedimentary OC to the pressures of bottom trawling in Scotland's coastal waters, with focus on the Firth of Clyde. This area has a rich trawling history which has led to the demise of white fish stocks and transition to predominantly *Nephrops* fisheries. Since *Nephrops* habit in muddy sediments which store greater quantities of labile OC, this study examines how carbon is 'lost' when resuspended. Using seabed samples collected from the Clyde, biogeochemical analysis is run in phase one of the study. From the sample set, an incubation experiment is devised in phase two, whereby samples are resuspended, mimicking the effects of disturbance and repeat disturbance on sedimentary OC. The experiment is guided by current fishing pressure using Vessel Monitoring Systems (VMS) and multibeam bathymetric data. This study evaluates benthic ecosystem functioning in a post-trawled environment in order to determine the vulnerability of the Clyde seabed to future disturbance.

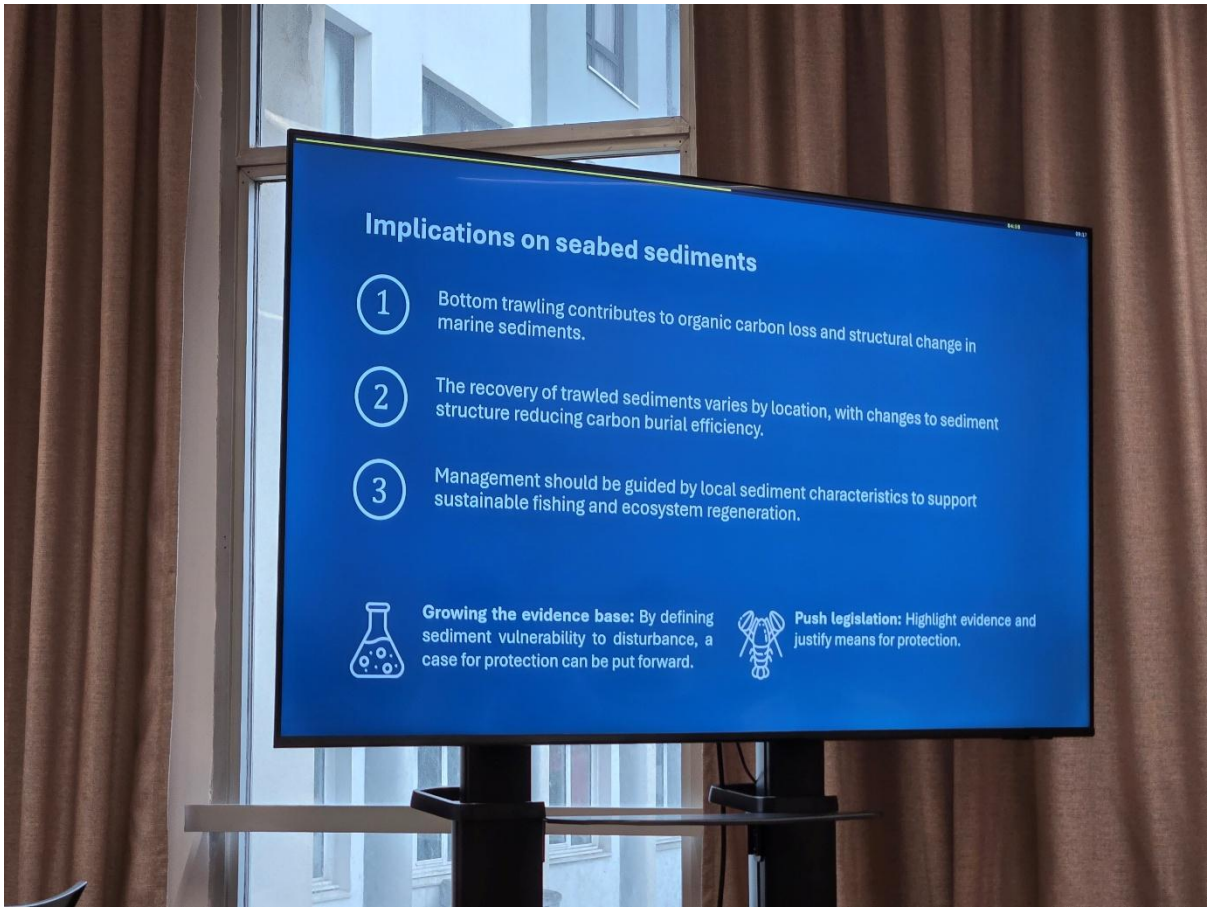
Understanding the long-term impacts of bottom trawling in the Firth of Clyde is critical in defining the vulnerability of sedimentary OC to mineralisation. By quantifying the effects of physical disturbance, this study utilises the scientific base necessary to inform the management and protection of the Clyde seabed. The decisions made in future research and policy planning are central to mitigating further ecological impacts in the Clyde, serving as an example which could be applied across British waters.

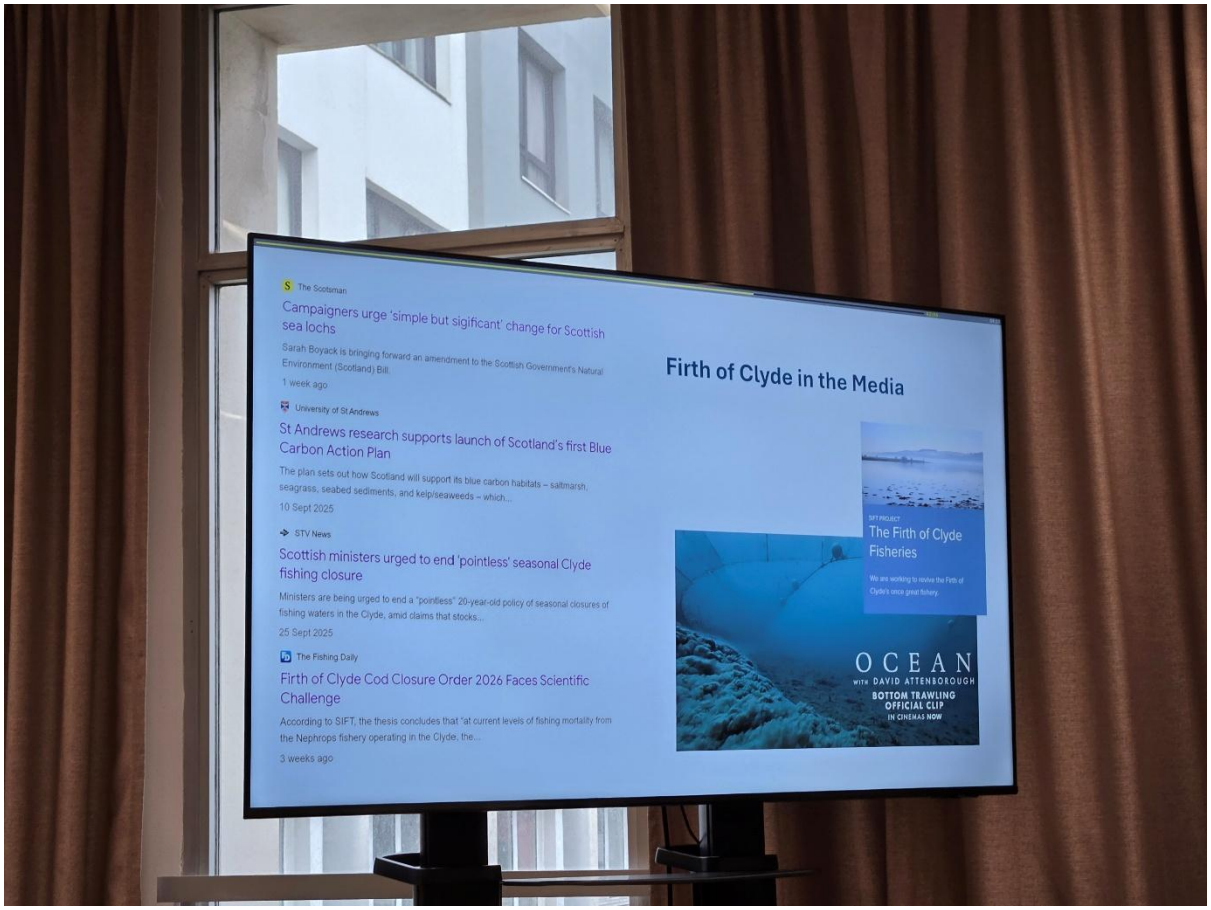

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University of St Andrews
FOUNDED 1413
Assessing the vulnerability of marine sedimentary organic carbon to the pressures of bottom trawling in Scotland's coastal waters
James Johnson, Professor William Austin, Dr Craig Smeaton

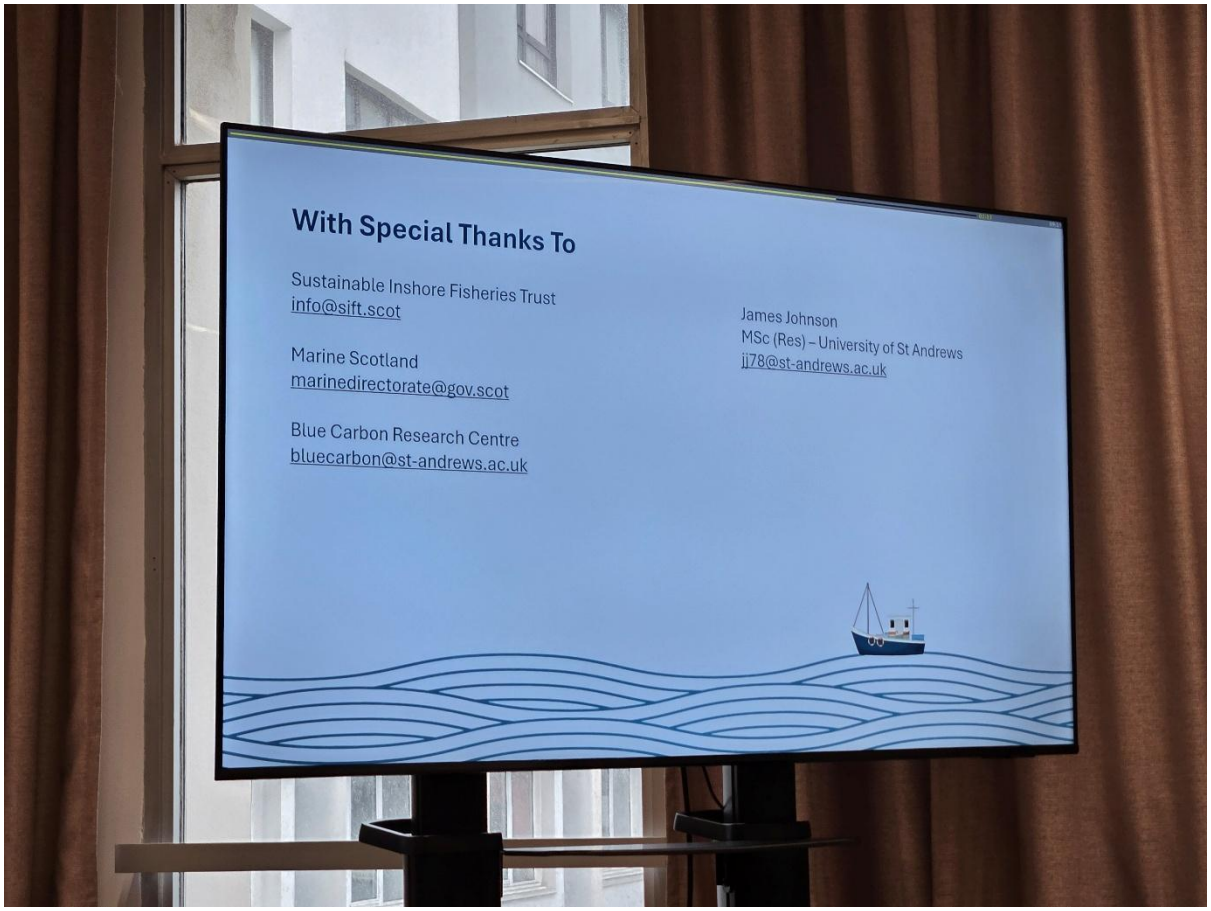

Firth of Clyde: A Historical Decline
Clyde historically known for its abundant fisheries
Industrialisation of fisheries lead to exploitation of fish stocks
Decline in white fish landings = Rise in Nephrops fisheries = Rise in demersal fishing
Impact on sedimentary carbon under researched
Landings (tonnes)
Year
Cod
Haddock
Hake
Plaice
Saithe
Whiting
Nephrops
Fish landings (Tonnes) from the Clyde since 1960. 3 nm Exclusion and inclusion years highlighted (Heath and Speirs, 2011).


Phase one
a
b
0
25
50km
Increasing Carbon Content
TOC %
R² value = 0.6787
Site
NCH
TROON
TURN
CRI
Increasing Reactivity
Relationship between TOC % and CRI across the dataset defined by site. Linear regression R² value = 0.6787, p <0.001. Samples Circled in green used for experiment.


Incubation Experiment Results
TOC (%)
Incubation Time (hours)
Sample
I1
I2
I3
TR7
TR8
TU1
TU2
Mean TOC % recordings for each sample across the incubation experiment. Hour 0 marks the original TOC % value for each sample prior to disturbance.
TOC change from Hour 0 (%)
Start Value
Incubation Time (hours)
Change in TOC % throughout the Incubation experiment for all samples. Hour 0 marks the starting TOC % as 0 for each sample, indicated by the dotted line.


Implications on seabed sediments
1
Bottom trawling contributes to organic carbon loss and structural change in marine sediments.
2
The recovery of trawled sediments varies by location, with changes to sediment structure reducing carbon burial efficiency.
3
Management should be guided by local sediment characteristics to support sustainable fishing and ecosystem regeneration.
Growing the evidence base: By defining sediment vulnerability to disturbance, a case for protection can be put forward.
Push legislation: Highlight evidence and justify means for protection.


The Scotsman
Campaigners urge 'simple but sigificant' change for Scottish sea lochs
Sarah Boyack is bringing forward an amendment to the Scottish Government's Natural Environment (Scotland) Bill.
1 week ago
University of St Andrews
St Andrews research supports launch of Scotland's first Blue Carbon Action Plan
The plan sets out how Scotland will support its blue carbon habitats – saltmarsh, seagrass, seabed sediments, and kelp/seaweeds – which...
10 Sept 2025
STV News
Scottish ministers urged to end 'pointless' seasonal Clyde fishing closure
Ministers are being urged to end a "pointless" 20-year-old policy of seasonal closures of fishing waters in the Clyde, amid claims that stocks...
25 Sept 2025
The Fishing Daily
Firth of Clyde Cod Closure Order 2026 Faces Scientific Challenge
According to SIFT, the thesis concludes that "at current levels of fishing mortality from the Nephrops fishery operating in the Clyde, the...
3 weeks ago
Firth of Clyde in the Media
SIFT PROJECT
The Firth of Clyde Fisheries
We are working to revive the Firth of Clyde's once great fishery.
OCEAN
WITH DAVID ATTENBOROUGH
BOTTOM TRAWLING
OFFICIAL CLIP
IN CINEMAS NOW


With Special Thanks To
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Ecological trajectories after 30 years of marine aggregates extraction: recovery or regime Shift?

Robert Alexandre

Marine aggregate extraction alters both the physical and biological characteristics of the seabed. Impacts occur directly, through sediment removal and destruction of benthic organisms, and indirectly, via changes in hydrodynamics caused by seabed deepening or the dispersion of turbid plumes during dredging. Beyond quantifying the initial disturbance, assessing the ecosystem's capacity for recovery is essential to understand the medium- and long-term persistence of extraction effects.

This study examines early recovery processes following the cessation of intensive dredging at a French extraction site. Located in the outer Loire estuary (Bay of Biscay), the 8.2 km^2 Le Pilier concession was exploited for 30 years and closed in 2017. Approximately 40 million m^3 of coarse sand were removed, creating a depression up to 8 m below the natural seabed.

A three-year survey (2020–2022) conducted within the RESISTE project, complemented by a 2017 regulatory survey, was used to analyse ecological trajectories of (i) sediment characteristics, (ii) macrobenthic species composition, and (iii) biological trait structure.

Five years after dredging ceased, the ecological state of the former extraction site remains markedly different from adjacent undisturbed areas. In the most exploited south-western sector, the deep pit likely traps fine particles from the Loire plume, leading to the temporary development of an *Abra alba* muddy habitat contrasting with surrounding sandy habitats dominated by *Spisula solida*. Species composition followed a diverging trajectory, increasingly differing from reference sites, while functional composition paradoxically appeared more similar. This suggests that the pit has shifted into a new ecological regime with its own dynamics, making full recovery sensu Holling (1973) unlikely.

On the pit slope, sediments remain dominated by mobile sands. Here, species composition converged toward reference conditions within five years, although functional differences persist. The presence of sand dunes near the western boundary of the concession may explain these discrepancies: cross-shore sediment transport from the continental shelf is trapped, generating large sand inputs and dune formation that migrates along the slope. Biological recovery in this area appears constrained by persistent sediment alterations and modified sediment dynamics induced by extraction, even after operations have ceased. Further monitoring will be required to confirm whether these trends persist over the longer term.





Assessing the compatibility of static gear fishing with biogenic reef conservation in a partially protected MPA

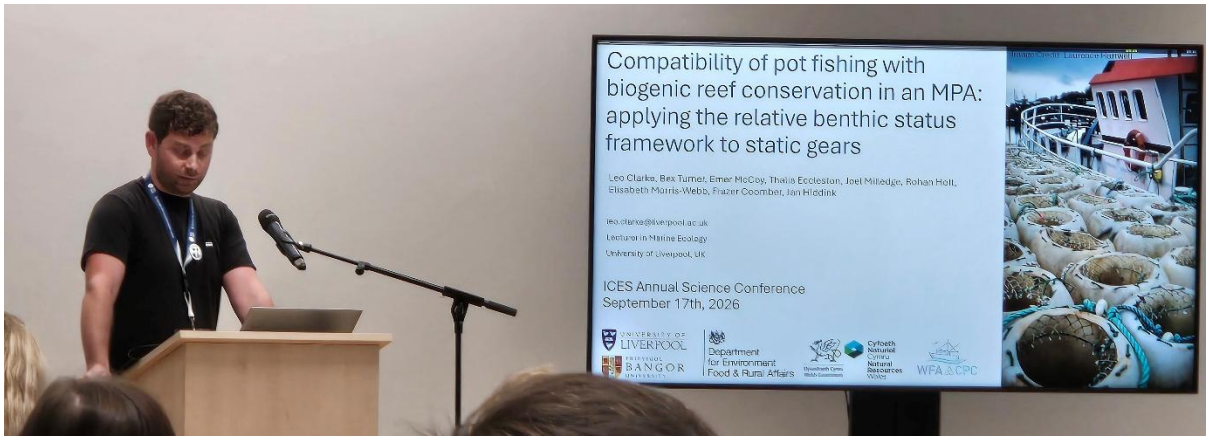
Leo Clarke

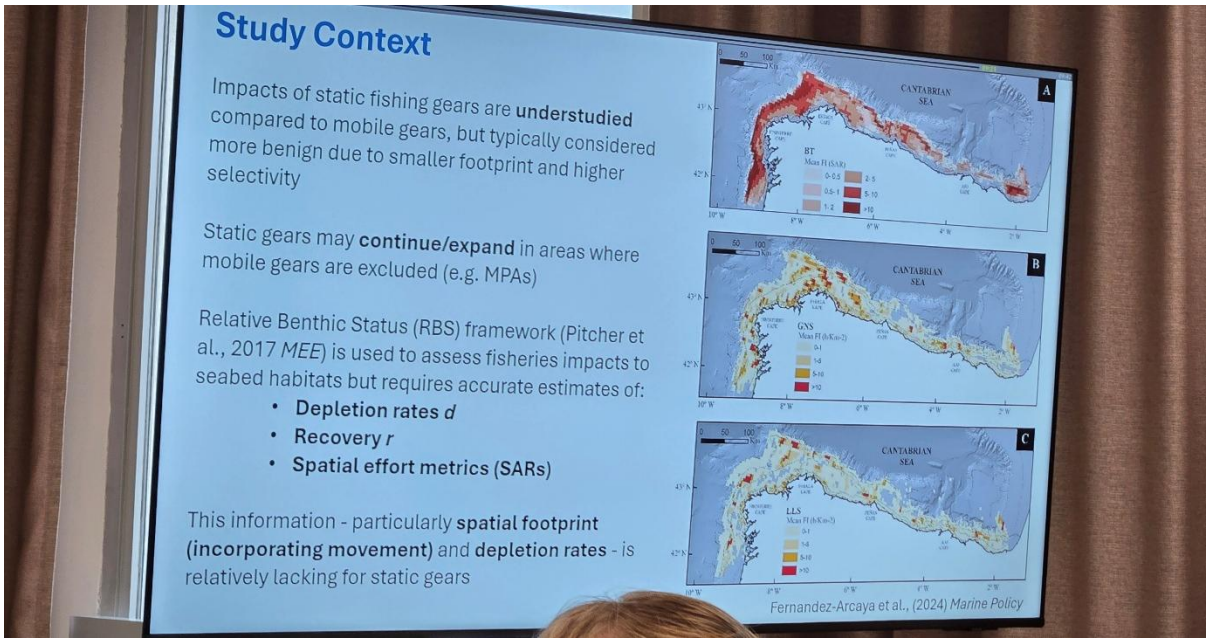
Marine protected areas (MPAs) are a widely used tool in an ecosystem-based approach to fisheries and marine conservation management, although many are only partially protected. MPA management typically excludes bottom-towed mobile fishing gears and allows the continued use of static gears. These are generally considered to be relatively benign and are expanding. Yet the impacts of static gears to seabed habitats remain understudied and our understanding of their impacts is limited to few studies on temperate rocky reefs, which suggest potential impacts to sensitive taxa through gear movement.

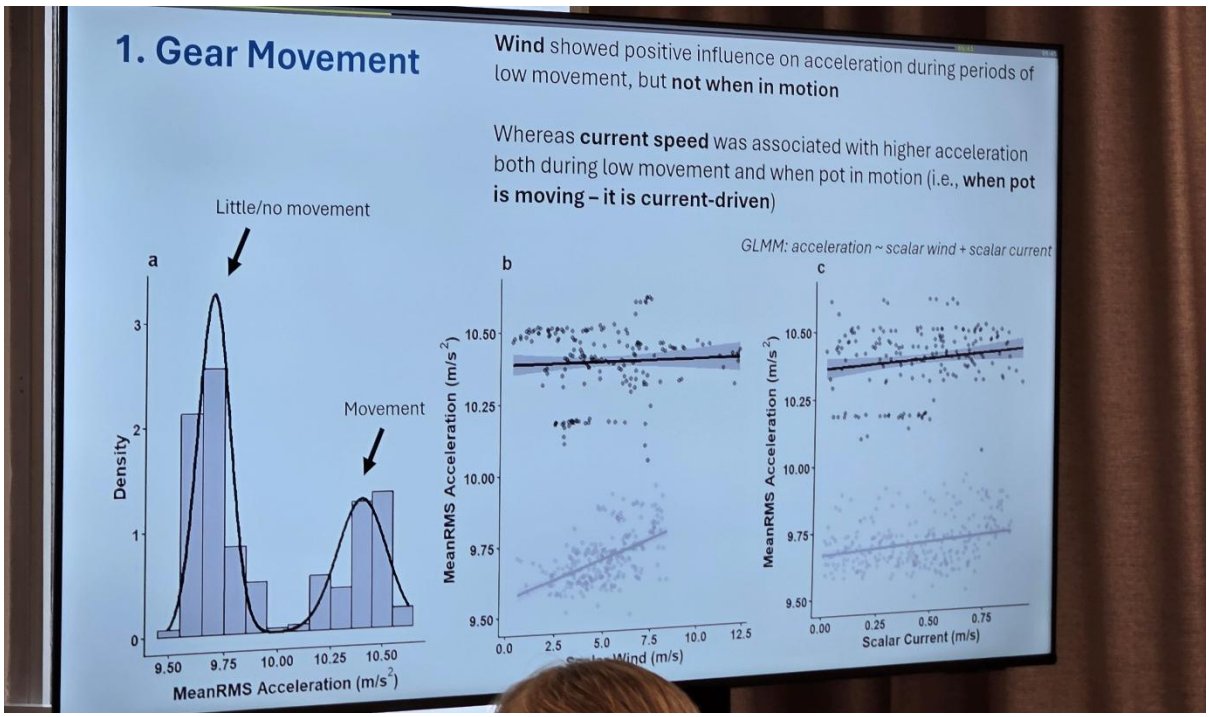
We used a novel application of accelerometry and acoustic telemetry to assess the magnitude and drivers of pot movement in a common whelk fishery operating on biogenic horse mussel (*Modiolus modiolus*) reef. Pot movement was primarily driven by current speed, which strongly influenced the area of seabed covered by a single pot in a typical 24 h fishing period, particularly in current speeds above ~ 0.5 m/s.

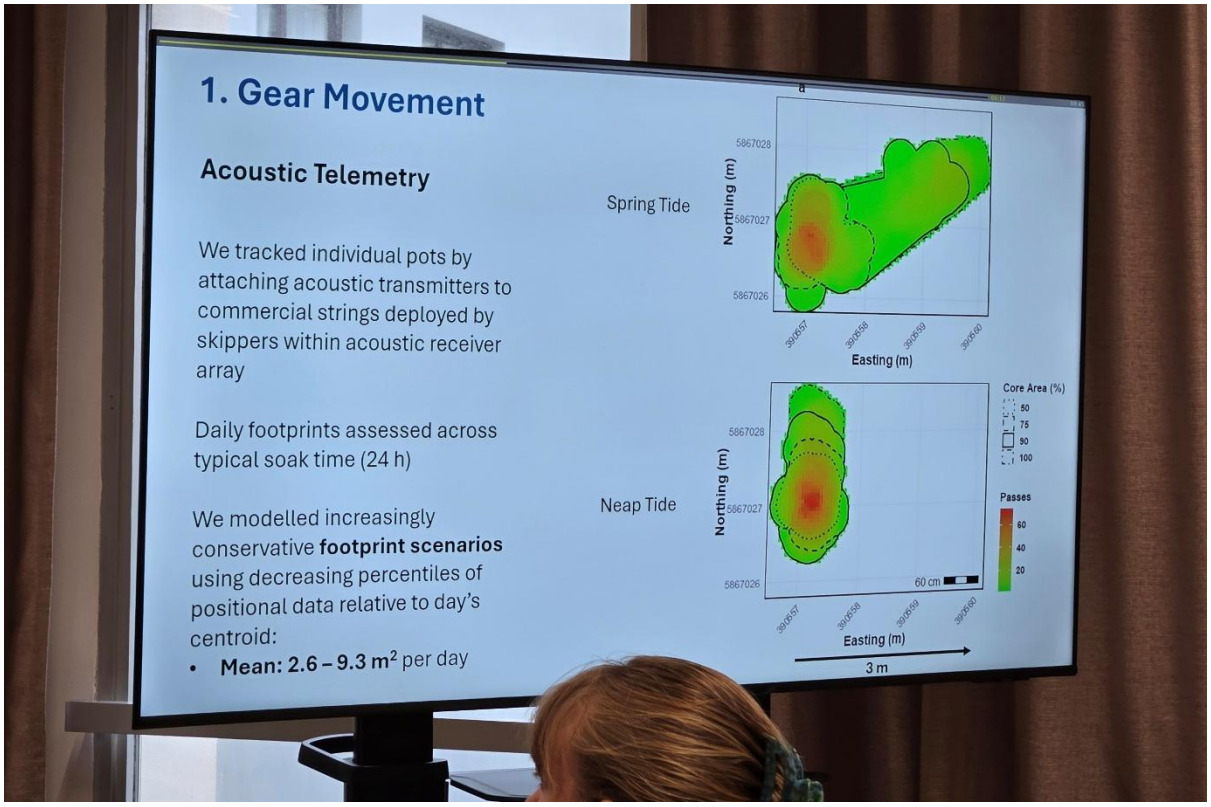
A control-impact study revealed immediate localised depletion of the soft coral *Alcyonium digitatum*, squat lobsters, hermit crabs, the brittle star *Ophiothrix fragilis*, and overall abundance, within the footprint of pot contact with the seabed. We found no similar trend in species densities in relation to chronic potting effort at the reef scale, however, although taxonomic richness and overall abundance were lower in areas of higher potting densities.

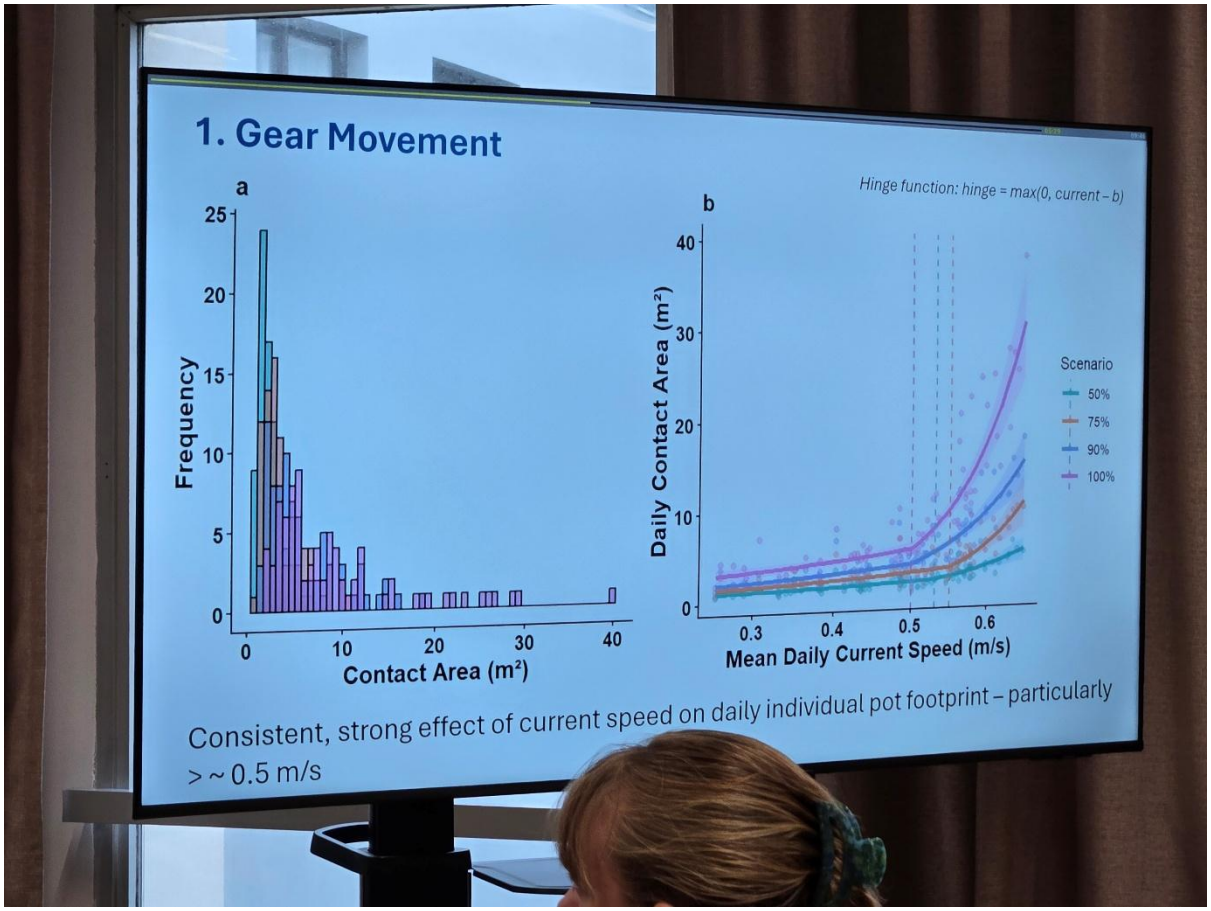
Our results indicate that environmental factors strongly influence the movement of static whelk fishing gear and that this movement may result in localised depletions of sensitive reef epifauna within the potting footprint. However, we found no detectable impacts of the fishery at the reef scale.

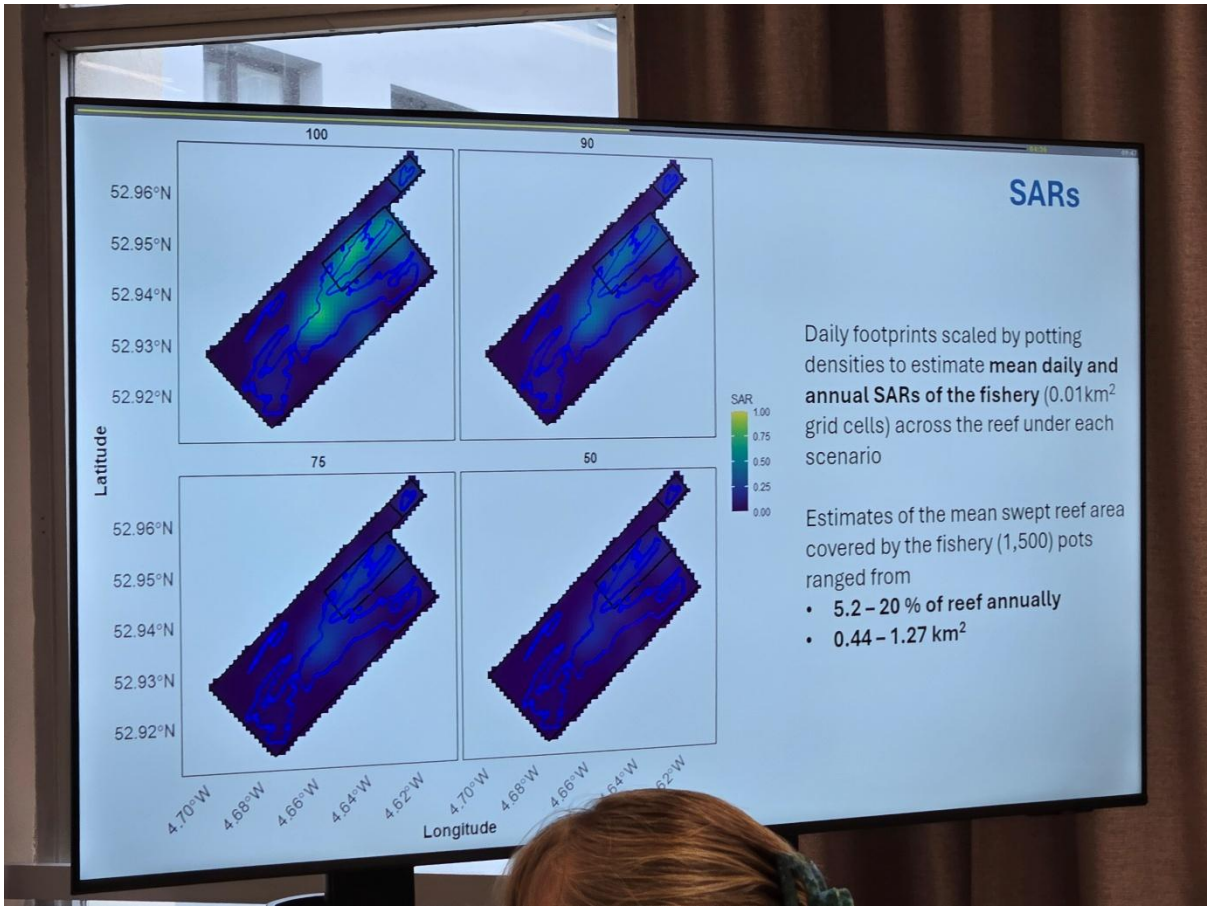

Compatibility of pot fishing with biogenic reef conservation in an MPA: applying the relative benthic status framework to static gears
Leo Clarke, Bex Turner, Emer McCoy, Thalia Eccleston, Joel Milledge, Rohan Holt, Elisabeth Morris-Webb, Frazer Coomber, Jan Hiddink
leo.clarke@liverpool.ac.uk
Lecturer in Marine Ecology
University of Liverpool, UK
ICES Annual Science Conference
September 17th, 2026
Department for Environment Food & Rural Affairs


Study Context
Impacts of static fishing gears are understudied compared to mobile gears, but typically considered more benign due to smaller footprint and higher selectivity
Static gears may continue/expand in areas where mobile gears are excluded (e.g. MPAs)
Relative Benthic Status (RBS) framework (Pitcher et al., 2017 MEE) is used to assess fisheries impacts to seabed habitats but requires accurate estimates of:
Depletion rates d
Recovery r
Spatial effort metrics (SARs)
This information - particularly spatial footprint (incorporating movement) and depletion rates - is relatively lacking for static gears
CANTABRIAN SEA
A
B
C
Fernandez-Arcaya et al., (2024) Marine Policy

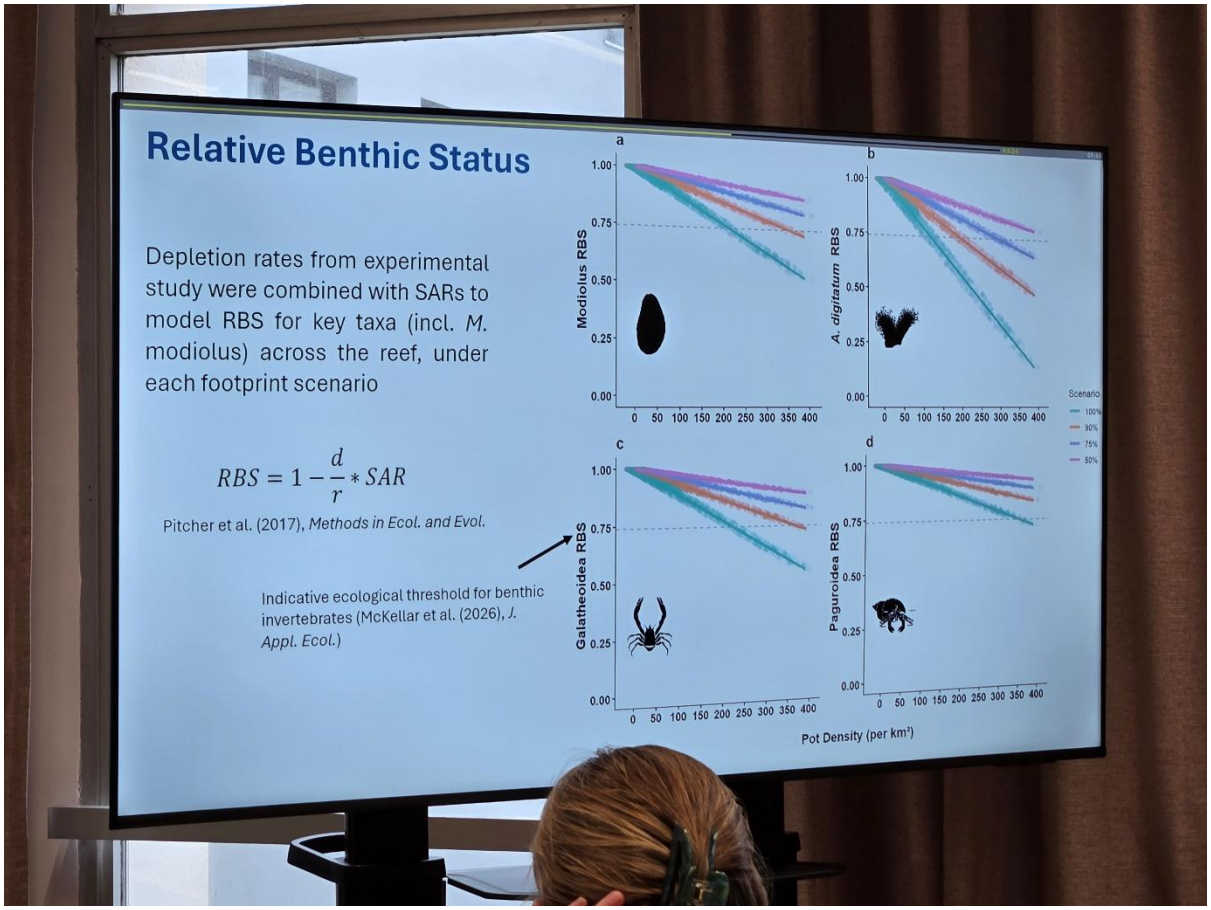

1. Gear Movement
Wind showed positive influence on acceleration during periods of low movement, but not when in motion
Whereas current speed was associated with higher acceleration both during low movement and when pot in motion (i.e., when pot is moving – it is current-driven)
GLMM: acceleration ~ scalar wind + scalar current
Little/no movement
Movement
a
b
c
Density
MeanRMS Acceleration (m/s²)
Scalar Current (m/s)

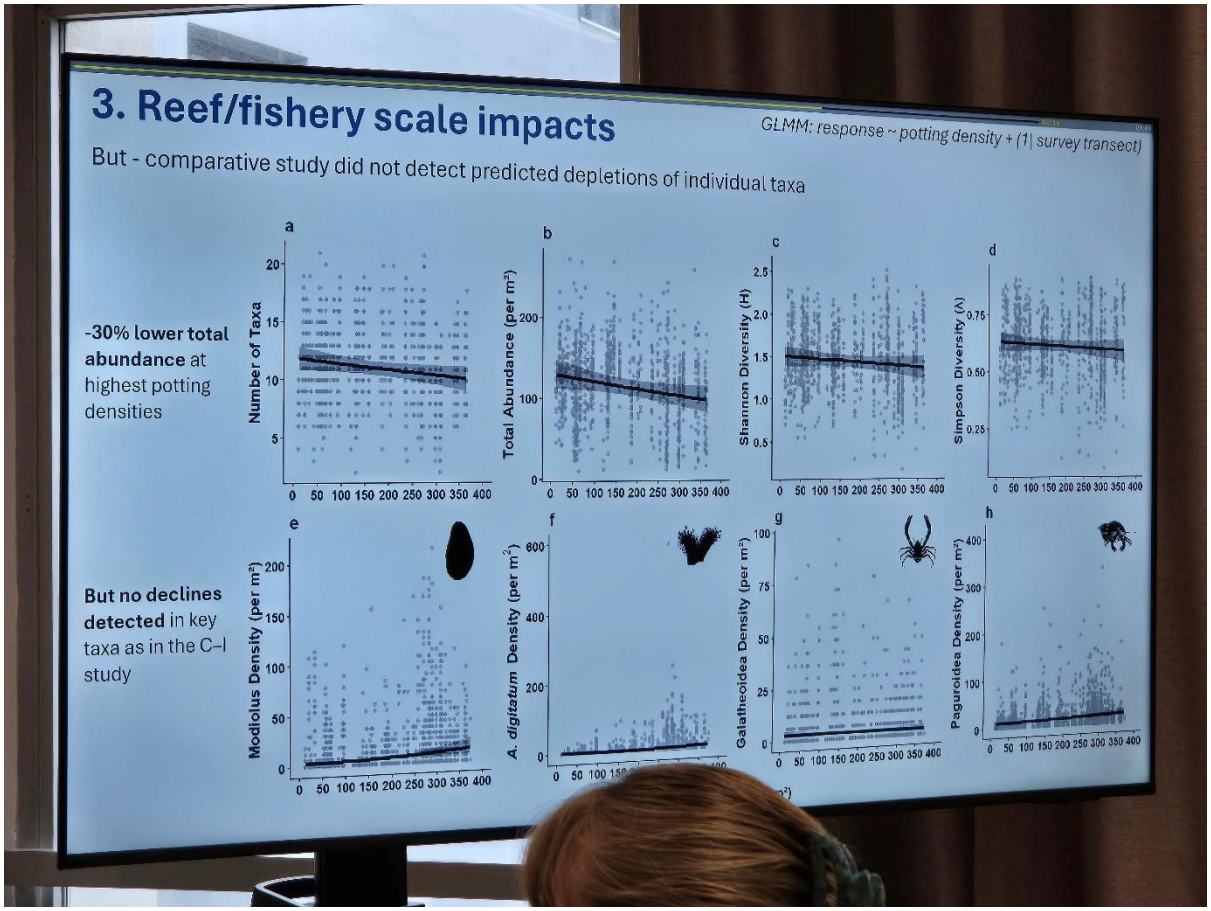

1. Gear Movement
Acoustic Telemetry
We tracked individual pots by attaching acoustic transmitters to commercial strings deployed by skippers within acoustic receiver array
Daily footprints assessed across typical soak time (24 h)
We modelled increasingly conservative footprint scenarios using decreasing percentiles of positional data relative to day's centroid:
Mean: 2.6 – 9.3 m² per day
Spring Tide
Neap Tide
Northing (m)
Easting (m)
Core Area (%)
Passes
60 cm
3 m

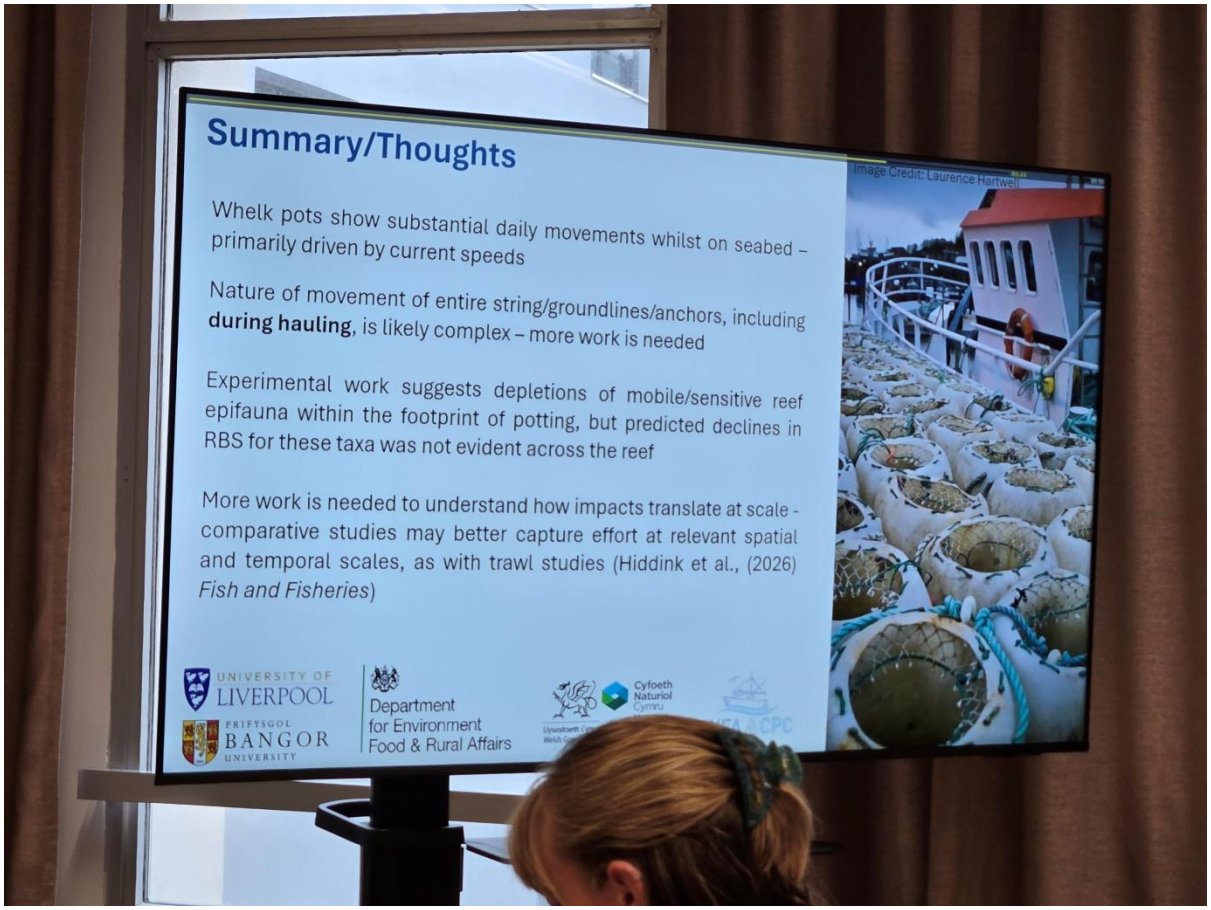

1. Gear Movement
Hinge function: hinge = max(0, current – b)
Frequency
Contact Area (m²)
Daily Contact Area (m²)
Mean Daily Current Speed (m/s)
Scenario
50%
75%
90%
100%
Consistent, strong effect of current speed on daily individual pot footprint – particularly > ~ 0.5 m/s


SARs
100
90
75
50
52.96°N
52.95°N
52.94°N
52.93°N
52.92°N
Latitude
4.70°W
4.68°W
4.66°W
4.64°W
4.62°W
Longitude
SAR
1.00
0.75
0.50
0.25
0.00
Daily footprints scaled by potting densities to estimate **mean daily and annual SARs of the fishery** (0.01km² grid cells) across the reef under each scenario
Estimates of the mean swept reef area covered by the fishery (1,500) pots ranged from
• **5.2 – 20 % of reef annually**
• **0.44 – 1.27 km²**


2. Point-scale depletions of reef biota
Control-Impact study indicated lower (**-27%**) total abundance of reef biota within footprint of potting, mostly characterised by mobile and soft-bodied sessile species:
• *Alcyonium digitatum* – **40%**
• Galatheoidea – **31%**
• Paguroidea – **40%**
• *Ophiothrix fragilis* – **62%**
Image Credit: NRW
Alcyonium digitatum
Anomiidae
Cellepora pumicosa
Galatheoidea
Modiolus modiolus
Ophiothrix fragilis
Paguroidea
Density (per m²)
C
I
GLMM: response ~ treatment + (1| deployment)


Relative Benthic Status
Depletion rates from experimental study were combined with SARs to model RBS for key taxa (incl. M. modiolus) across the reef, under each footprint scenario
$RBS = 1 - \frac{d}{r} * SAR$
Pitcher et al. (2017), Methods in Ecol. and Evol.
Indicative ecological threshold for benthic invertebrates (McKellar et al. (2026), J. Appl. Ecol.)
a
b
c
d
Modiolus RBS
A. digitatum RBS
Galatheoidea RBS
Paguroidea RBS
Scenario
100%
90%
75%
60%
Pot Density (per km²)

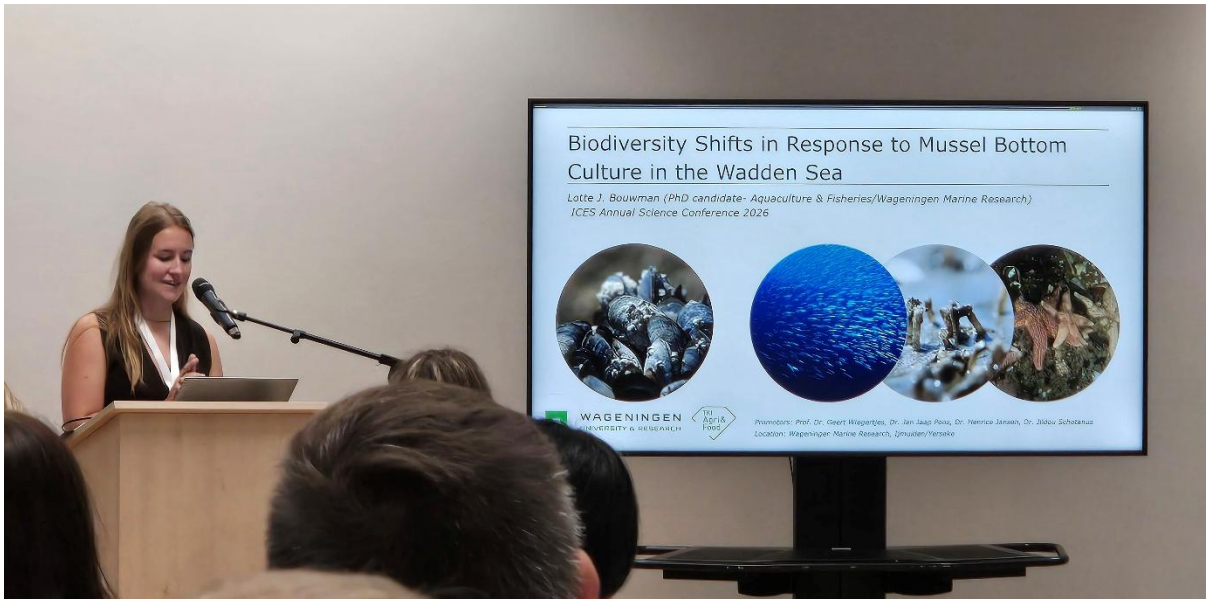

3. Reef/fishery scale impacts
GLMM: response ~ potting density + (1| survey transect)
But - comparative study did not detect predicted depletions of individual taxa
-30% lower total abundance at highest potting densities
But no declines detected in key taxa as in the C–I study
a
b
c
d
e
f
g
h
Number of Taxa
Total Abundance (per m²)
Shannon Diversity (H)
Simpson Diversity (λ)
Modiolus Density (per m²)
A. digitatum Density (per m²)
Galatheoidea Density (per m²)
Paguroidea Density (per m²)

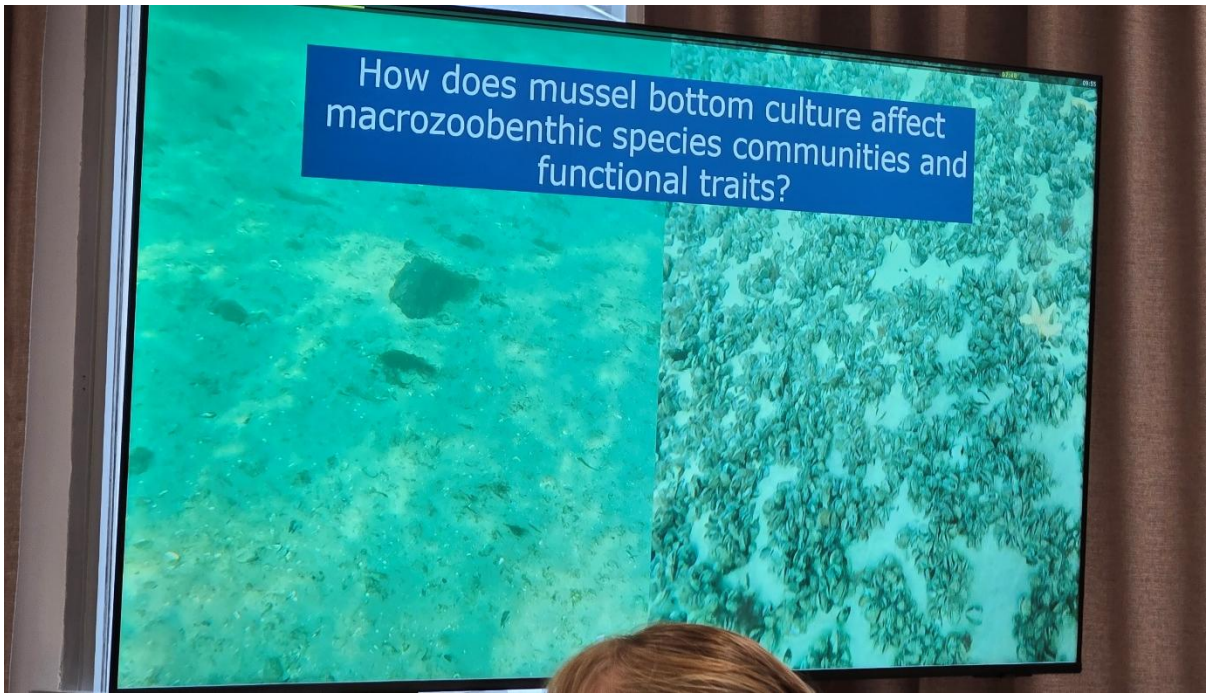

Summary/Thoughts
Whelk pots show substantial daily movements whilst on seabed – primarily driven by current speeds
Nature of movement of entire string/groundlines/anchors, including **during hauling**, is likely complex – more work is needed
Experimental work suggests depletions of mobile/sensitive reef epifauna within the footprint of potting, but predicted declines in RBS for these taxa was not evident across the reef
More work is needed to understand how impacts translate at scale - comparative studies may better capture effort at relevant spatial and temporal scales, as with trawl studies (Hiddink et al., (2026) *Fish and Fisheries*)
Image Credit: Laurence Hartwell
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PRIFYSGOL BANGOR UNIVERSITY
Department for Environment Food & Rural Affairs
Cyfoeth Naturiol Cymru

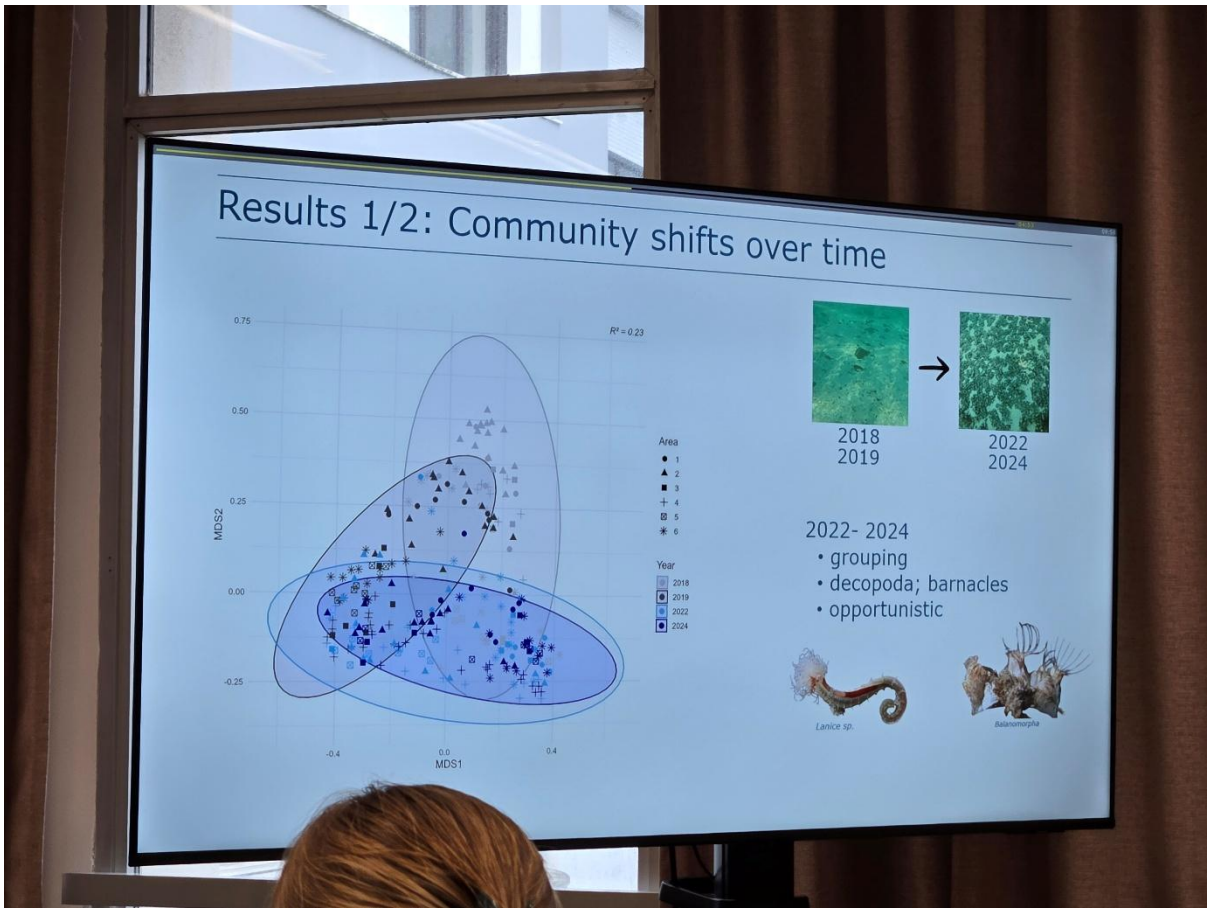

Thank you for listening
Dr Leo Clarke
leo.clarke@liverpool.ac.uk
Lecturer in Marine Ecology
University of Liverpool, UK
Image Credit: Laurence Hartwell
UNIVERSITY OF LIVERPOOL
PRIFYSGOL BANGOR UNIVERSITY
Department for Environment Food & Rural Affairs

Shifts in Biodiversity in Response to Mussel Bottom Culture in the Wadden Sea
Lotte Bouwman

Wild mussels are key ecosystem engineers, forming complex biogenic habitats that support diverse marine communities. Although mussel culture plots share many structural similarities with natural mussel beds, the extent to which mussel aquaculture influences biodiversity remains largely unknown. Dutch mussel culture, occurring in the Western Wadden Sea and Oosterschelde Estuary, covers 11,500 ha of designated plots alongside wild bivalve beds of similar scale. During the 2021 optimisation of mussel plots, we conducted a unique before-and-after study across six newly designated blocks. A longitudinal sampling campaign monitored changes in infauna and epifauna, providing insights into the facilitative role of mussel plots for (associated) macrozoobenthos. Here, we present findings on benthic community development on the newly established plots. Using biodiversity indices and functional trait approaches, we examine community structure, ecological functioning, and temporal dynamics. This large-scale monitoring illuminates ecological succession and species establishment, offering guidance for sustainable management of aquaculture impacts in Dutch waters.



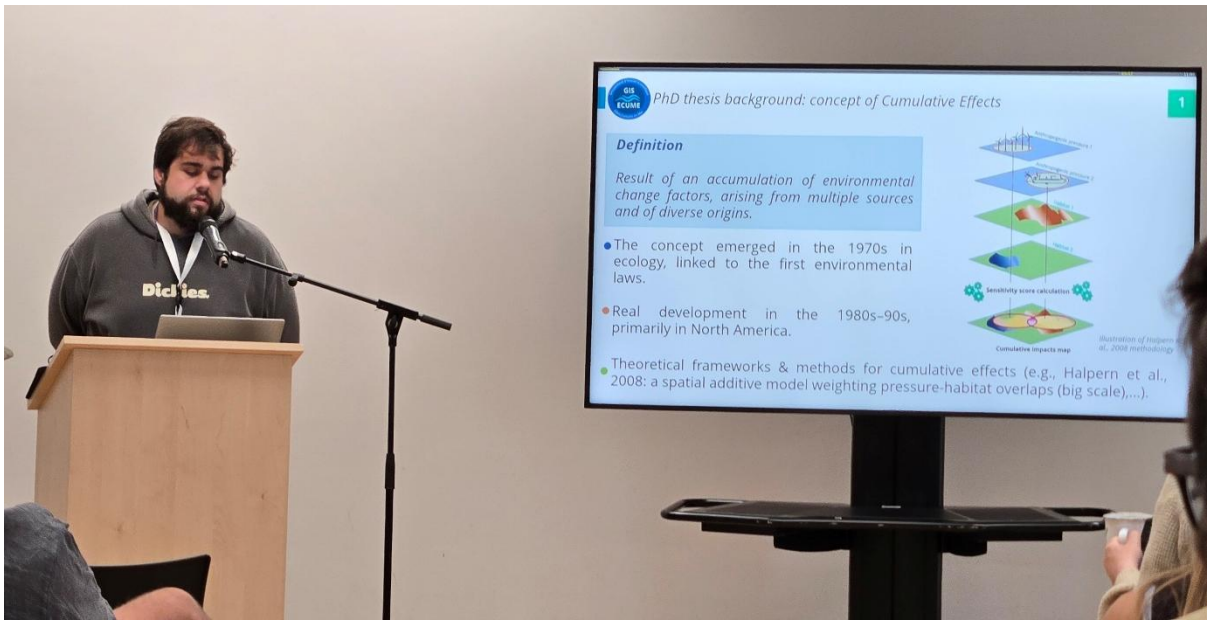


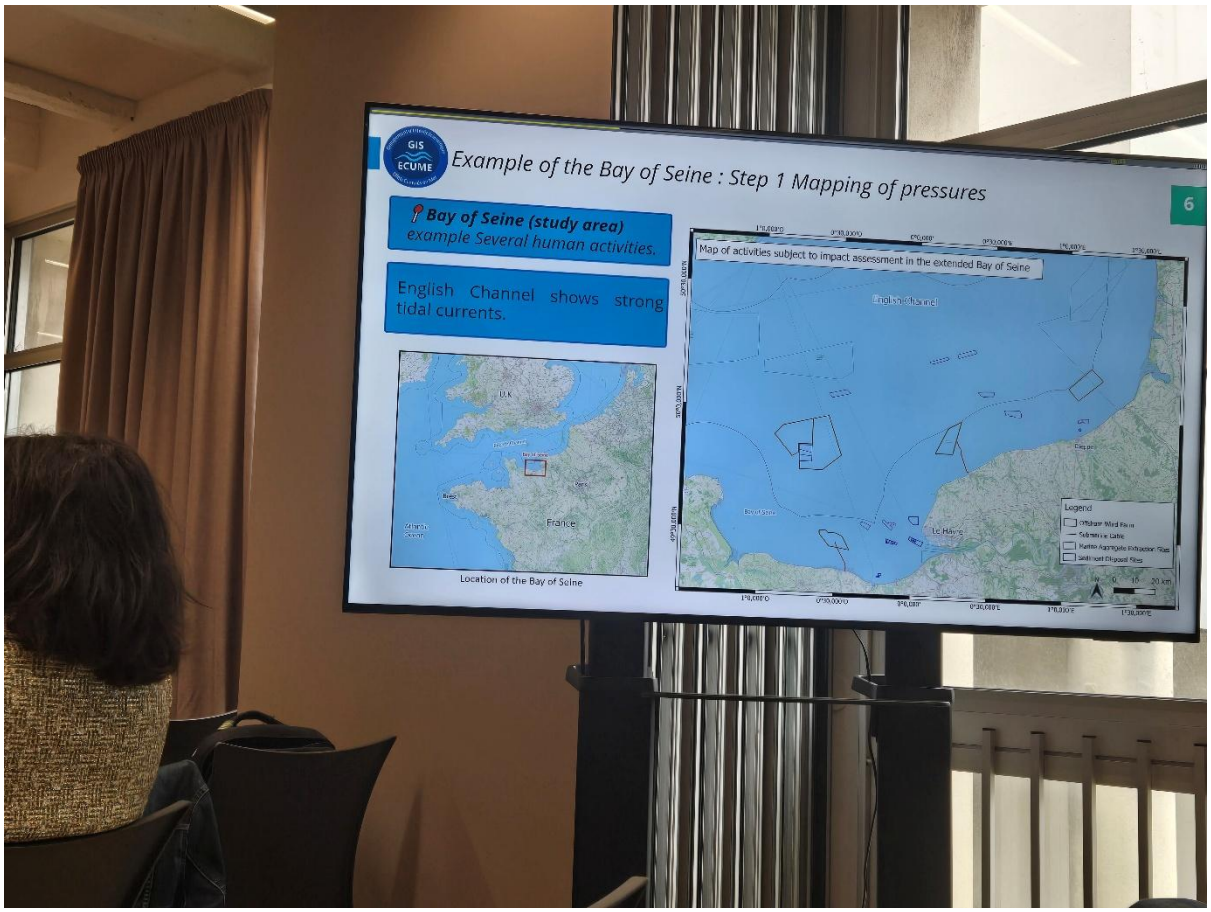


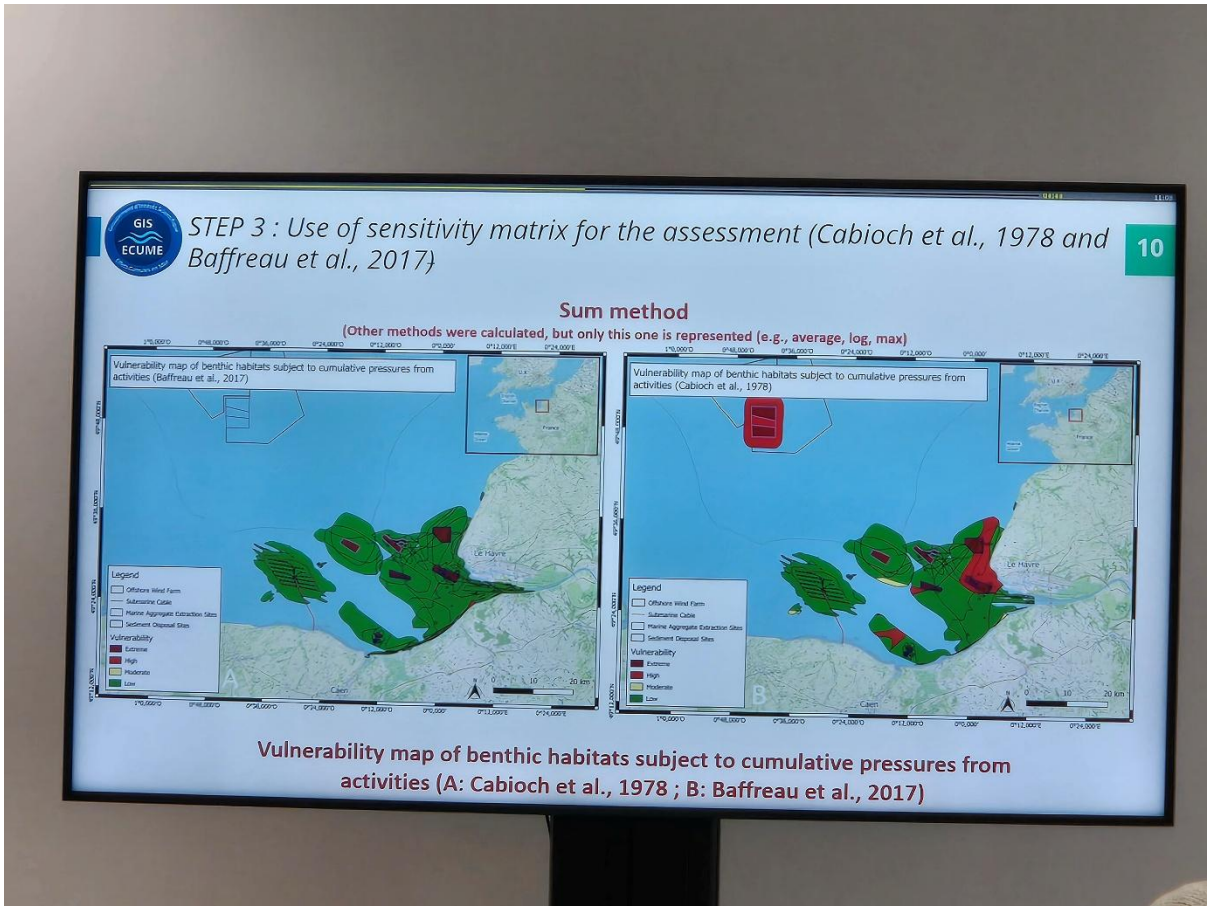
Methodological and operational approaches to assess the cumulative effects of human activities at sea
Simon POLICE

The English Channel–North Sea (ECNS) facade is one of the most anthropized maritime zones in the world, with diverse human activities such as fishing, marine aggregate extraction, submarine cables, port dredging, disposal of dredged materials, and recently offshore wind farms. This growth of uses raises the question of cumulative effects as several drivers of change can interact with each other with concomitant impacts on ecosystem functioning.
The concept of cumulative effects, linked to the accumulation of multiple drivers of change, is used in many scientific fields and was introduced in ecology in North America in the 1990s. European scientists took up the topic later, particularly in connection with the European Marine Strategy Framework Directive and the recognition of the need for an integrated, ecosystem-based approach. In France, article R122-5 of the Environmental Code specifies that Environmental Impact Assessment (EIA) studies must address the “cumulation of impacts with other existing or approved projects”. Within the context of this legislative framework, all project leaders subject to EIA face the shared challenge of developing a shared methodology to build the “cumulative effects” chapter of EIA studies. On the ECNS facade, marine project leaders have combined their knowledge and expertise with the Universities of Caen, Rouen and Le Havre within the Scientific Interest Group “Cumulative Effects at Sea” (GIS ECUME), a public-private consortium, with the development of a methodology for cumulative effect assessment being one of the group’s core research lines
This study aims to develop an operational methodology for industrial actors, to assess cumulative effects of human activities in coastal environments. Its first focus consists of mapping the maximum extent of physical effects (e.g. morphology and seabed substrate modification, hydrodynamic change, turbidity, …) of each activity using EIA data. It subsequently

aims to visualize and identify benthic habitats at stake in the eastern part of the Seine Bay using benthic habitats maps and sensitivity matrices (MarESA and MNHN) adapted to local environmental conditions. Overlaying maps of cumulative effects on the physical environment with the spatially distributed sensitivity levels of habitats allows for the qualification and quantification of cumulative effects at the project scale. An application is proposed in the Seine Bay where marine aggregate extraction, disposal of dredged materials, submarine cables and offshore wind farms take place.





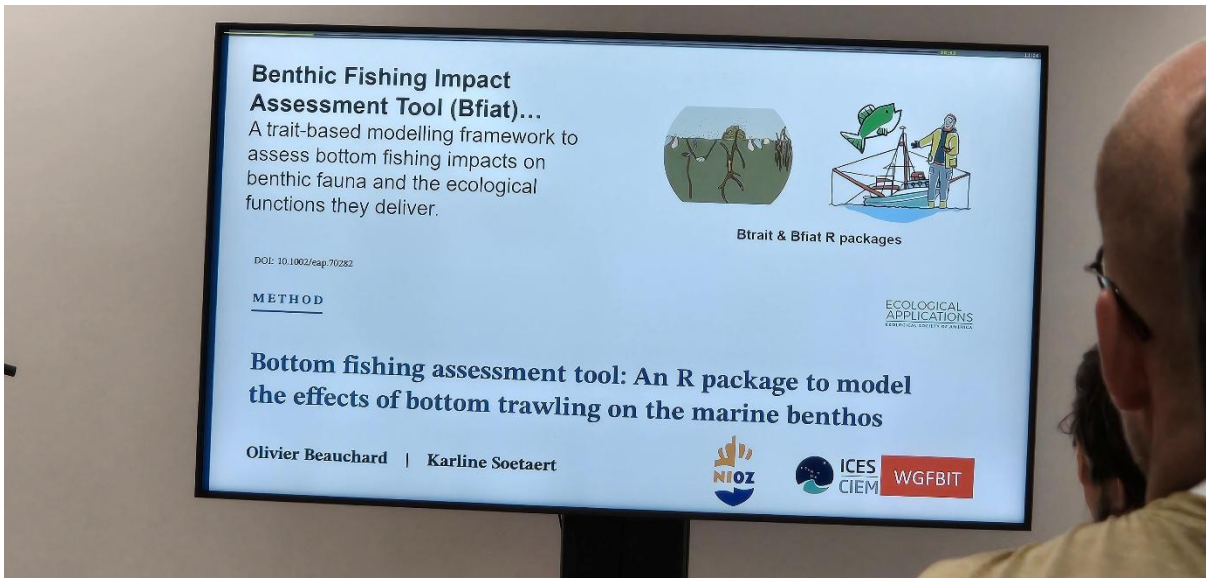


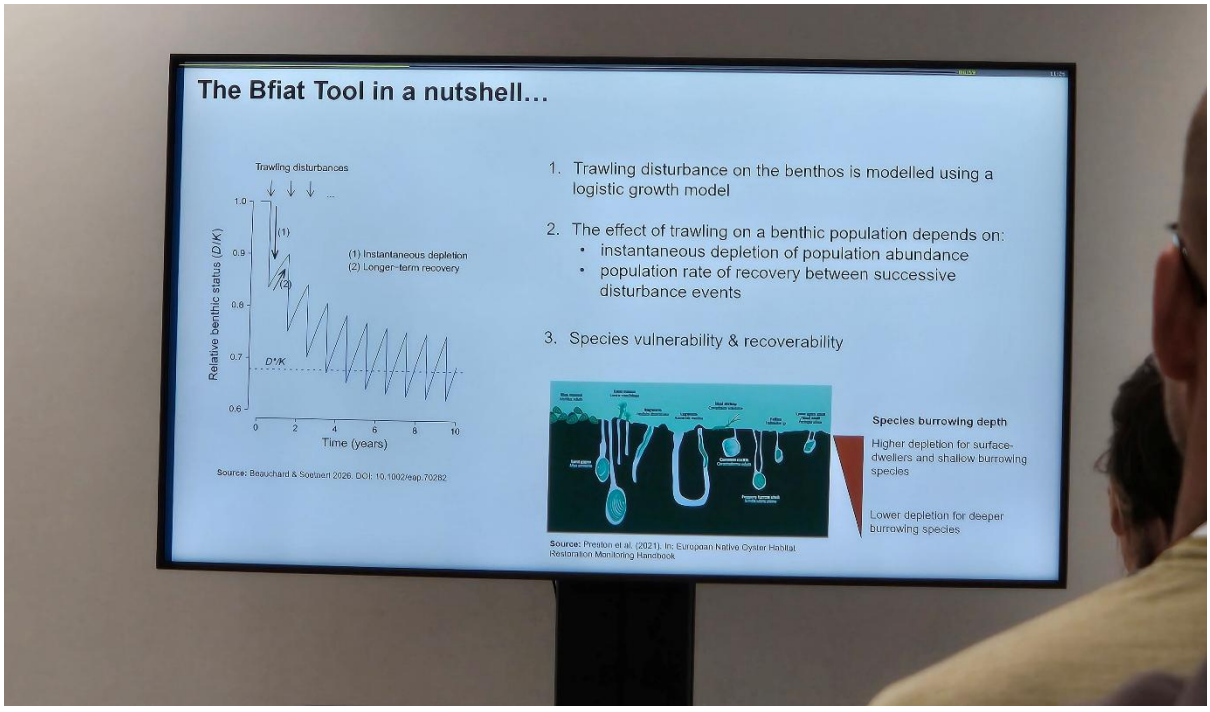
A trait-based modelling assessment of bottom fishing impacts and functional recovery in European shelf-sea benthic ecosystems

Marija Sciberras

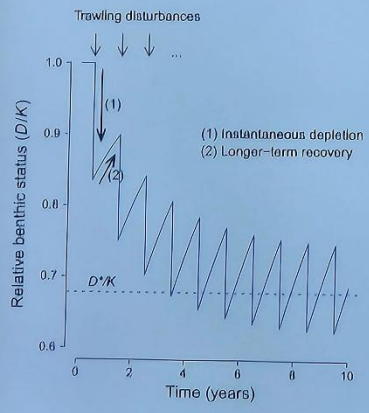
Growing awareness of the environmental impacts of bottom fishing has led to increasing demand for comprehensive assessments of its spatial extent and ecological consequences. We applied the Benthic Fishing Impact Assessment Tool (Bfiat), a deterministic trait-based modelling framework, to quantify how fishing intensity, sediment type, and species life-history traits interact to shape benthic community state and ecosystem functioning. Using macrofaunal data from 234 stations across seven European shelf-sea case studies, characterized by different fishing intensity and habitat type, we predicted the Relative Benthic State (RBS) and recovery trajectories of benthic communities. Response was assessed across key functional groups (suspension and deposit feeders) and processes, namely bioturbation and bioirrigation, which play central roles in regulating sediment organic matter cycling. Impacts varied strongly among case-studies and habitats. The most degraded benthic states (RBS < 0.75) occurred in locations exposed to high fishing intensity (mean SAR 7–14 yr^{-1}) and communities dominated by surface-dwelling or shallow-burrowing (0-5 cm). In contrast, communities dominated by early-maturing or deep-burrowing species exhibited greater resistance and faster recovery, even under moderate fishing pressure. Functional declines mirrored structural changes, with suspension feeders and bioturbation potential showing marked reductions in heavily fished muddy areas, indicating impaired sediment mixing and bentho-pelagic coupling. There are also potential, but yet undetermined implications for nutrient cycling and carbon storage. Recovery times ranged from 3–4 years in lightly impacted systems to 6–8 years in heavily disturbed muddy habitats, with recovery in sand generally faster and less sensitive to fishing intensity. This study demonstrates how functional indicators can be incorporated alongside structural metrics to provide a more comprehensive assessment of faunal seabed condition and supports habitat-specific, risk-based management of demersal fisheries.


Trait-based modelling assessment of bottom fishing impacts and functional recovery in European shelf-sea benthic ecosystems
Marija Sciberras, Olivier Beauchard, Mats Blomqvist, Stefan Bolam, Clare Bradshaw, Clement Garcia, Anna Grunder, Pascal Laffargue, Ruth Parker, Nadia Papadopoulou, Christopher Smith, Irini Tsikopoulou, Karline Soetaert
HERIOT WATT
Cefas
hcmr
Stockholm University
the Lyell centre
NIOZ
Ifremer
ICES CIEM
WGFBIT


Benthic Fishing Impact Assessment Tool (Bfiat)…
A trait-based modelling framework to assess bottom fishing impacts on benthic fauna and the ecological functions they deliver.
Btrait & Bfiat R packages
DOI: 10.1002/eap.70282
METHOD
ECOLOGICAL APPLICATIONS
Bottom fishing assessment tool: An R package to model the effects of bottom trawling on the marine benthos
Olivier Beauchard | Karline Soetaert
NIOZ
ICES CIEM
WGFBIT

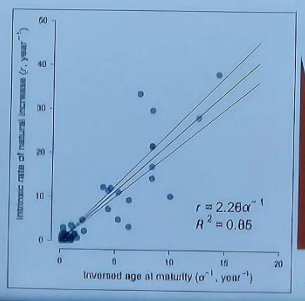

The Bfiat Tool in a nutshell…
Trawling disturbances
Relative benthic status (D/K)
(1) Instantaneous depletion
(2) Longer-term recovery
D*/K
Time (years)
Source: Beauchard & Soetaert 2026. DOI: 10.1002/eap.70282
1. Trawling disturbance on the benthos is modelled using a logistic growth model
2. The effect of trawling on a benthic population depends on:
• instantaneous depletion of population abundance
• population rate of recovery between successive disturbance events
3. Species vulnerability & recoverability
Species burrowing depth
Higher depletion for surface-dwellers and shallow burrowing species
Lower depletion for deeper burrowing species
Source: Preston et al. (2021). In: European Native Oyster Habitat Restoration Monitoring Handbook

The Bfiat Tool in a nutshell…



Source: Beauchard & Soetaert 2026. DOI: 10.1002/eap.70282

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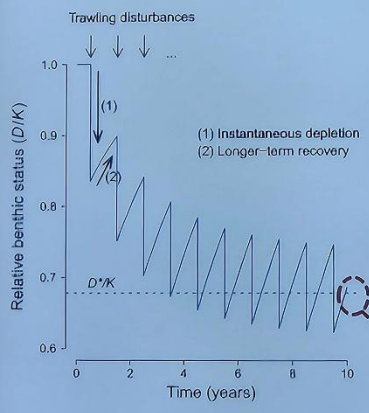


Rate of natural increase

Late-maturing species have lower intrinsic rate of natural increase and take longer to recover from fishing disturbance.

Source: Beauchard & Soetaert 2026. DOI: 10.1002/eap.70282

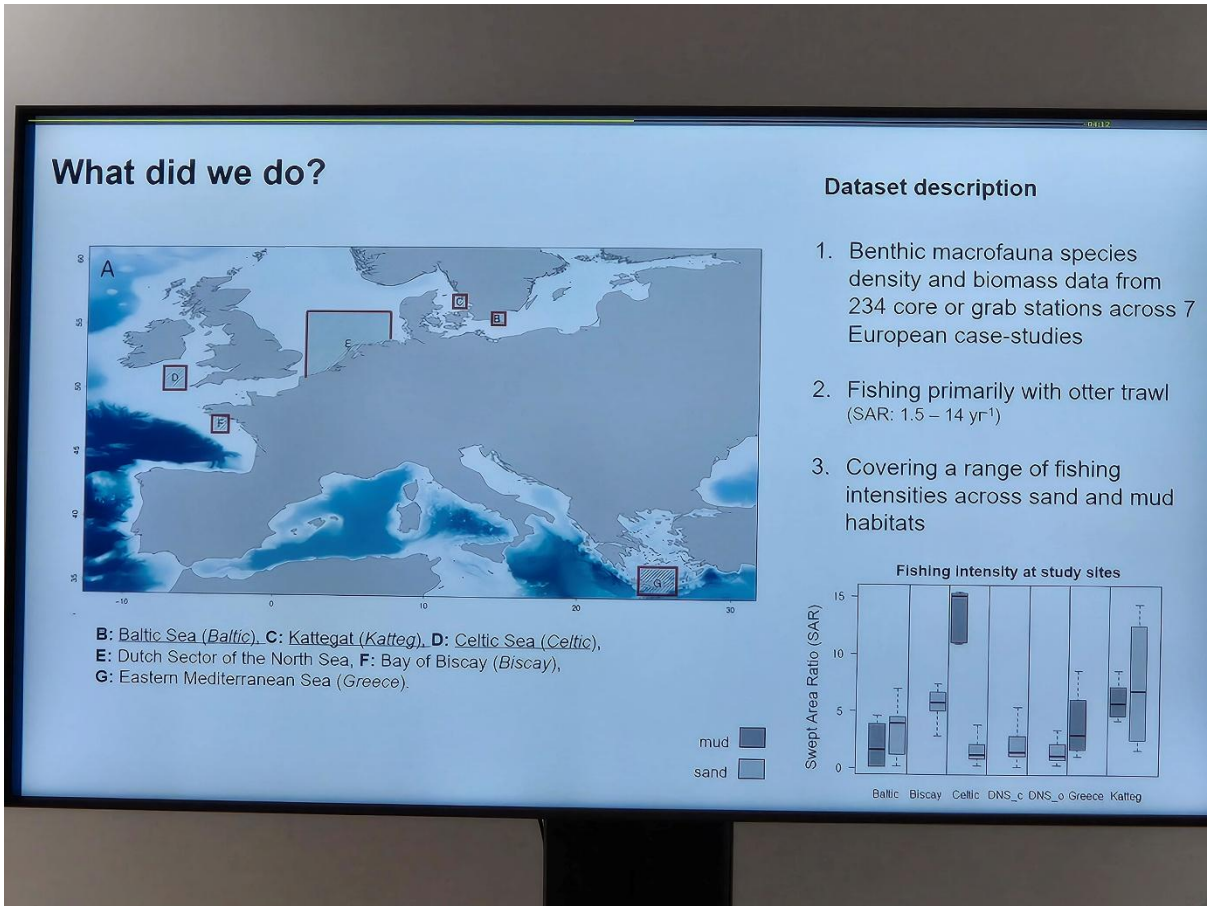
The Bfiat Tool in a nutshell…



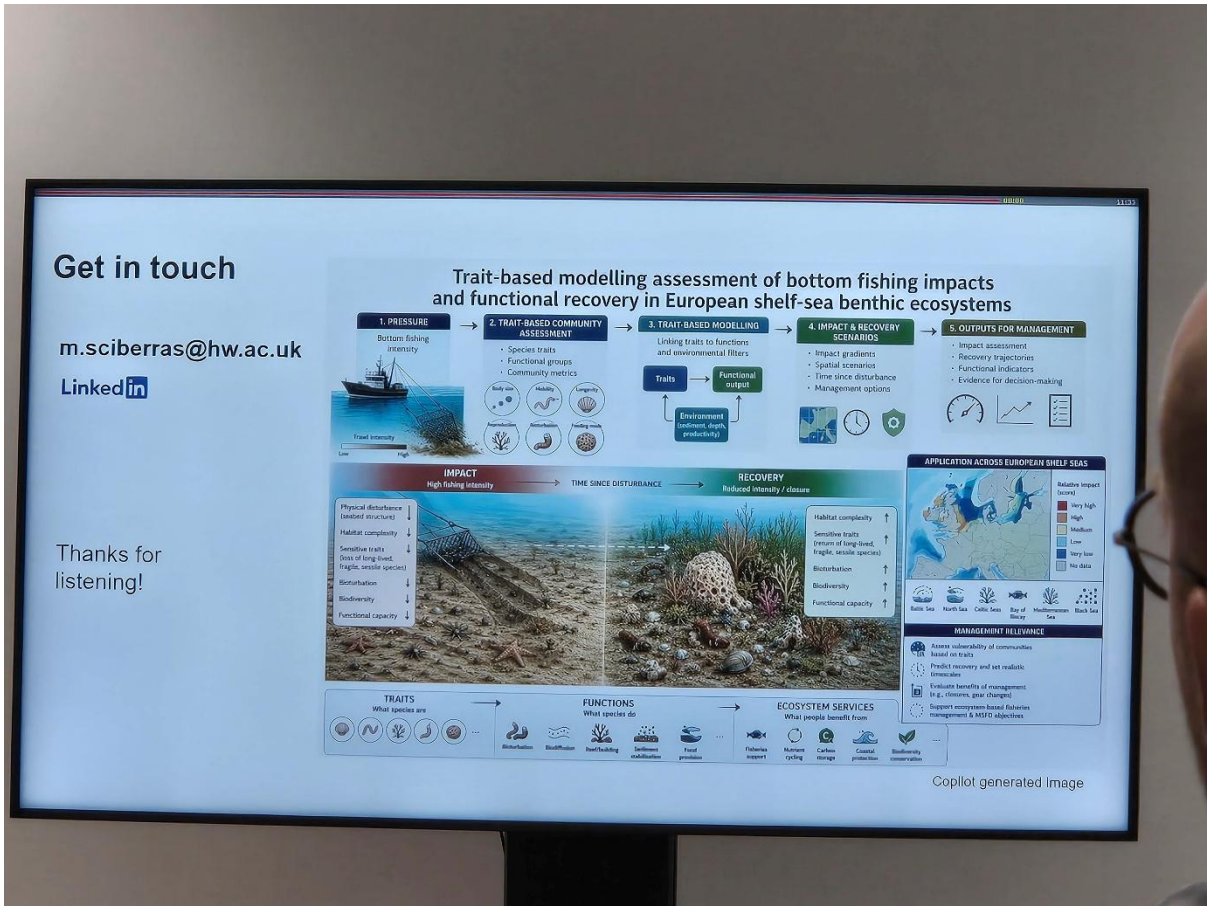
Source: Beauchard & Soetaert 2026. DOI: 10.1002/eap.70282

1. Trawling disturbance on the benthos is modelled using a logistic growth model
2. The effect of trawling on a benthic population depends on:
   - instantaneous depletion of population abundance
   - population rate of recovery between successive disturbance events
3. Species vulnerability & recoverability
4. Impact modulated by gear penetration depth & sediment type
5. Output: D/K

   Prediction of state of benthic species following trawling disturbance as a fraction of pre-disturbance state



Not allowed to take pictures of the rest

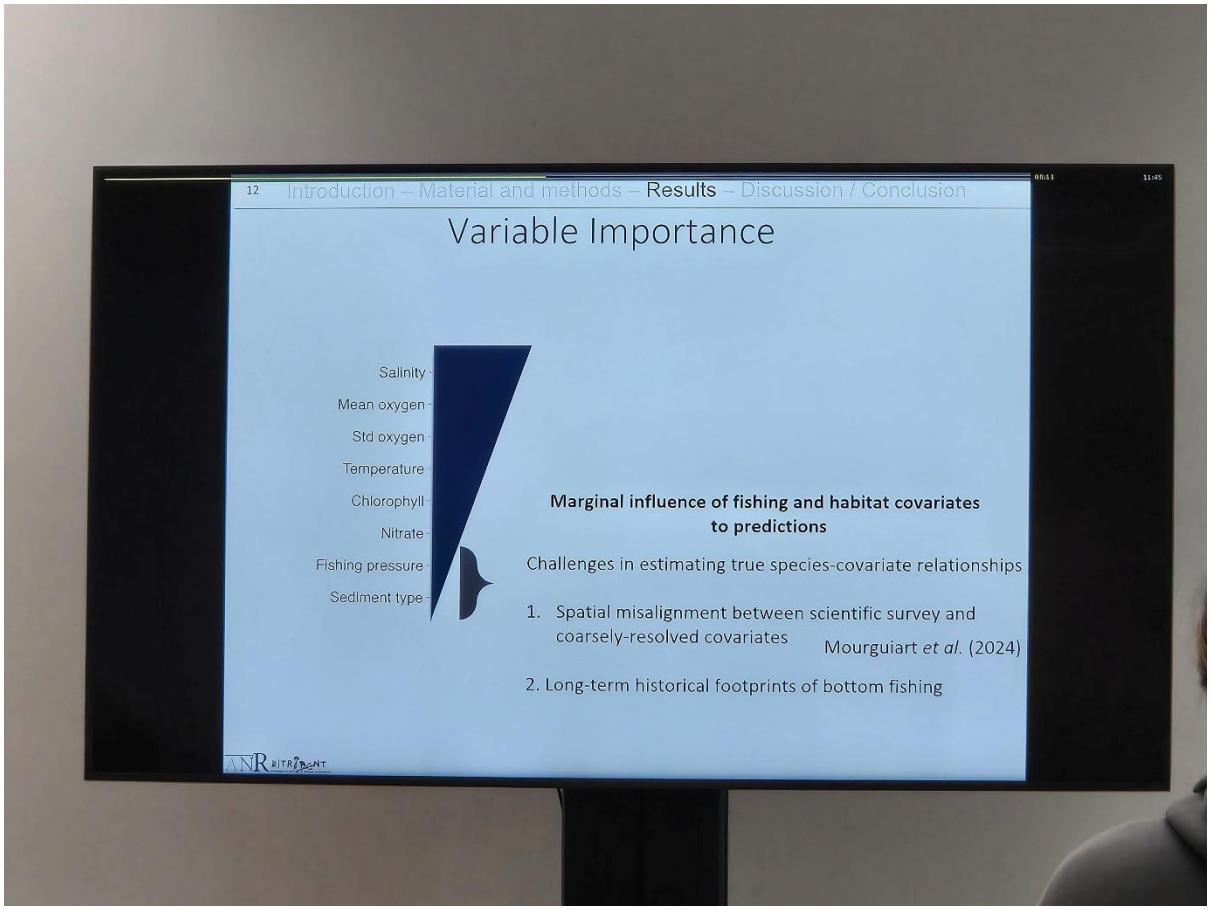


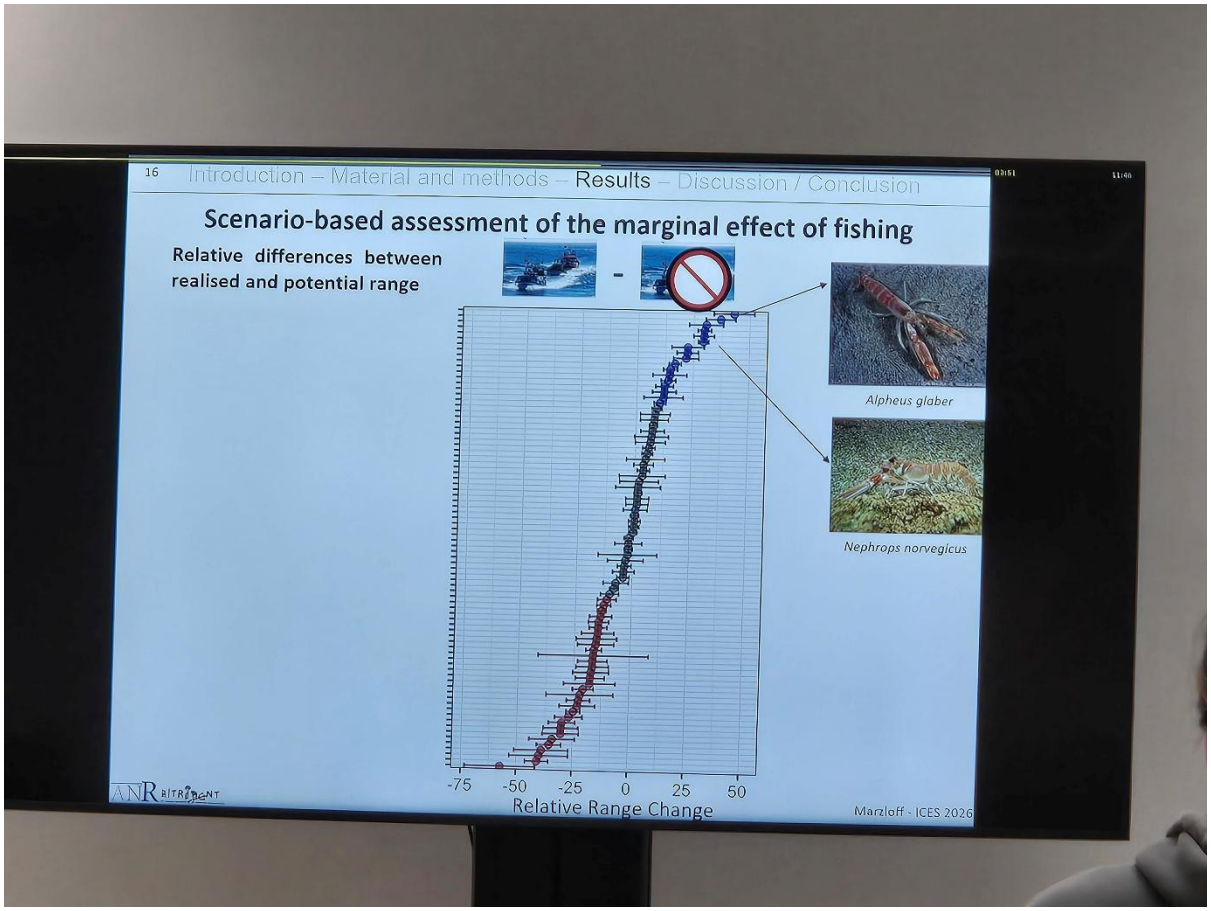
Can species distribution models reliably estimate the effects of bottom trawling on benthic species distributions?
Martin Marzloff

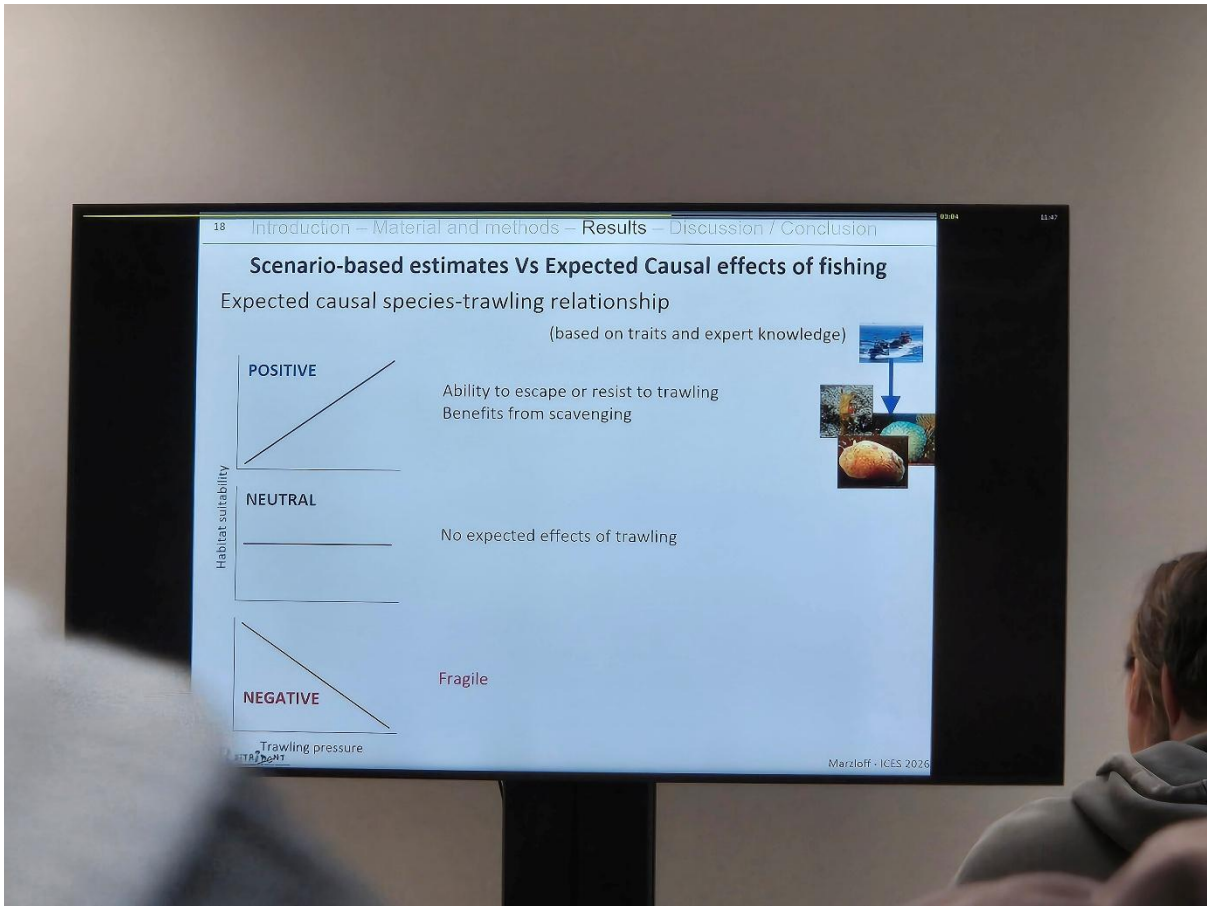
Characterising the structure and the distribution of seafloor invertebrate species communities is key to understanding benthic marine ecosystems functioning across continental shelves. Moreover, disentangling the effects of environmental drivers and bottom trawling on benthic communities is critical to predict changes in ecosystem structure and functioning under future scenarios; and to implement effective ecosystem-based management of bottom trawl fisheries. Here, using species distribution models to relate presence/absence of 71 non-rare benthic macrofauna species (sampled across the Bay of Biscay and Celtic Sea over 15 years of fisheries-independent surveys) to a range of environmental covariates (e.g. bottom temperature, sediment types) as well as to proxies of bottom fishing effort, our objectives are two-fold: (i) to investigate the relative effects of climate and trawling intensity on the distribution of macroinvertebrate species; and, (ii) to quantify species-specific effects of bottom trawling using model projections under no-fishing scenarios.

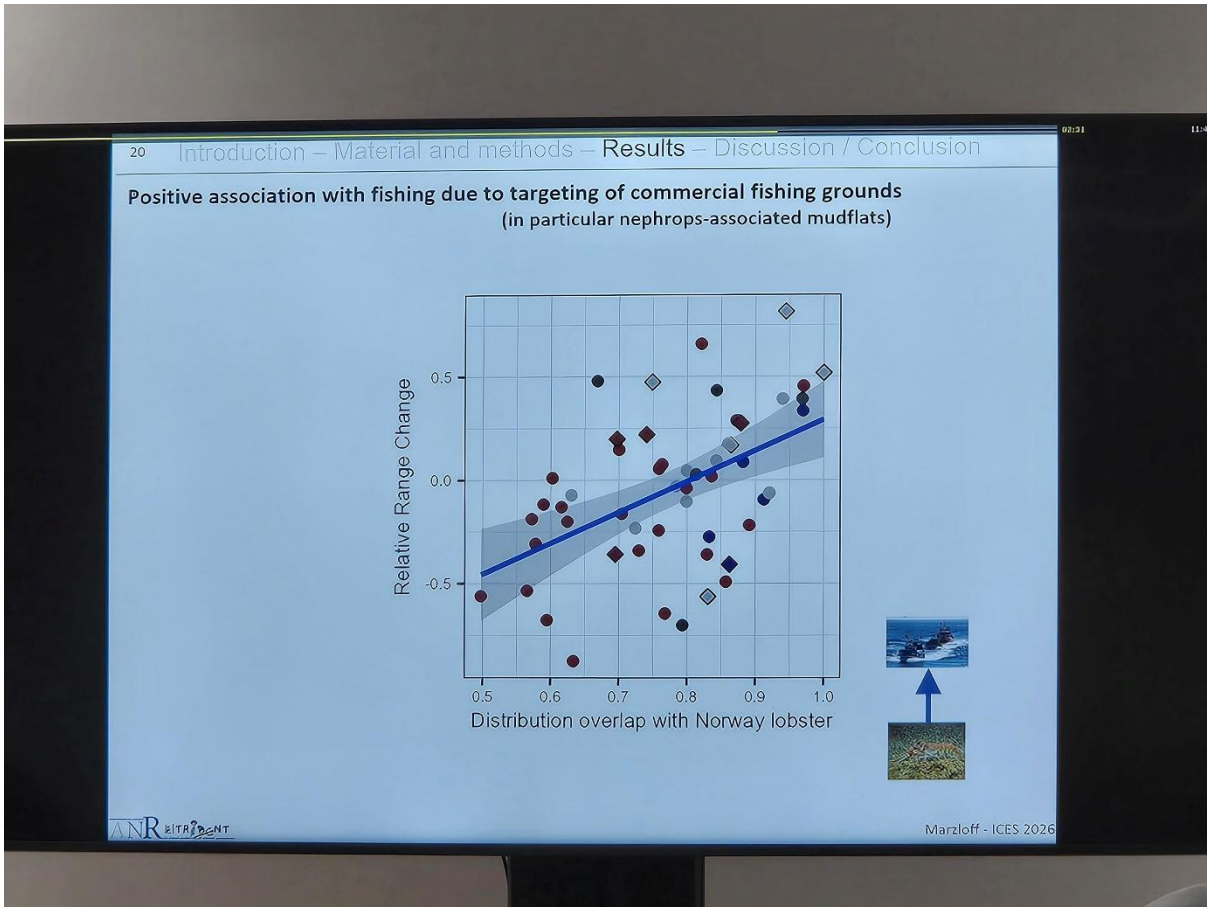
Modelled species distributions help characterise how the six distinct benthic community types across the continental shelf are driven by large-scale environmental gradients. Despite relatively low contributions of trawling intensities to modelled species distributions, projections under no-fishing scenarios indicate that trawling can impact realised species range sizes in different species-specific manners (both in terms of sign, i.e. positive or negative, and magnitude of effects). However, discrepancies between expert knowledge about species-specific vulnerability to trawling and model projections reveal that, for certain species, modelled species-trawling relationships confuses the causal effects of trawling on species distribution on the one hand, and spurious effects related to targeted fishing on main commercial fishing grounds, on the other hand. For instance, most of the commercial species (e.g. Nephrops norvegicus) display positive estimated trawling-species relationships, which highlight how targeting of commercial species can induce spurious non-causal relationships. Similarly, we found that such spurious effects (positive relationships to bottom trawling) hold for most non-commercial taxa that share similar habitats with N. norvegicus. Overall, our study provides novel insights regarding large-scale drivers of benthic community structure in the NE Atlantic continental shelf. Importantly, our results also call for caution when applying scenario-based approaches using species distribution models.



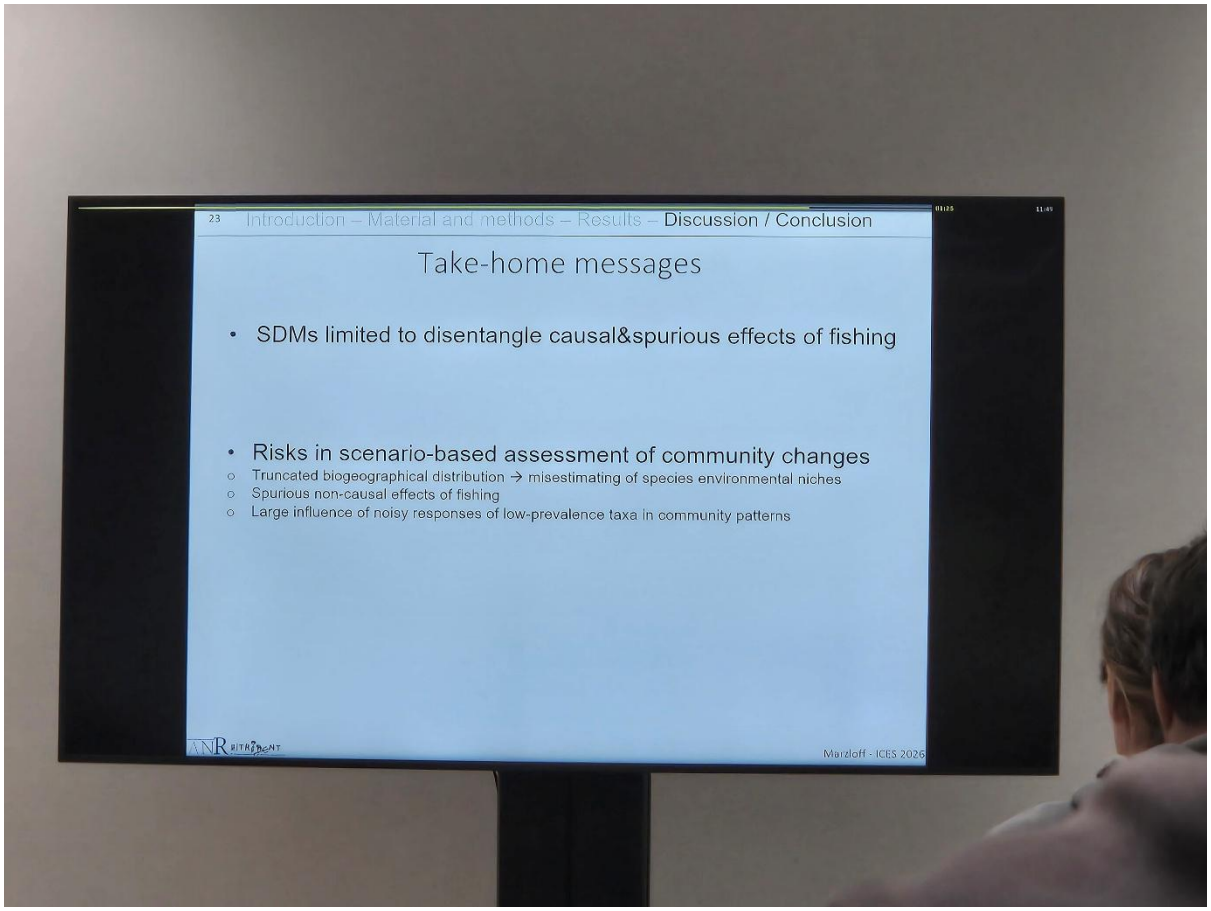

12
Introduction – Material and methods – Results – Discussion / Conclusion
Variable Importance
Salinity
Mean oxygen
Std oxygen
Temperature
Chlorophyll
Nitrate
Fishing pressure
Sediment type
Marginal influence of fishing and habitat covariates to predictions
Challenges in estimating true species-covariate relationships
1. Spatial misalignment between scientific survey and coarsely-resolved covariates
Mourguiart et al. (2024)
2. Long-term historical footprints of bottom fishing


16
Introduction – Material and methods – Results – Discussion / Conclusion
Scenario-based assessment of the marginal effect of fishing
Relative differences between realised and potential range
-
Alpheus glaber
Nephrops norvegicus
-75
-50
-25
0
25
50
Relative Range Change
Marzloff - ICES 2026


18
Introduction – Material and methods – Results – Discussion / Conclusion
Scenario-based estimates Vs Expected Causal effects of fishing
Expected causal species-trawling relationship
(based on traits and expert knowledge)
POSITIVE
Ability to escape or resist to trawling
Benefits from scavenging
NEUTRAL
No expected effects of trawling
NEGATIVE
Fragile
Habitat suitability
Trawling pressure
Marzloff - ICES 2026


20
Introduction – Material and methods – Results – Discussion / Conclusion
Positive association with fishing due to targeting of commercial fishing grounds
(in particular nephrops-associated mudflats)
Relative Range Change
0.5
0.0
-0.5
0.5
0.6
0.7
0.8
0.9
1.0
Distribution overlap with Norway lobster
Marzloff - ICES 2026


22 Introduction – Material and methods – Results – Discussion / Conclusion
Take-home messages
• SDMs limited to disentangle causal&spurious effects of fishing
○ Targeting-induced association between pressure and species blur SDM interpretability
○ Fishing as a weak predictor that mostly captures association with / exclusion from fishing grounds
Expected causal species-trawling relationship
Potential targeting-induced trawling-species association
Marzloff - ICES 2026


23 Introduction – Material and methods – Results – Discussion / Conclusion
Take-home messages
• SDMs limited to disentangle causal&spurious effects of fishing
• Risks in scenario-based assessment of community changes
○ Truncated biogeographical distribution → misestimating of species environmental niches
○ Spurious non-causal effects of fishing
○ Large influence of noisy responses of low-prevalence taxa in community patterns
Marzloff - ICES 2026

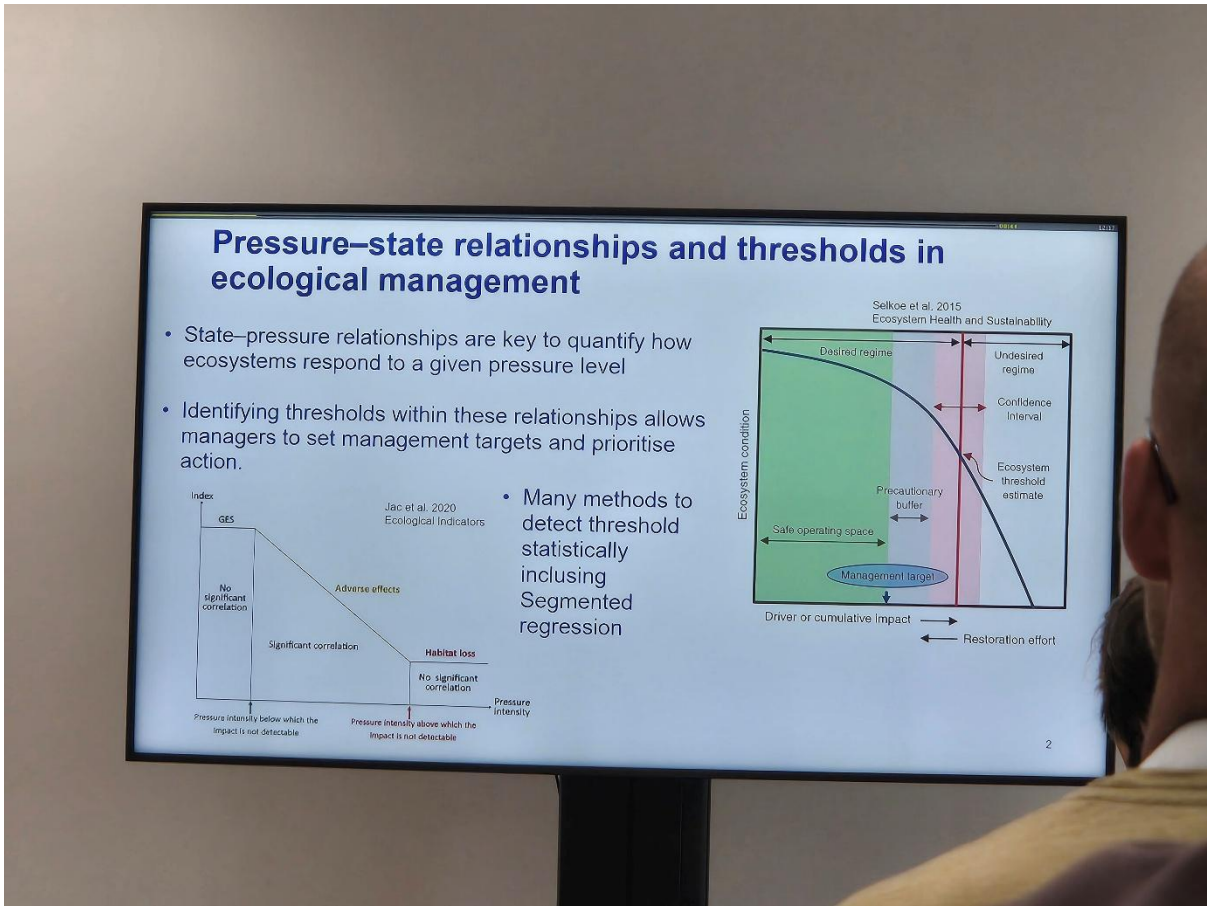


Beyond mean responses: using segmented quantile regression to identify trawling pressure thresholds in benthic ecosystems
Sandrine Vaz

Identifying pressure thresholds beyond which marine benthic ecosystems experience rapid degradation is a central challenge for ecosystem-based management. Such thresholds provide operational reference points to inform spatial planning, fisheries management and conservation actions. However, detecting them statistically remains difficult due to high variability in ecological data, incomplete coverage of pressure gradients, and the widespread reliance on central tendency approaches (mean or median) that may obscure ecologically relevant responses. Indeed, unmeasured factors may act as the actual limiting constraints, generating unequal variation in the biological response variable through interactions with measured factors. Here, we explore the potential of segmented quantile regression as a tool to identify pressure thresholds in benthic ecosystems. Unlike conventional segmented regression methods that focus on central responses and assume homoscedasticity, quantile regression allows the examination of different parts of the response distribution. In particular, upper quantiles can better reveal the effect of limiting factors when a given pressure is the active constraint, and where degradation signals may emerge earlier or more clearly than in central trends.
We apply this approach to data collected during scientific trawl surveys to examine the response of benthic megafauna to bottom-trawling pressure, proxied by swept area ratio (SAR). By combining segmented regression with quantile regression across multiple upper quantiles, we identify breakpoints in various ecological indicators that indicate shifts from weak to strong pressure–state relationships. Bootstrapping procedures are used to estimate confidence intervals around breakpoint locations, allowing explicit characterization of uncertainty in threshold estimates. Our results demonstrate that segmented quantile regression can detect pressure thresholds that remain undetected when focusing on central responses alone, and that

different quantiles may reveal alternative but ecologically meaningful thresholds. This approach provides a robust and transparent framework for identifying management-relevant pressure limits and contributes to improving the assessment and management of human impacts on marine benthic ecosystem functioning.



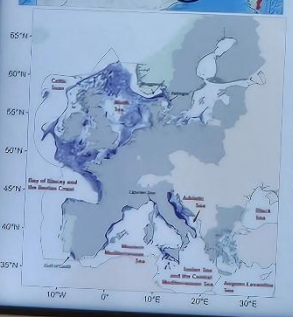


Detecting bottom fishery effect on epibenthic communities



Biomass data from fishery scientific surveys





Abrasion due to trawling (Swept Area Ratio, Hiddink *et al., 2026*)

Sentinels of Seabed (SoS) indicator
Serrano et al., 2022

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5

CONCLUSIONS and PERSPECTIVES

- Data-driven method that requires to:
  - Cover most of the pressure gradient
  - Identify the appropriate indicator for the habitat x pressure investigated

- It is suited to detect pressure threshold (not so much for indicator threshold)
- It is not sensitive to local variation of the environment (or other factors)
- It does not require a reference state (zero pressure)
- It quantifies thresholds objectively (no expert decision, all stats)

Improvements still needed…

- Use data bootstrapping to better quantify uncertainty and threshold value range
- Implement a risk-base approach using the range of threshold detected

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17/09/2026 Titre modifiable dans insertion / en tête/Pied

Integrating benthic structural and functional indicators into a spatial status/sensitivity map to assess and manage bottom trawling in the Southern North Sea.

Gert Van Hoey

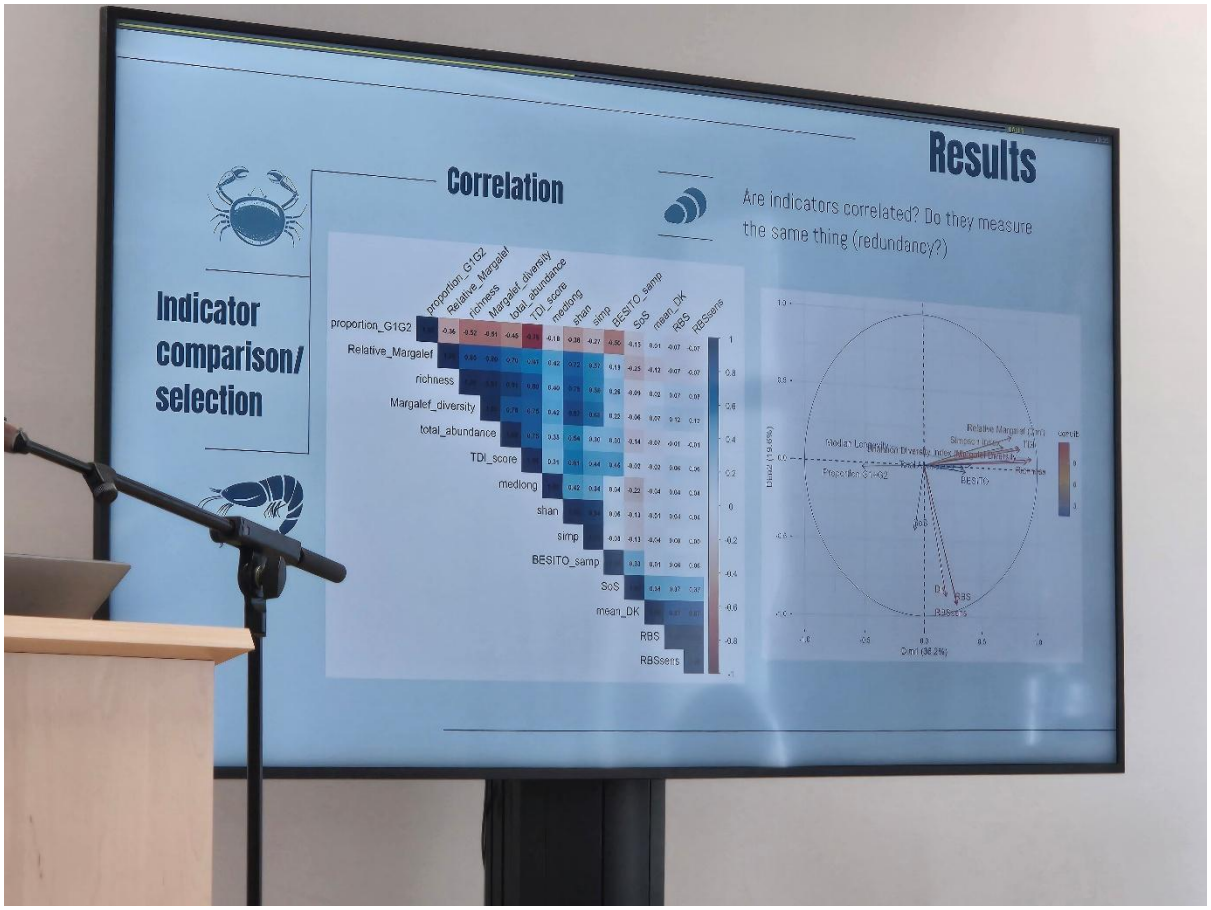
Europe's coastal and continental shelf sediments are increasingly impacted by human disturbances, with mobile bottom-contacting fishing among the dominant pressures. Bottom trawling not only causes extensive physical abrasion but also has significant ecological impacts, reducing benthic biomass, diversity and size structure, and altering functional composition. The severity of these effects varies across habitats and gear types. Consequently, assessing the ecological status and sensitivity of the seafloor has become a central objective of several EU policies, including the EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries, the EU Biodiversity Strategy, and the Marine Strategy Framework Directive.

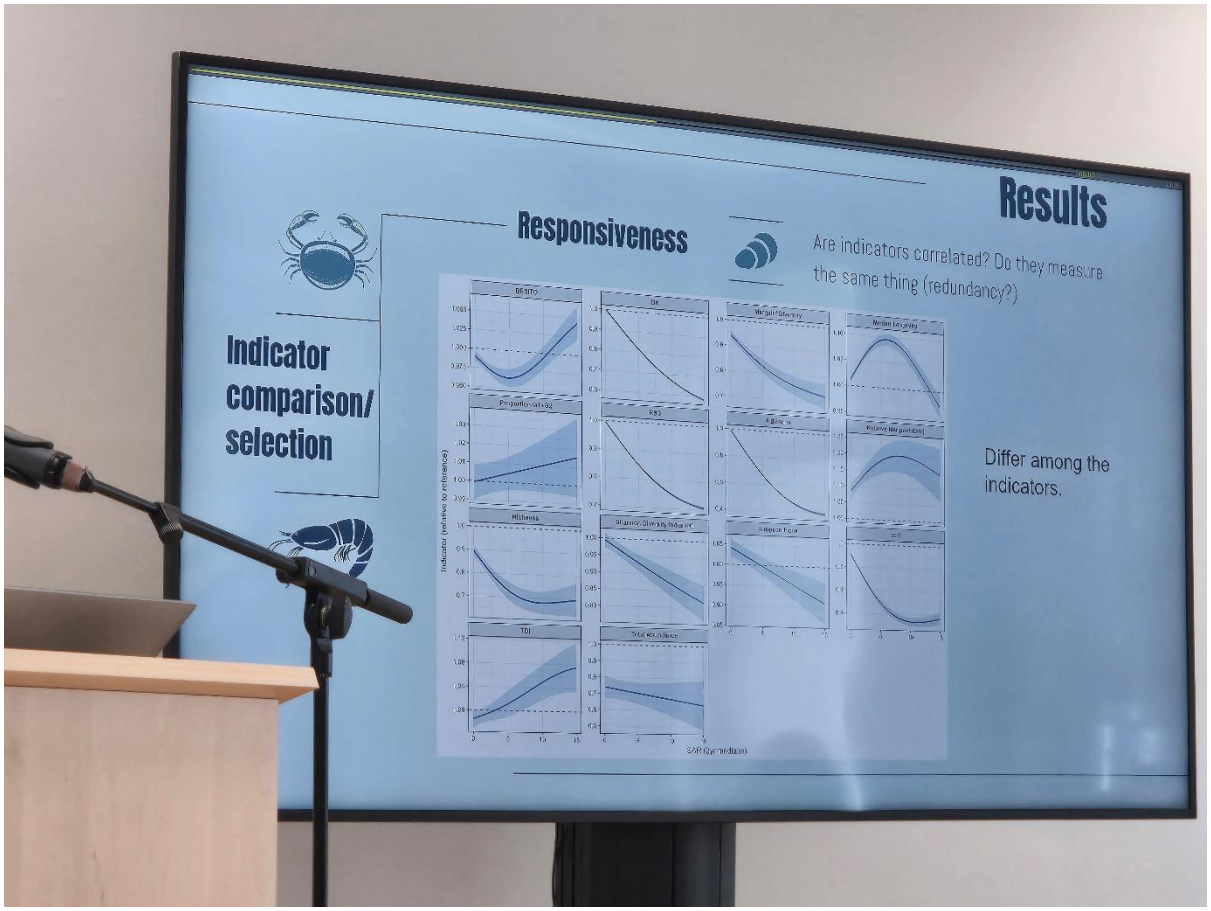
The Belgian Sea fishery relies heavily on bottom trawling for sole, plaice and shrimp, making the sustainable use of their fishing grounds a key priority to ensure a viable future. Several benthic indicators have been developed to assess seafloor status and sensitivity under trawling pressure. Earlier assessments often relied on single indicators, with the risk of overlooking important ecosystem functions. More recent multi-indicator approaches, such as those proposed in the ICES WKBENTH3 report, address this limitation but introduce new challenges, as different indicators may identify different habitats as sensitive or respond unequally to trawling pressure. Integrating these indicators into a single, coherent assessment therefore remains difficult.

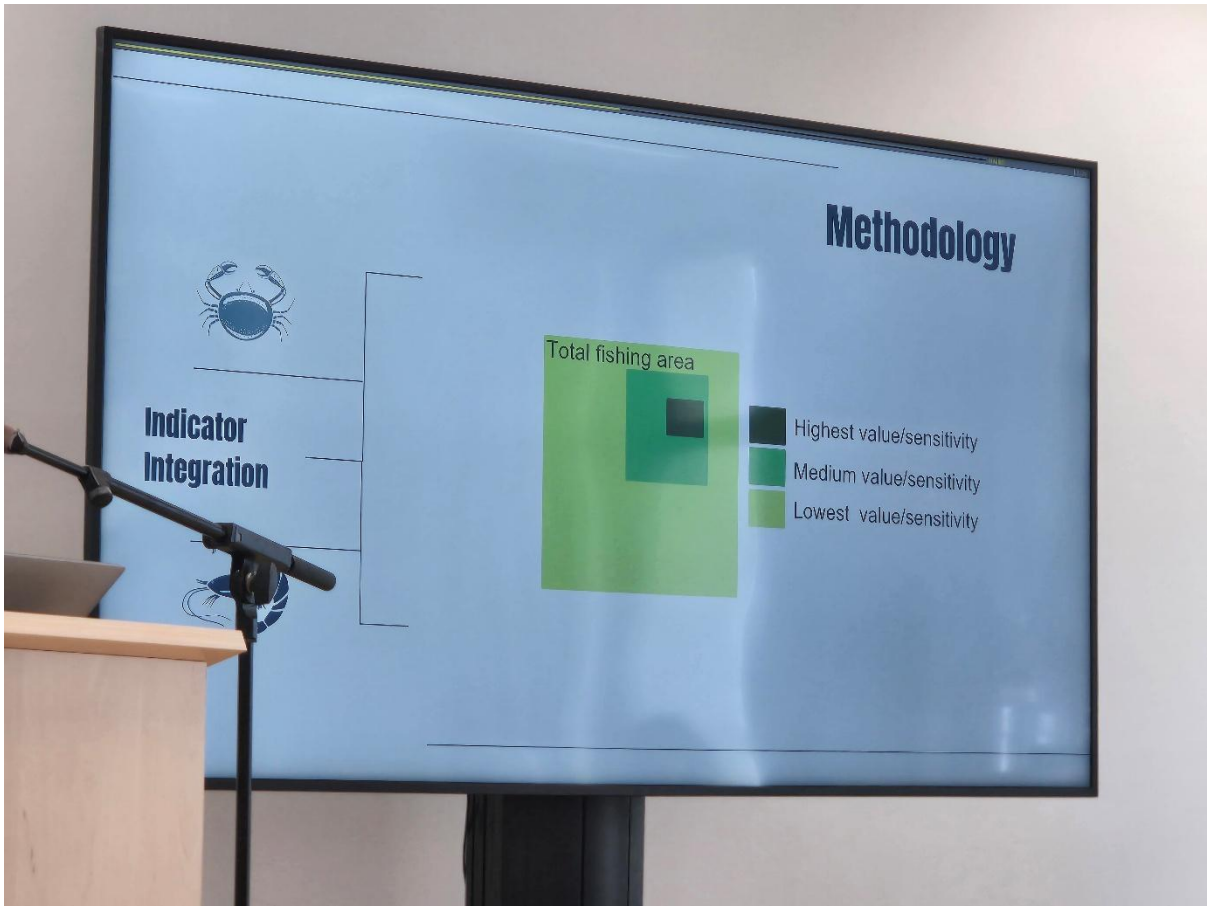
In this contribution, we develop and test and integrative framework to compare and combine multiple structural and functional benthic indicators (FBIAT, SOS, Margalef richness, and the ICES FBIT RBS model). This framework is applied across the Southern North Sea region with the aim of generating a spatially explicit benthic state and/or sensitivity map for the Belgian fishing grounds, based on an integrated indicator score.

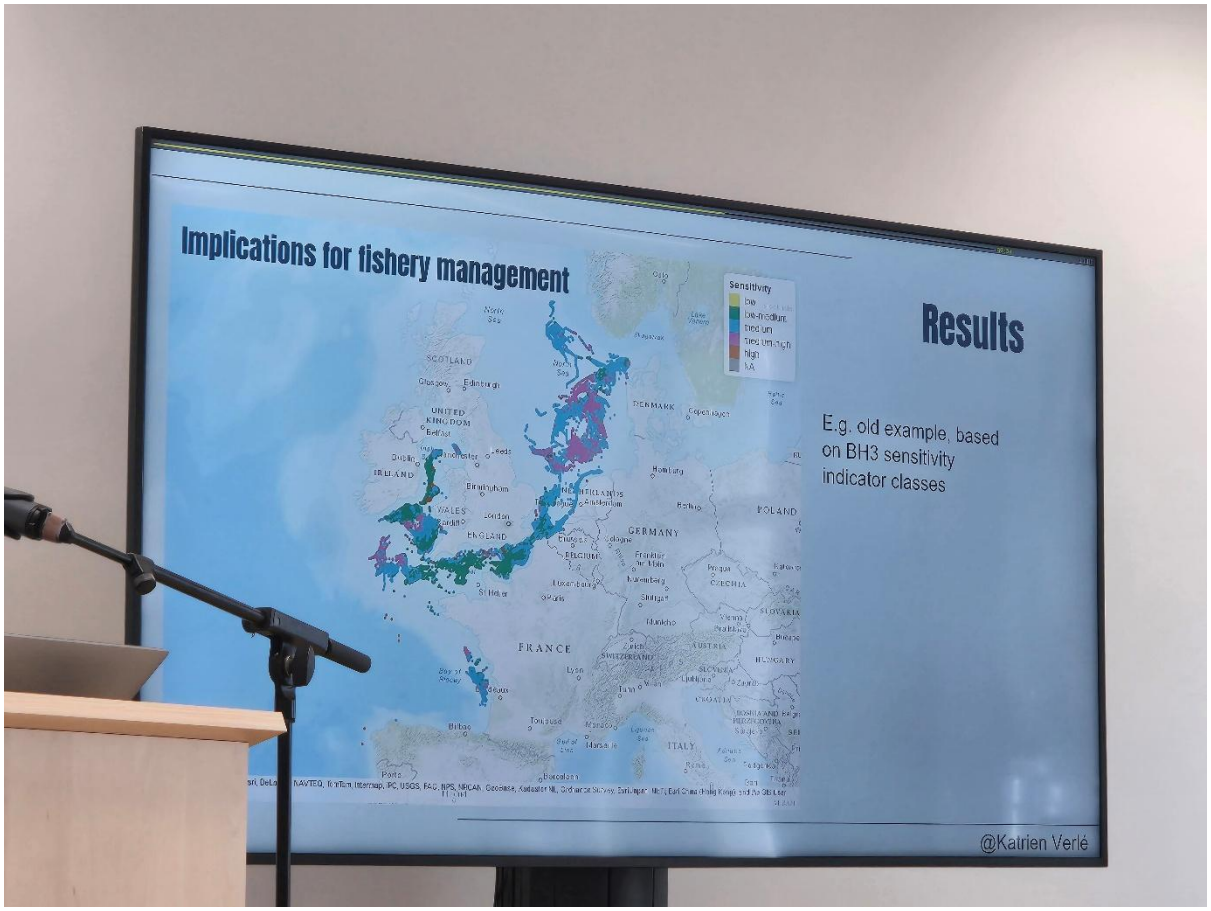
This map can be used by policy makers for fisheries management and is also made available to Belgian fishers via the existing onboard platform VISTOOLS, which will enable voluntary adjustments in fishing behavior. VISTOOLS output feeds directly into the VALDUVIS sustainability assessment, where reducing fishing activities in high-state or sensitive areas can improve a vessel's sustainability score, which is visible to consumers. By translating indicator-based assessments into an operational management tool, this work contributes to more sustainable and ecosystem-aware Belgian demersal fisheries.

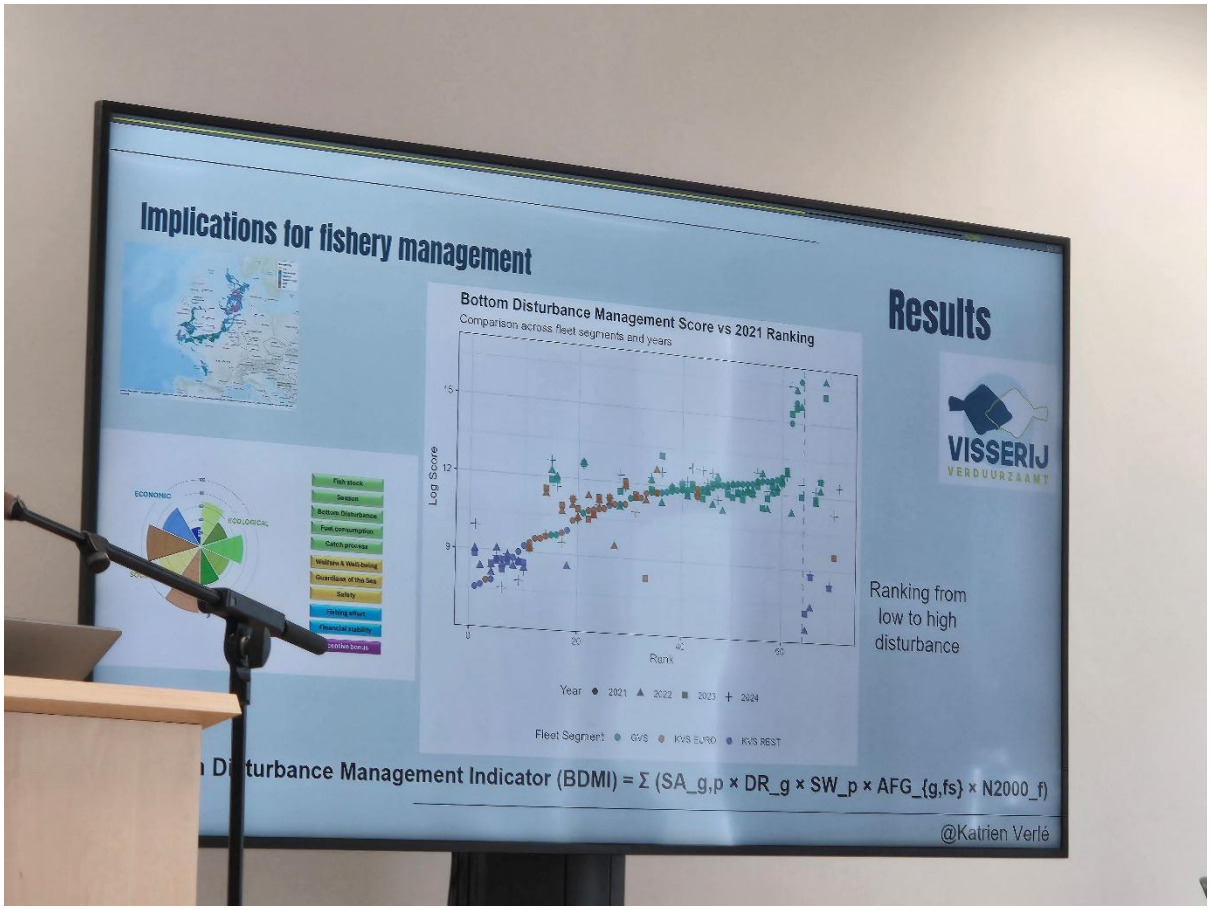



Results
Correlation
Are indicators correlated? Do they measure the same thing (redundancy?)
Indicator comparison/ selection
proportion_G1G2
Relative_Margalef
richness
Margalef_diversity
total_abundance
TDI_score
medlong
shan
simp
BESITO_samp
SoS
mean_DK
RBS
RBSsens


Results
Responsiveness
Are indicators correlated? Do they measure the same thing (redundancy?)
Indicator comparison/ selection
Differ among the indicators.
BESITO
DK
RBS
TDI
SAR (Qyr^median)


Methodology
Indicator Integration
Total fishing area
Highest value/sensitivity
Medium value/sensitivity
Lowest value/sensitivity


Implications for fishery management
Results
E.g. old example, based on BH3 sensitivity indicator classes
@Katrien Verlé


Implications for fishery management
Bottom Disturbance Management Score vs 2021 Ranking
Comparison across fleet segments and years
Log Score
Rank
Year 2021 2022 2023 2024
Fleet Segment GVS KVS EURO KVS REST
Results
VISSERIJ
VERDUURZAAMT
Ranking from low to high disturbance
Disturbance Management Indicator (BDMI) = Σ (SA_g,p × DR_g × SW_p × AFG_{g,fs} × N2000_f)
@Katrien Verlé


Thanks!
Do you have any questions?
Joanna.Desmidt@ilvo.vlaanderen.be
gert.vanhoey@ilvo.vlaanderen.be
CRED : This presentation template was created by Slidesgo, and
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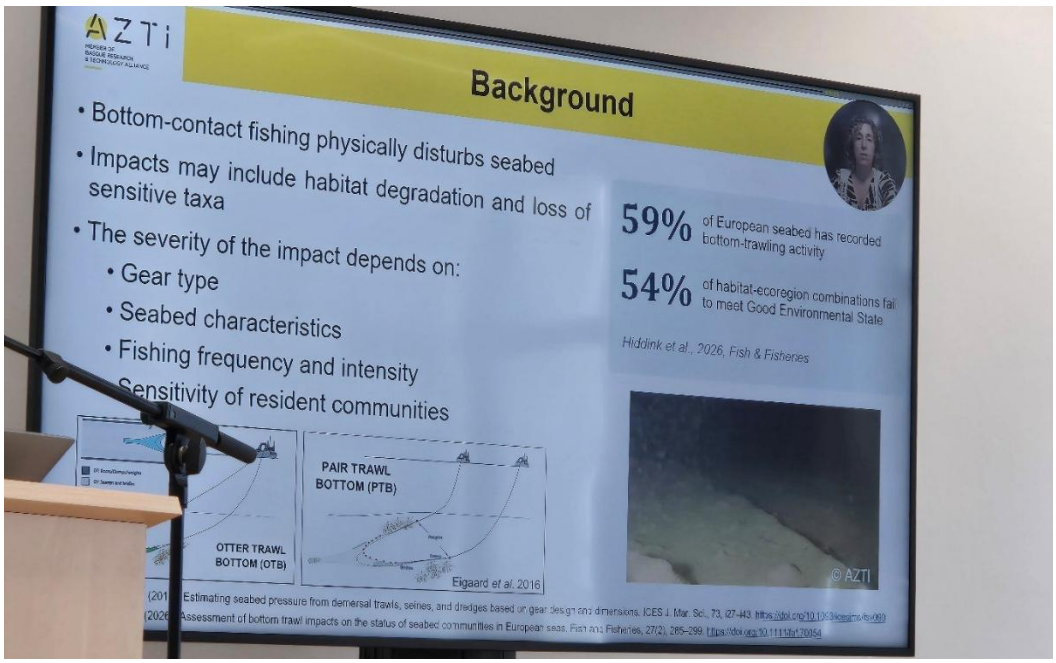
Assessing bottom-trawling impacts on benthic communities using sensitivity indicators
Natalia Montero

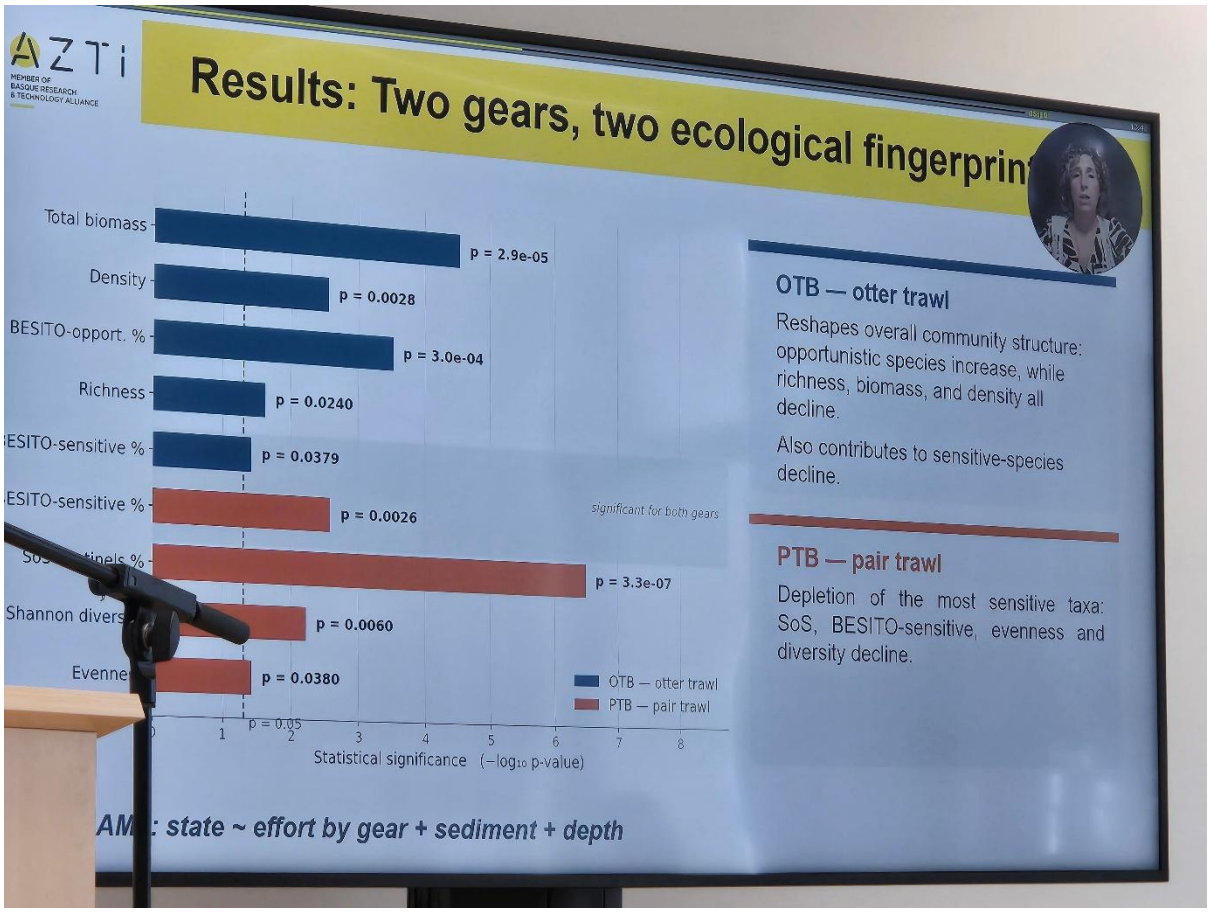
Bottom-contact fishing can cause substantial physical disturbances on the seabed, frequently resulting in the structural degradation of habitats and the loss of key taxa. The magnitude of these impacts is determined by multiple factors, including the type of fishing gear employed, seabed characteristics, and the frequency and intensity of fishing effort. Furthermore, the capacity of benthic communities to recover after trawling operations depends on the intrinsic vulnerability of the resident species, which is largely governed by specific biological traits. Consequently, robust assessments of trawling impacts require the integration of spatial and temporal fishing activity data, seabed geomorphological characteristics and community-level biological information.

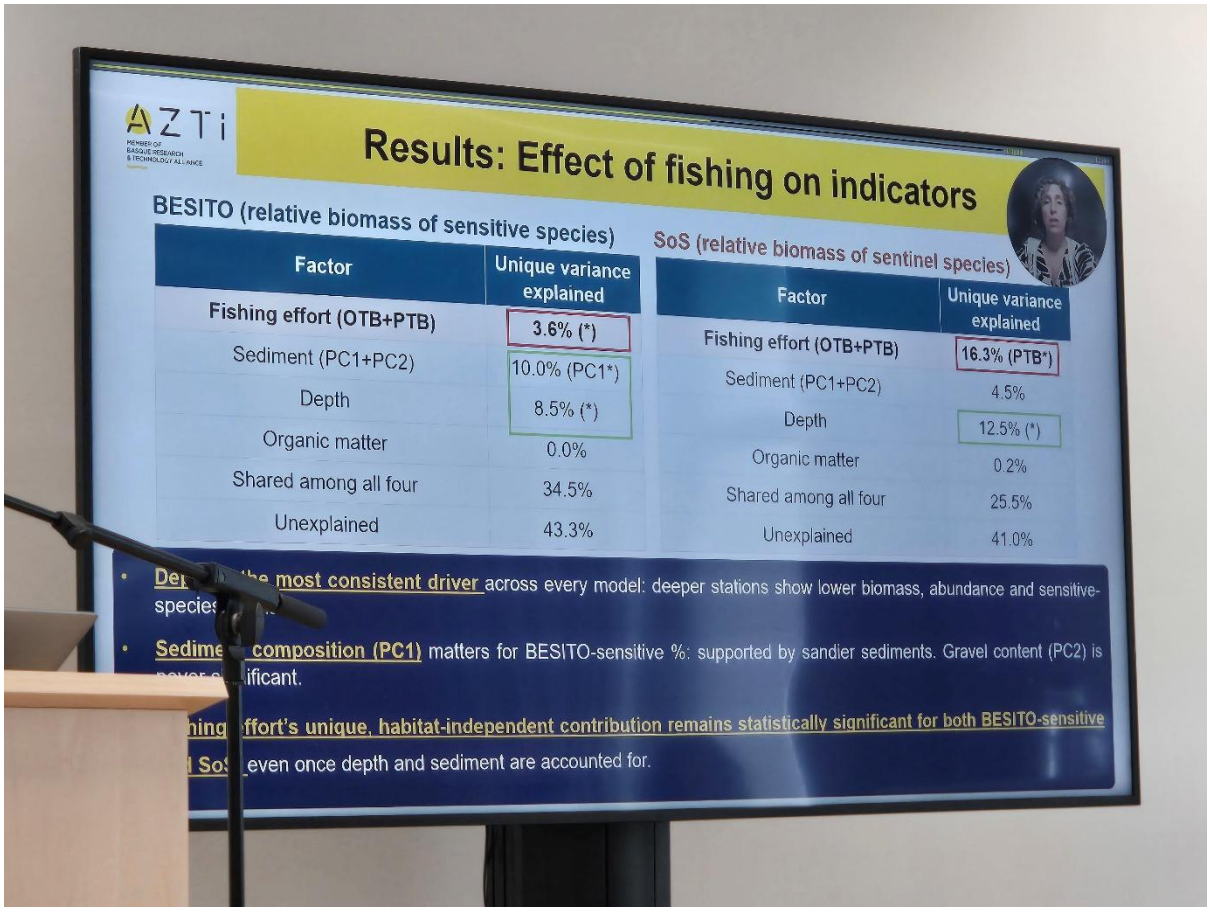
Between 2022 and 2025, seven sampling campaigns were conducted on the Basque continental shelf (SE Bay of Biscay) to evaluate the impact of bottom trawling on benthic habitats. Sampling stations were distributed to encompass a broad range of depths, seabed characteristics, fishing intensities (derived from Vessel Monitoring System (VMS) data merged with logbook records[1]), and regulatory contexts (i.e., stations located within partial or total fishing closure areas or subject to varying degrees of fishing pressure). Biological and environmental characterization involved 75 beam trawls for megabenthic epifauna and 69 sediment grab samples for macrobenthic infauna, grain size analysis and organic matter content determination. Community metrics, including density, species richness and biomass of both epifaunal and infaunal organisms were examined, and stations were classified through taxonomic similarity analyses. Additionally, the Benthos Sensitivity Index to Trawling Operations (BESITO)[2] and the Sentinels of Seabed (SoS)[3] indicator were applied to assess trawling impacts on megabenthic communities.

Results indicate that macrobenthic community composition is primarily shaped by environmental variables, with fishing effort playing a secondary role. In contrast, while total megabenthic biomass showed no clear spatial correlation with fishing intensity, community structure shifted significantly along the fishing-pressure gradient. Accordingly, high intensity trawling areas were dominated by opportunistic and tolerant taxa, whereas the abundance of sensitive megabenthic organisms decreased consistently with increasing fishing effort.

These findings provide valuable insights for assessing seabed integrity and determining the environmental status of benthic habitats subjected to bottom-contact fishing. Moreover, this research offers a solid empirical foundation for the development of targeted management strategies aimed at mitigating the ecological impacts of bottom-trawling activities.




AZTI
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
Results: Two gears, two ecological fingerprin
Total biomass
Density
BESITO-opport. %
Richness
ESITO-sensitive %
ESITO-sensitive %
Shannon divers
Evenne
p = 2.9e-05
p = 0.0028
p = 3.0e-04
p = 0.0240
p = 0.0379
p = 0.0026
p = 3.3e-07
p = 0.0060
p = 0.0380
significant for both gears
OTB — otter trawl
PTB — pair trawl
p = 0.05
Statistical significance (−log10 p-value)
OTB — otter trawl
Reshapes overall community structure: opportunistic species increase, while richness, biomass, and density all decline.
Also contributes to sensitive-species decline.
PTB — pair trawl
Depletion of the most sensitive taxa: SoS, BESITO-sensitive, evenness and diversity decline.
: state ~ effort by gear + sediment + depth

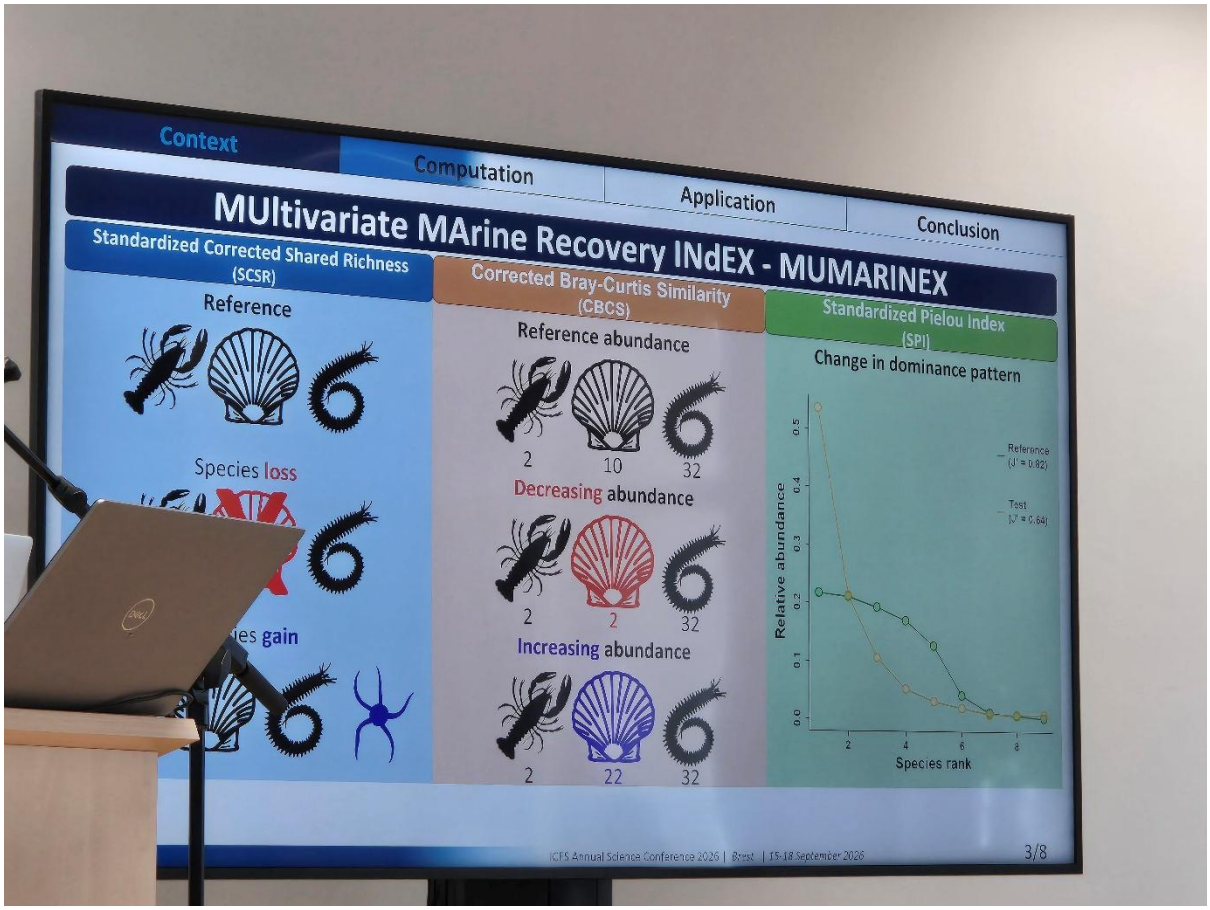

AZTI
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE
Results: Effect of fishing on indicators
BESITO (relative biomass of sensitive species)
Factor
Unique variance explained
Fishing effort (OTB+PTB)
3.6% (*)
Sediment (PC1+PC2)
10.0% (PC1*)
Depth
8.5% (*)
Organic matter
0.0%
Shared among all four
34.5%
Unexplained
43.3%
SoS (relative biomass of sentinel species)
Factor
Unique variance explained
Fishing effort (OTB+PTB)
16.3% (PTB*)
Sediment (PC1+PC2)
4.5%
Depth
12.5% (*)
Organic matter
0.2%
Shared among all four
25.5%
Unexplained
41.0%
most consistent driver across every model: deeper stations show lower biomass, abundance and sensitive-
composition (PC1) matters for BESITO-sensitive %: supported by sandier sediments. Gravel content (PC2) is
effort's unique, habitat-independent contribution remains statistically significant for both BESITO-sensitive
even once depth and sediment are accounted for.

Introducing MUMARINEX: A multivariate generalist index for assessing anthropogenic impacts and recovery in marine ecosystems

Nathan Chauvel

Marine ecosystems worldwide are increasingly exposed to a growing range of human pressures. To quantify their impacts and to monitor ecosystem recovery, numerous ecological indices have been developed over recent decades. Despite their diversity, most existing indices remain constrained by context-specific limitations, either in terms of the types of pressures they can reliably assess, or by the habitats and biological communities to which they can be applied. Here, we introduce a new multivariate indicator designed to be applicable across a broad range of pressures and marine habitats: the Multivariate Marine Recovery IndEX (MUMARINEX). This index is based on the assumption that the ecological status of marine communities can be described through the combination of three complementary components: conservation of species (or taxonomic) richness, preservation of community structure, and the absence of shifts in dominance patterns. To evaluate the performance of MUMARINEX, we compared it with two generalist deviation-based indices (the General Purpose Biotic Index, GPBI, and the Ecological Quality Assessment, EQA), as well as with the widely used M-AMBI. All four indices were applied to multiple case studies encompassing diverse marine habitats and anthropogenic pressures. Across all case studies, MUMARINEX consistently exhibited responses aligned with impact intensity and proved sensitive to intermediate recovery stages. Importantly, MUMARINEX was also able to account for situations where moderate disturbance led to local increases in diversity, in line with the Intermediate Disturbance Hypothesis, patterns that are often poorly captured by conventional indices assuming systematic diversity loss under anthropogenic pressure. These results highlight several unique strengths of MUMARINEX, including its continuous response directly proportional to both disturbance intensity and recovery degree, its ability to disentangle the ecological components driving degradation (loss of richness, structural changes, dominance shifts, or their combination), and its capacity to identify the taxa most affected by anthropogenic pressures, features not directly provided by most commonly used indices. Moreover, owing to its simple underlying assumptions, MUMARINEX is readily applicable by both scientists and environmental managers, with computation facilitated through an R package or an user-friendly online interface. Taken together, its flexibility, interpretability, and broad applicability make MUMARINEX a promising tool for future marine monitoring programs and impact assessments worldwide.





Assessing the impacts of fishing pressure on Tyrrhenian Sea benthic ecosystems: a comparative analysis of the RBS and SoS indicators to support the Italian assessment of Good Environmental Status

Bianca di Lorenzo

Fishing activities conducted by means of bottom trawling represent one of the most significant anthropogenic pressures affecting Italian marine waters. Despite the substantial national efforts undertaken through the implementation of the Marine Strategy Framework Directive (MSFD), in situ measurements have so far not been sufficient to enable the application of the Relative Benthic Status (RBS) indicator in the Tyrrhenian Sea.

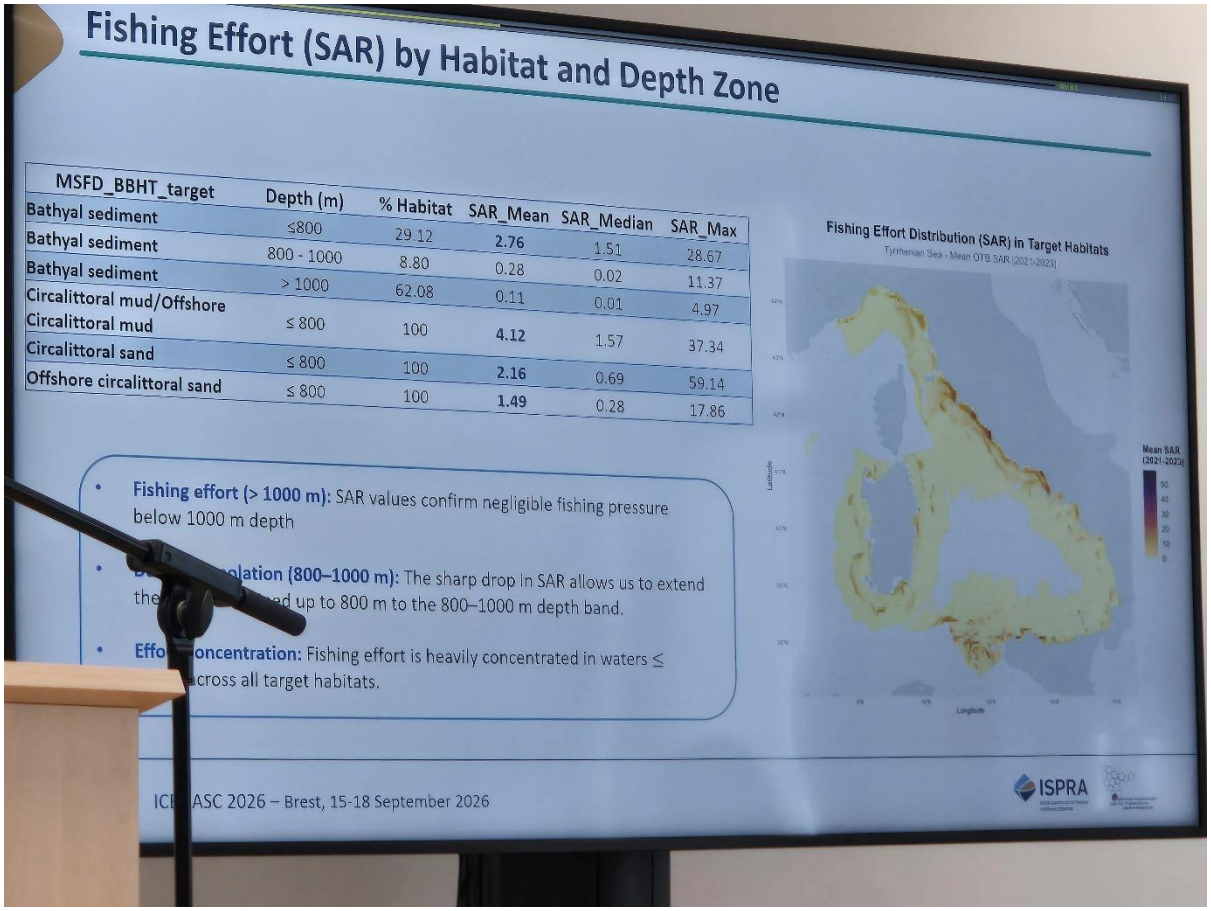
Recently, the Italian Ministry of Agriculture, Food Sovereignty and Forests (MASAF) has made publicly available the extensive long-term dataset of the MEDITS program (International bottom trawl survey in the Mediterranean). Although MEDITS in situ surveys conducted in Italian waters are primarily designed to assess demersal fish stocks and benthic ecosystems in support of sustainable fisheries management and European environmental policies, the data they provide can be effectively exploited within the MSFD Descriptor 6 (seafloor integrity) assessment framework.

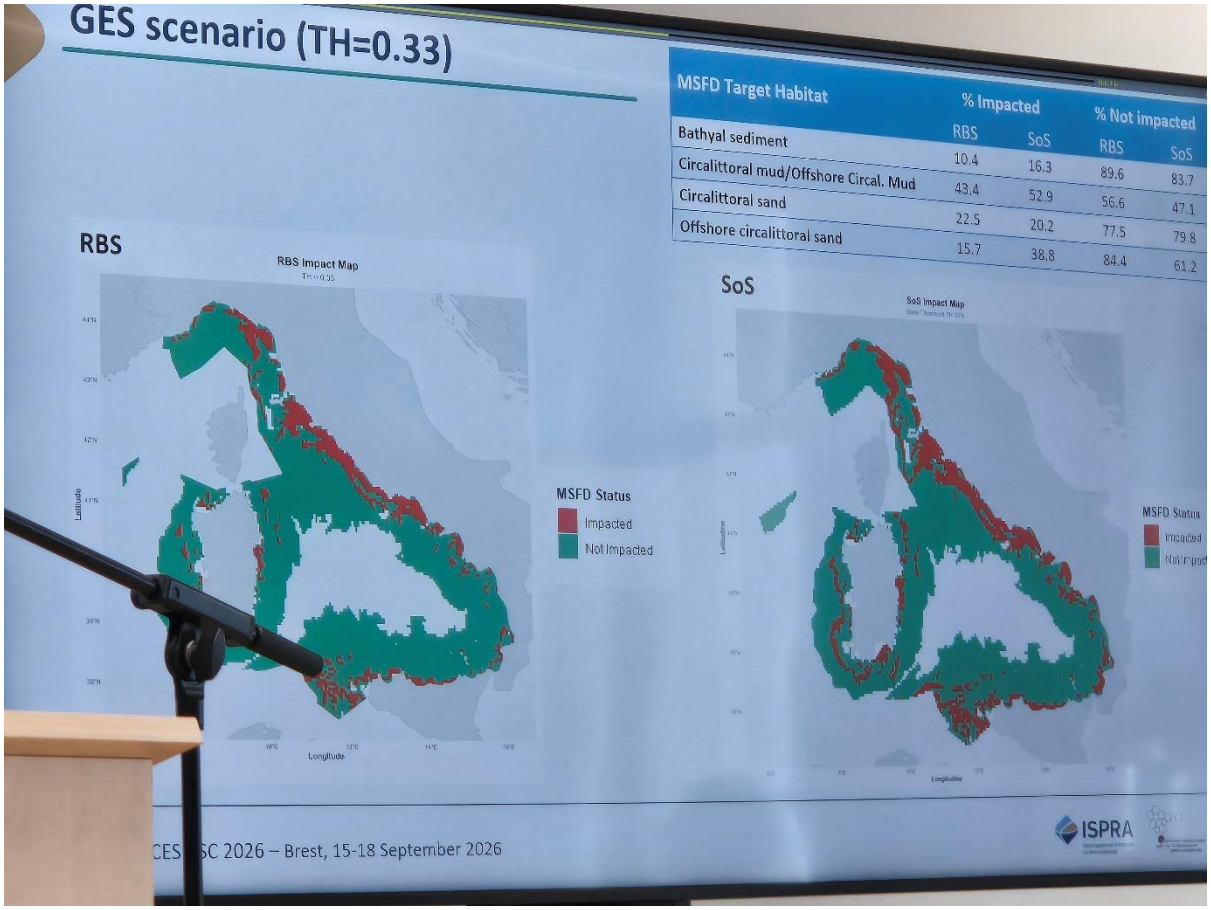
Taking advantage of this extensive dataset, we applied both the RBS and the Sentinel of the Seabed (SoS) indicators to evaluate the impacts of fishing activities on Tyrrhenian Sea broad benthic habitat types (BBHTs). The analysis integrates biological data derived from Italian MSFD monitoring programs and MEDITS surveys (covering 2200 sampling stations), 12 Broad Benthic Habitat Types (EUSeMap, 2023), and a depth range of 700 m, together with fishing pressure data based exclusively on Vessel Monitoring System (VMS) information, spanning the period 2015–2023.

Results from the RBS and SoS indicators are compared across habitat types, focusing on the distribution of indicator values, their variability along the depth gradient, and their sensitivity to

spatial and temporal patterns of fishing pressure, thereby highlighting differences in benthic status among Tyrrhenian BBHTs.







Implementation of cumulative effects risk analysis in marine protected areas: 4 case studies

Frédéric Quemmerais

Maritime human activities are numerous and overlap in space and time. These activities contribute to generating physical, chemical and biological pressures that interact with marine ecosystems, particularly with benthic habitats.

Since 2017, France has been developing a comprehensive and coordinated approach to all public policies applicable to maritime and coastal areas, with the aim of ensuring their integrated management, both in terms of activities and protection. This framework highlights methods that consider the socio-ecosystem in its entirety, and recommend that impact studies carried out to assess the compatibility of activities with ecological conservation objectives should consider the marine ecosystems and the different economic sectors involved. These recommendations apply to all projects subject to environmental assessment and to Marine Protected Areas (MPAs).

The cumulative effects assessment provides a conceptual and methodological framework that can helps to address these challenges by allowing us to assess the relative contributions of each of the activities and pressures using an intersectoral approach, thus enabling us to identify and prioritize the most appropriate management levers.

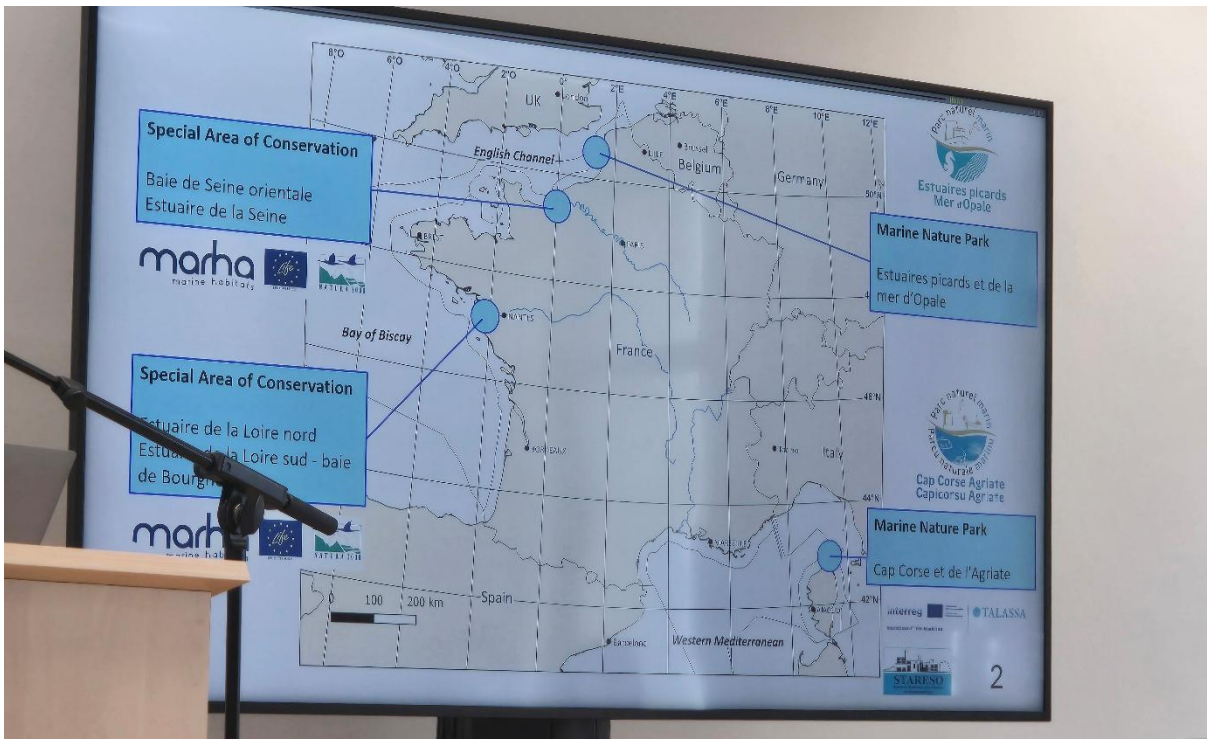
However, the implementation of this approach at the national, regional, and MPAs levels faces scientific and technical challenges in developing robust and operational tools, and remains highly variable and dependent on the technical and human resources available to move from theory to practice.

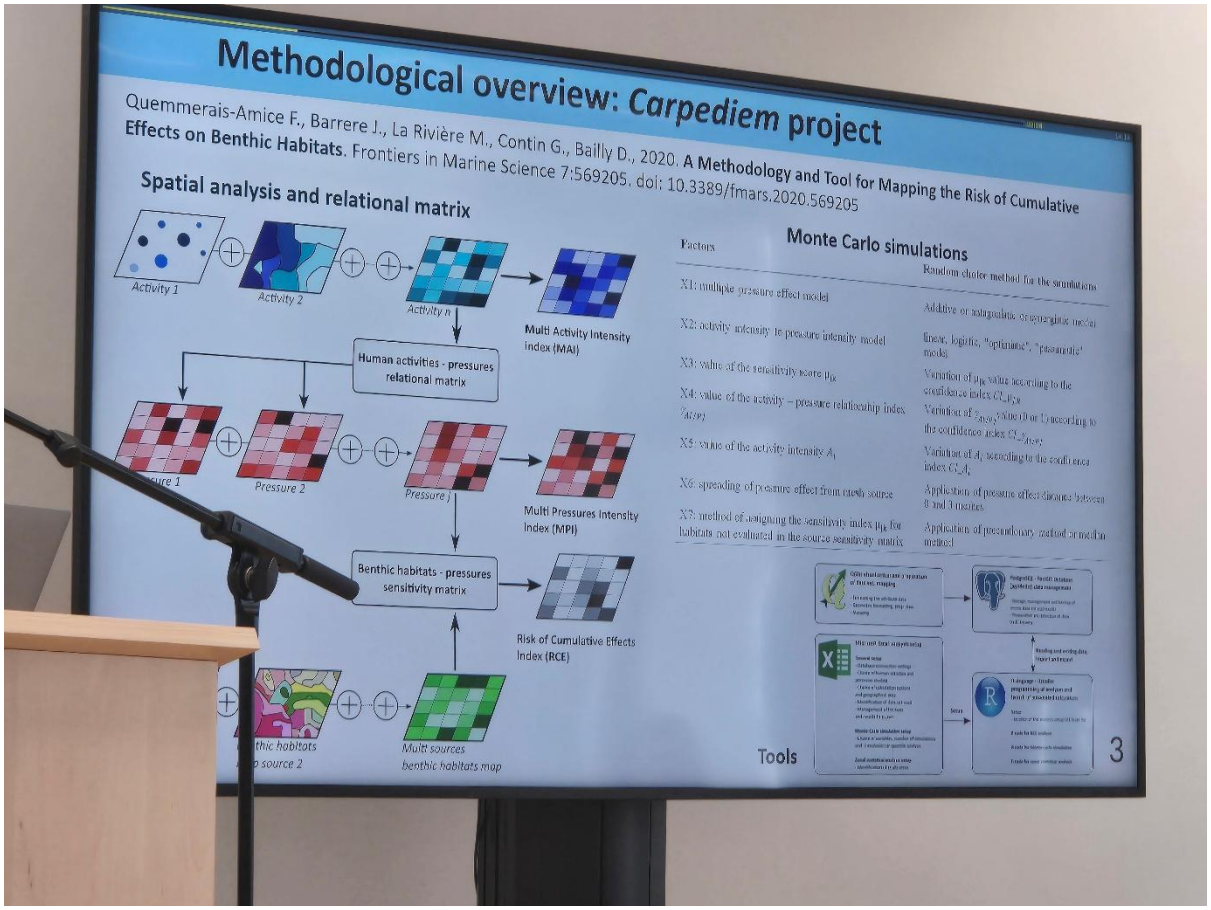
I will present four examples of Cumulative Effects Assessments in French MPAs from recent years (2023-ongoing). Using the same methodology and tool (Carpediem), we evaluated the cumulative effects of human driven physical pressures on benthic habitats.

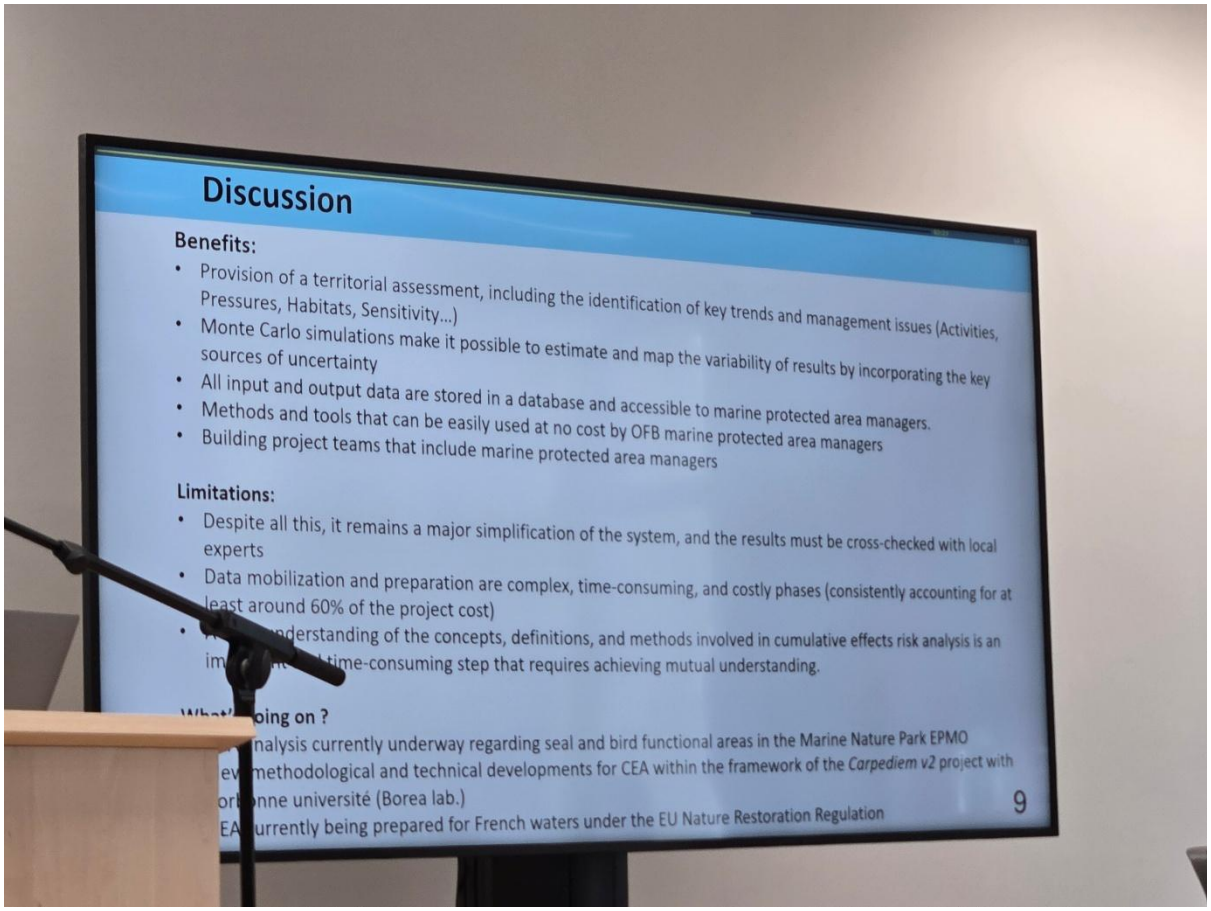
Two studies were conducted as part of the integrated Life Marha project (LIFE 16 IPE/FR001) and concern the Special Areas of Conservation of the Natura 2000 network in the Seine estuary

(English Channel) and the Loire estuary (Bay of Biscay). One study has been underway since 2024 with the Marine Natural Park *Estuaires picards et de la mer d'Opale*, located in the English Channel. One study is being conducted since 2025 with the Marine Natural Park *Cap Corse et Agriate* located in the Mediterranean sea and funded by the European Interreg project Talassa (Italy-France). All these studies were conducted by the French Office for Biodiversity and carried out in close collaboration with the MPAs managers.
This aims to present the different MPAs management issues and needs, the common methodological framework applied, some specific developments that had been carried out, the main results that could inform MPAs managers, the challenges of working with MPAs managers, progress made in implementing this approach, as well as its limitations and constraints.






Methodological overview: Carpediem project
Quemmerais-Amice F., Barrere J., La Rivière M., Contin G., Bailly D., 2020. A Methodology and Tool for Mapping the Risk of Cumulative Effects on Benthic Habitats. Frontiers in Marine Science 7:569205. doi: 10.3389/fmars.2020.569205
Spatial analysis and relational matrix
Activity 1
Activity 2
Activity n
Multi Activity Intensity Index (MAI)
Human activities - pressures relational matrix
Pressure 2
Pressure j
Multi Pressures Intensity Index (MPI)
Benthic habitats - pressures sensitivity matrix
Risk of Cumulative Effects Index (RCE)
Multi sources benthic habitats map
Monte Carlo simulations
Factors
Tools
3


Discussion
Benefits:
Provision of a territorial assessment, including the identification of key trends and management issues (Activities, Pressures, Habitats, Sensitivity...)
Monte Carlo simulations make it possible to estimate and map the variability of results by incorporating the key sources of uncertainty
All input and output data are stored in a database and accessible to marine protected area managers.
Methods and tools that can be easily used at no cost by OFB marine protected area managers
Building project teams that include marine protected area managers
Limitations:
Despite all this, it remains a major simplification of the system, and the results must be cross-checked with local experts
Data mobilization and preparation are complex, time-consuming, and costly phases (consistently accounting for at least around 60% of the project cost)
time-consuming step that requires achieving mutual understanding.
analysis currently underway regarding seal and bird functional areas in the Marine Nature Park EPMO
methodological and technical developments for CEA within the framework of the Carpediem v2 project with
nne université (Borea lab.)
urrently being prepared for French waters under the EU Nature Restoration Regulation
9

A bio-economic modelling framework for evaluating the effects of spatial closures on benthic communities and fisheries

Pierre-Yves Hernvann

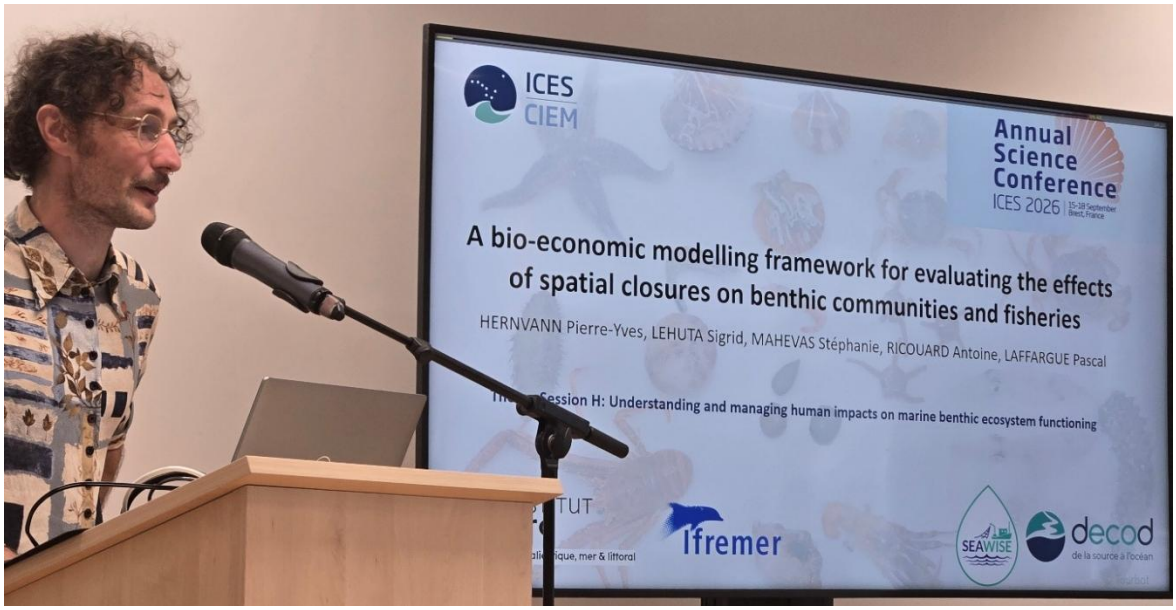
Regulating mobile bottom-contacting gears (hereafter 'bottom trawling') epitomizes the challenge of balancing marine conservation and resource exploitation, calling for operational decision-support tools.

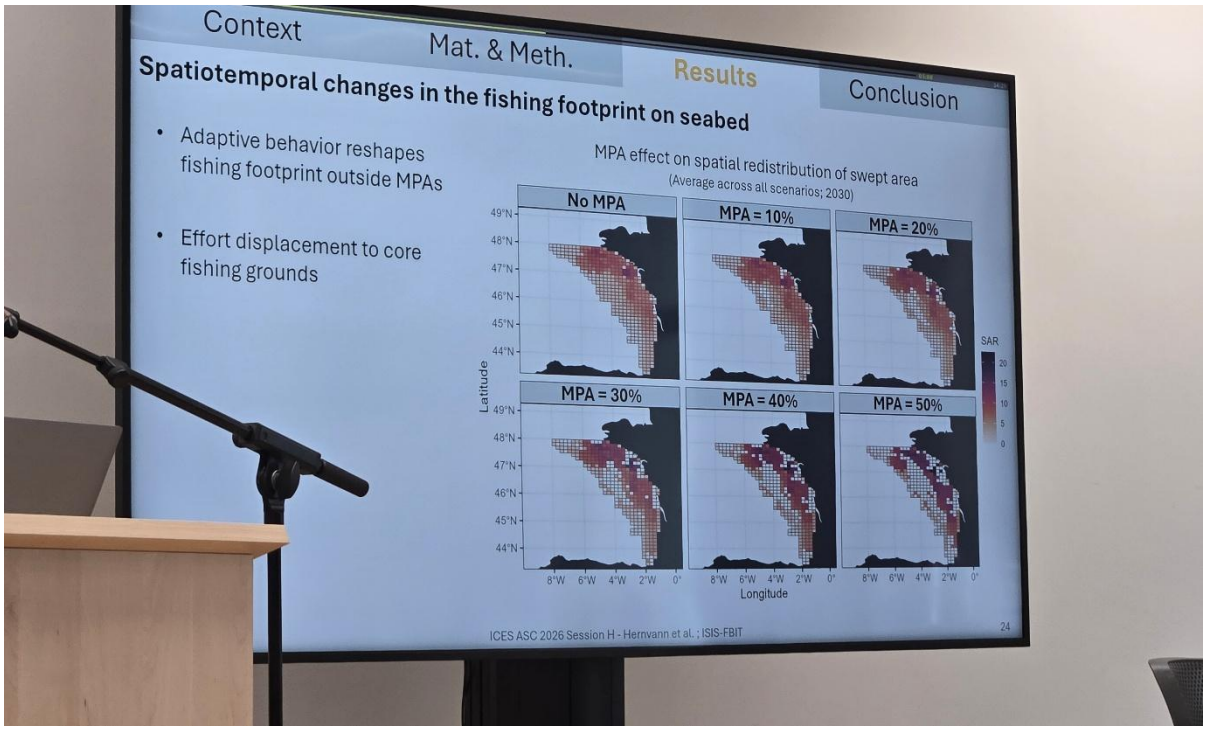
Building on recent advances in monitoring and mapping the relative state of benthic communities, the ICES working group on Fisheries Benthic Impact and Trade-offs of ICES (WGFBIT) proposed areas of spatial restrictions on bottom trawling (MPAs) based on a pragmatic strategy that preserves core fishing grounds by closing the least impacted areas first until a target proportion of the surface area of each habitat is closed to bottom trawling. Although innovative and promising, such an approach does not assess the direct and indirect effects of MPAs on exploited resources, fisheries viability, and cannot account for counter-effects induced by fleet dynamics.

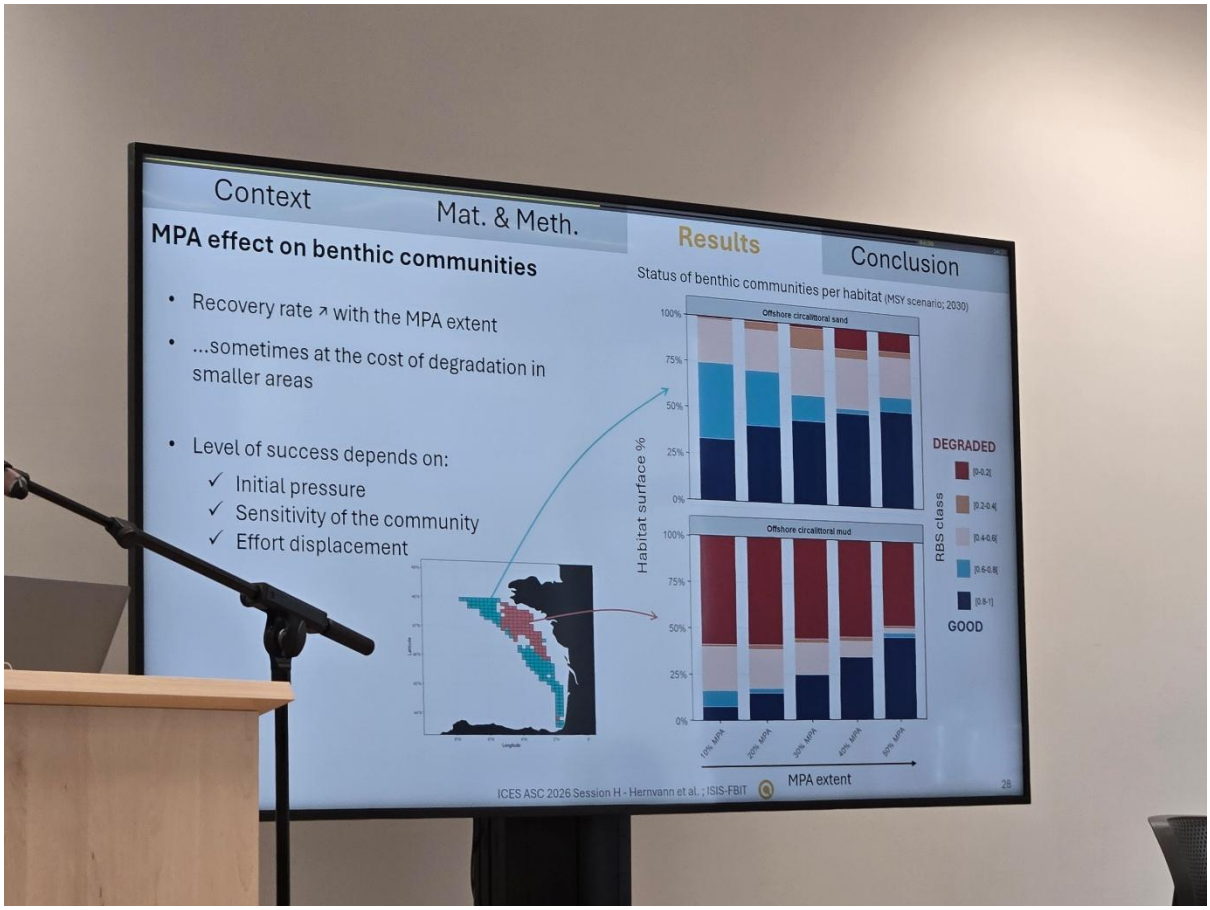
We developed a simulation approach to move beyond MPAs identification and, using the Bay of Biscay as a case study, assess their performance and their consequences on the entire socio-ecosystem. To do so we used the bio-economic multi-species ISIS-Fish model, which simulates stocks' dynamics and technical interactions among the 48 demersal fleets of the BoB mixed fishery and represents fleet responses to management through adaptation of fishing strategies.

Our approach consisted of (i) representing MPA under alternative coverage levels, (ii) predicting fleet responses under different assumptions regarding the redistribution of fishing effort in space and among métiers, (iii) assessing the MPA performance in terms of benthic communities' status, (iv) quantifying the socio-economic consequences for fleets and the entire fishery, and (v) predicting indirect effects on main exploited stocks under alternative non-spatial management measures.

WGBIT strategy to define MPAs appears effective in protecting benthic communities, particularly when more than 30% of habitat surface area is closed, while limiting the proportion of fishing effort lost or redistributed. However, its effectiveness varies among habitats, suggesting differing sensitivities to spatial redistribution of effort. Changes in fleet economic viability reflect MPA-induced shifts in resource accessibility, catchability and target species driven by adaptive fishing strategies. In most configurations, negative impacts are associated with limited diversification within fishing strategies and strong dependence on specific fishing areas. Nevertheless, winners and loosers differ across scenarios combinations, underscoring the sensitivity of outcomes to fishing effort redistribution assumptions and the cascading effects of fleet responses through technical interactions (e.g. choke species dynamics).



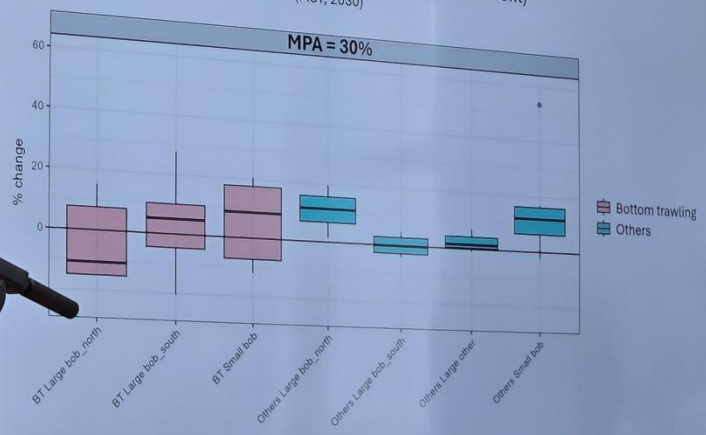

Context
Mat. & Meth.
Results
Conclusion
Spatiotemporal changes in the fishing footprint on seabed
Adaptive behavior reshapes fishing footprint outside MPAs
Effort displacement to core fishing grounds
MPA effect on spatial redistribution of swept area
(Average across all scenarios; 2030)
No MPA
MPA = 10%
MPA = 20%
MPA = 30%
MPA = 40%
MPA = 50%
SAR
Latitude
Longitude
ICES ASC 2026 Session H - Hernvann et al. ; ISIS-FBIT
24


Context
Mat. & Meth.
Results
Conclusion
MPA effect on benthic communities
Recovery rate ↗ with the MPA extent
...sometimes at the cost of degradation in smaller areas
Level of success depends on:
✓ Initial pressure
✓ Sensitivity of the community
✓ Effort displacement
Status of benthic communities per habitat (MSY scenario; 2030)
Offshore circalittoral sand
Offshore circalittoral mud
Habitat surface %
RBS class
DEGRADED
GOOD
MPA extent
ICES ASC 2026 Session H - Hernvann et al. ; ISIS-FBIT
28

Context Mat. & Meth. Results Conclusion

Taking advantage of a socioecosystem modeling framework

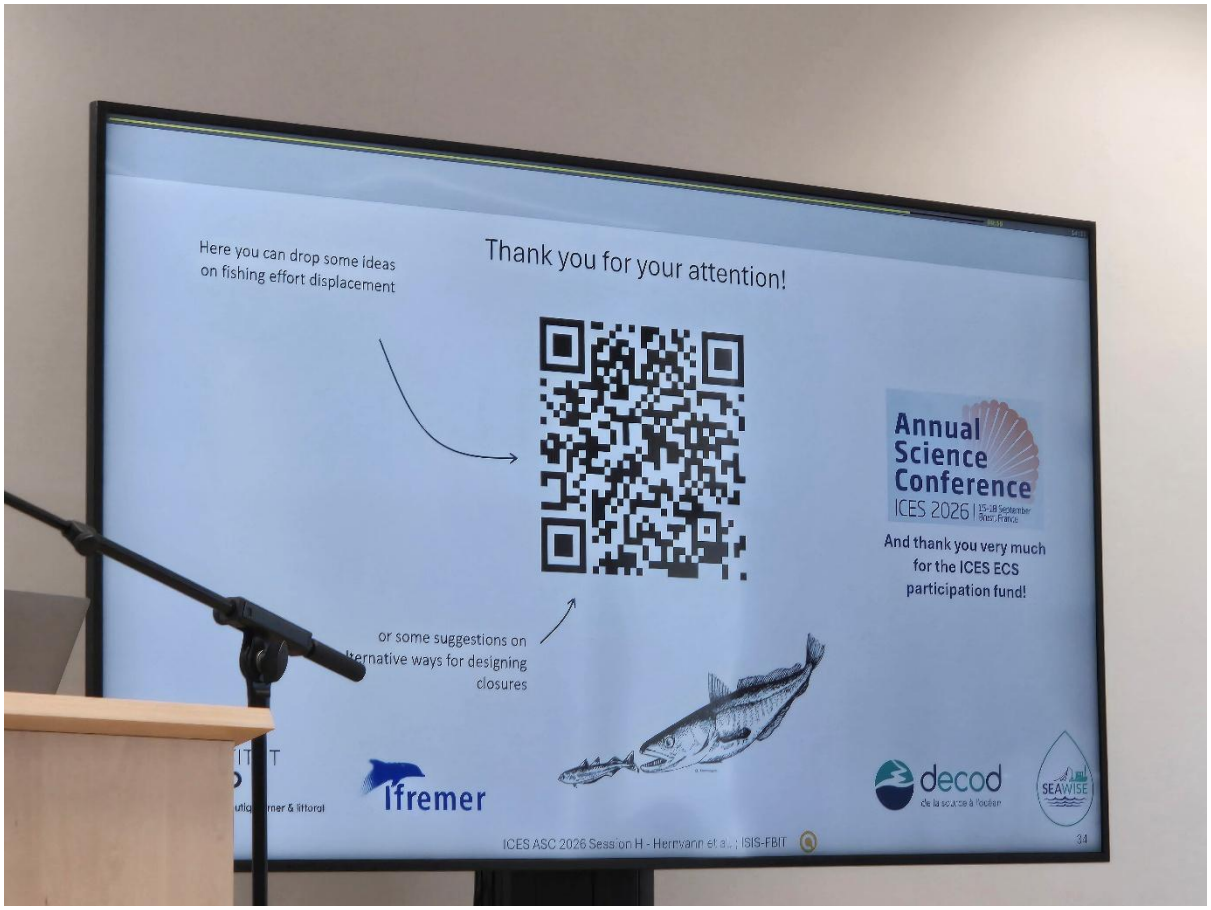
MPA effect on Economic viability of fleets (Gross Profit)
(MSY; 2030)



Context Mat. & Meth. Results Conclusion

KEY TAKE AWAYS!

- MPAs maintaining core fishing grounds can meet objectives of benthic communities protection/restoration
- MPA efficiency varies across habitats!
- Don't forget intricate interactions between management and MPA
- We need more knowledge about fishing behavior to anticipate MPA performance



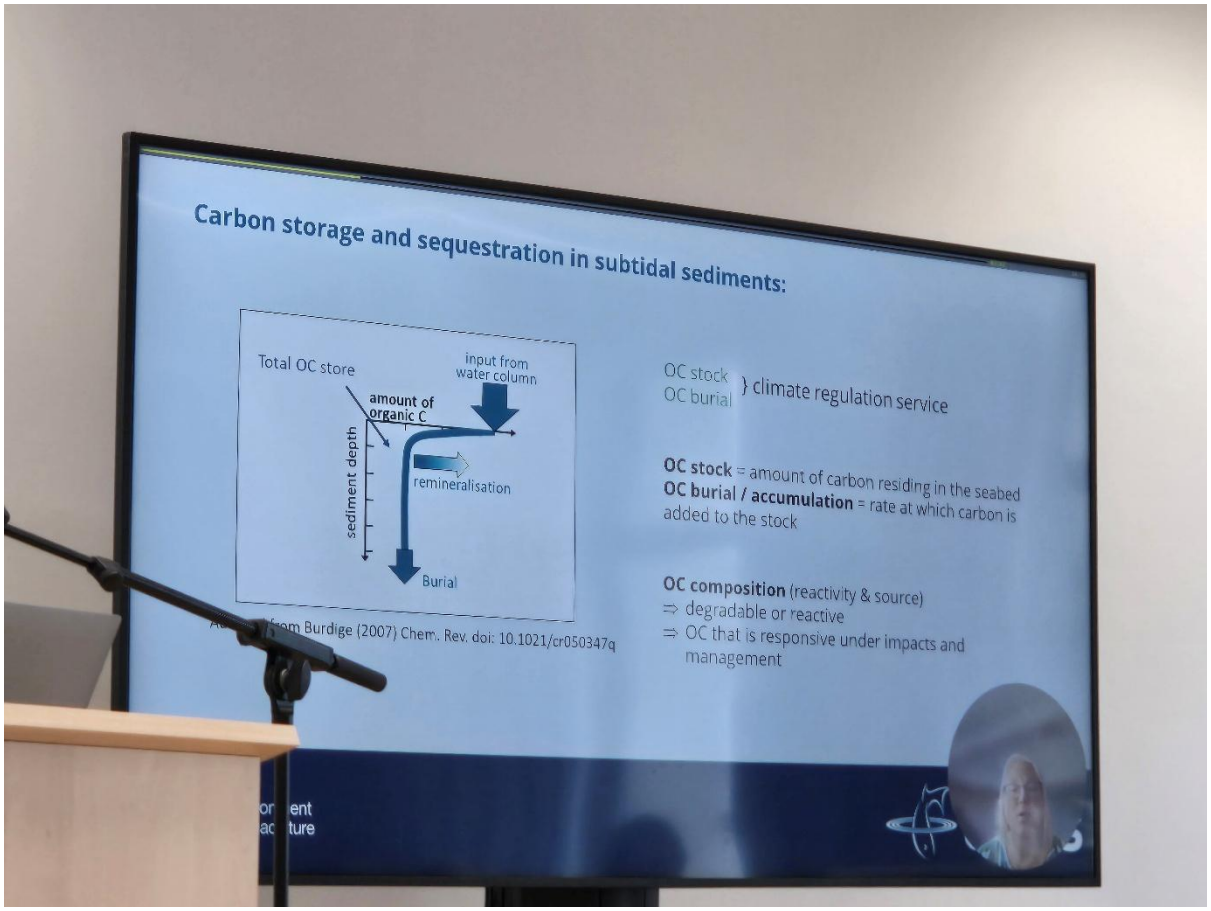
Taking stock of seabed carbon storage and sequestration (Blue Carbon) – future implications for impact, recovery and management interventions
Ruth Parker

The subtidal seabed sedimentary habitats in the UK's English waters contain between 80 and 100 Mt of organic carbon (OC) and so have a significant climate change mitigation potential (as Blue Carbon).
However, much of this organic carbon stock is under pressure and risk of degradation from physical disturbances by various human activities. Management of human activities, including protection or restoration of seabed areas containing OC, may therefore provide a significant Nature-based Solution (NbS) to climate change itself.
We present a case study focused in English waters to highlight key considerations for seabed OC management:

- · Organic carbon storage and burial across the shelf: what drives variability, and what is the role of OC composition, source and reactivity? What are the trade-offs with biodiversity or nature recovery?
- · Present pressures on seabed carbon: Where is OC storage under pressure and risk? By how much? What is the potential impact?
- · Policy and management: How can this evidence base inform spatial management interventions and measures, including protection and recovery measures which promote the potential of the seabed climate change regulation service? How does this interact with biodiversity, food or energy security sectors?

Within each element, insights into the developing evidence base, confidence level and remaining knowledge gaps and priorities will be presented as well as recommendations for future inclusion of carbon considerations within integrated seabed management approaches.


Taking stock of seabed carbon storage and sequestration:
implications for impact and management interventions
SEDIMENT TYPE
81-104 million tonnes of carbon is estimated to be stored in English shelf sediments
Deep mud
Sandy mud
Fine sand
Coarse sand
Shelly sand
Gravel
MUD ~2.5kg C m-2
SAND ~0.5kg C m-2
Team: Ruth Parker, Louise Brown, Richard Heal, Roi Martinez, Robert Brooks, Will
Proctor, Roi Martinez, Claire Powell, Claire Mason, David Hughes, John Aldridge, Rob
Franck Dal Molin, Clement Garcia, David Clare, Clare Hynes, Carolyn
many more...
Department for Environment Food & Rural Affairs
Centre for Environment Fisheries & Aquaculture Science


Carbon storage and sequestration in subtidal sediments:
Total OC store
input from water column
amount of organic C
sediment depth
remineralisation
Burial
from Burdige (2007) Chem. Rev. doi: 10.1021/cr050347q
OC stock
OC burial
} climate regulation service
OC stock = amount of carbon residing in the seabed
OC burial / accumulation = rate at which carbon is added to the stock
OC composition (reactivity & source)
⇒ degradable or reactive
⇒ OC that is responsive under impacts and management

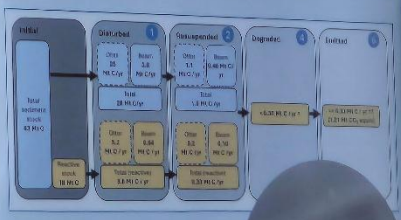
Trawling impacts:

- Gears can impact the bed by mixing or relocation; resuspension and by changes in benthic assemblage (carbon flow diagram)
- **Net** effect on carbon storage and sequestration remains highly uncertain – is highly context dependant (sediment type, gear metier, environmental conditions)



Maximum carbon at risk estimates:
Estimates of total OC disturbed and resuspended (steps 1 and 2)
Combines gear and OC stock information

0.33 Mt labile OC resuspended / yr = > maximum of 1.21 Mt CO_2 equiv / yr emitted (<<<aviation levels but still significant ~ 10% UK car emissions)



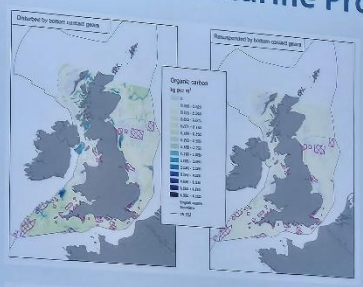
Evidence priorities: Fate of OC once in the water-column (steps 3 to 6 especially) => Net increase or decrease in sink/emission terms?

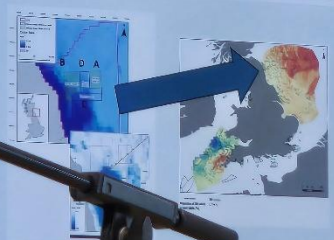
More inform
Evidence revi blished February 2026 covering trawling, infrastructure, climate impacts and m agement measures (See Poster)

Cefas

Parker and Graves 2026
Evidence review: Evidence Review: English seabed sediment carbon storage
Blog: Seabed Carbon Risks: What Our Evidence Show – Marine Science

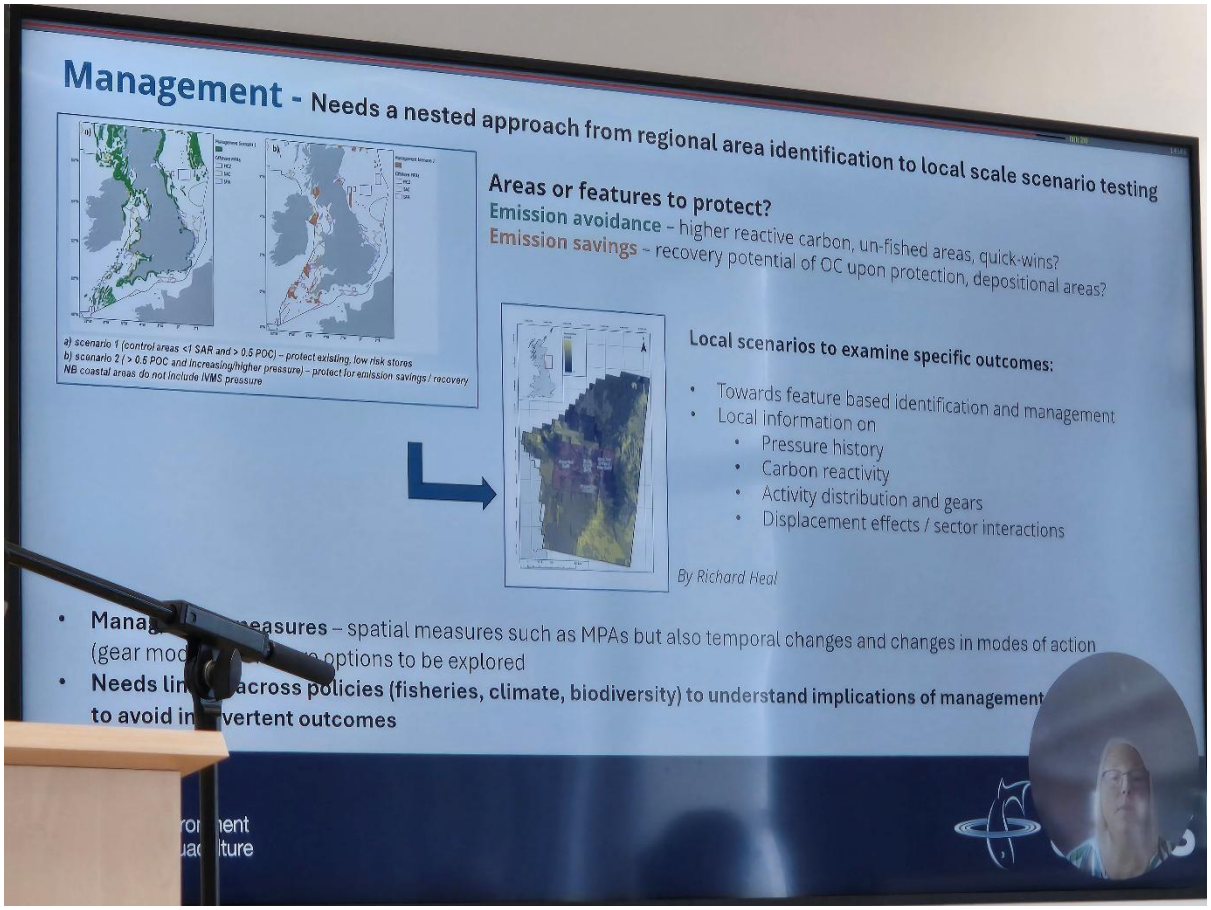
Management: Marine Protected Areas & carbon impact considerations





- **Carbon levels, trawling and MPAs:** Most carbon storage and disturbance is outside network - 19 to 33% stock inside in English waters (see map left)
- **Location of carbon stocks and reactivity is complex – impact history**
  Change in reactivity in chronically fished areas? Is there any risk remaining? Keep trawling in place?
- **Closure can increase OC – fleet interaction and potential release**
  HPMA example; area of low OC; surrounded by higher stocks
  Relocation of effort => 5-10% increase in reactive OC disturbance upon protection
- **Trawling effort relocation / displacement is key to overall net outcomes –** fishers response behaviour and assumptions; socio-economic decisions
- **Blanket closure / protection of MPA network may not deliver for net zero/carbon objectives and drive inadvertent outcomes**

From Par and Graves, 2026 (R. Heal)


Management - Needs a nested approach from regional area identification to local scale scenario testing
a) scenario 1 (control areas <1 SAR and > 0.5 POC) – protect existing, low risk stores
b) scenario 2 (> 0.5 POC and increasing/higher pressure) – protect for emission savings / recovery
NB coastal areas do not include IVMS pressure
Areas or features to protect?
Emission avoidance – higher reactive carbon, un-fished areas, quick-wins?
Emission savings – recovery potential of OC upon protection, depositional areas?
Local scenarios to examine specific outcomes:
Towards feature based identification and management
Local information on
Pressure history
Carbon reactivity
Activity distribution and gears
Displacement effects / sector interactions
By Richard Heal
Needs lin across policies (fisheries, climate, biodiversity) to understand implications of management to avoid in vertent outcomes


Thank you for listening
To find out more:
Ruth.parker@cefas.gov.uk
To learn about Cefas scan the QR code or visit
linktr.ee/CefasGovUK
SCAN ME
Cefas

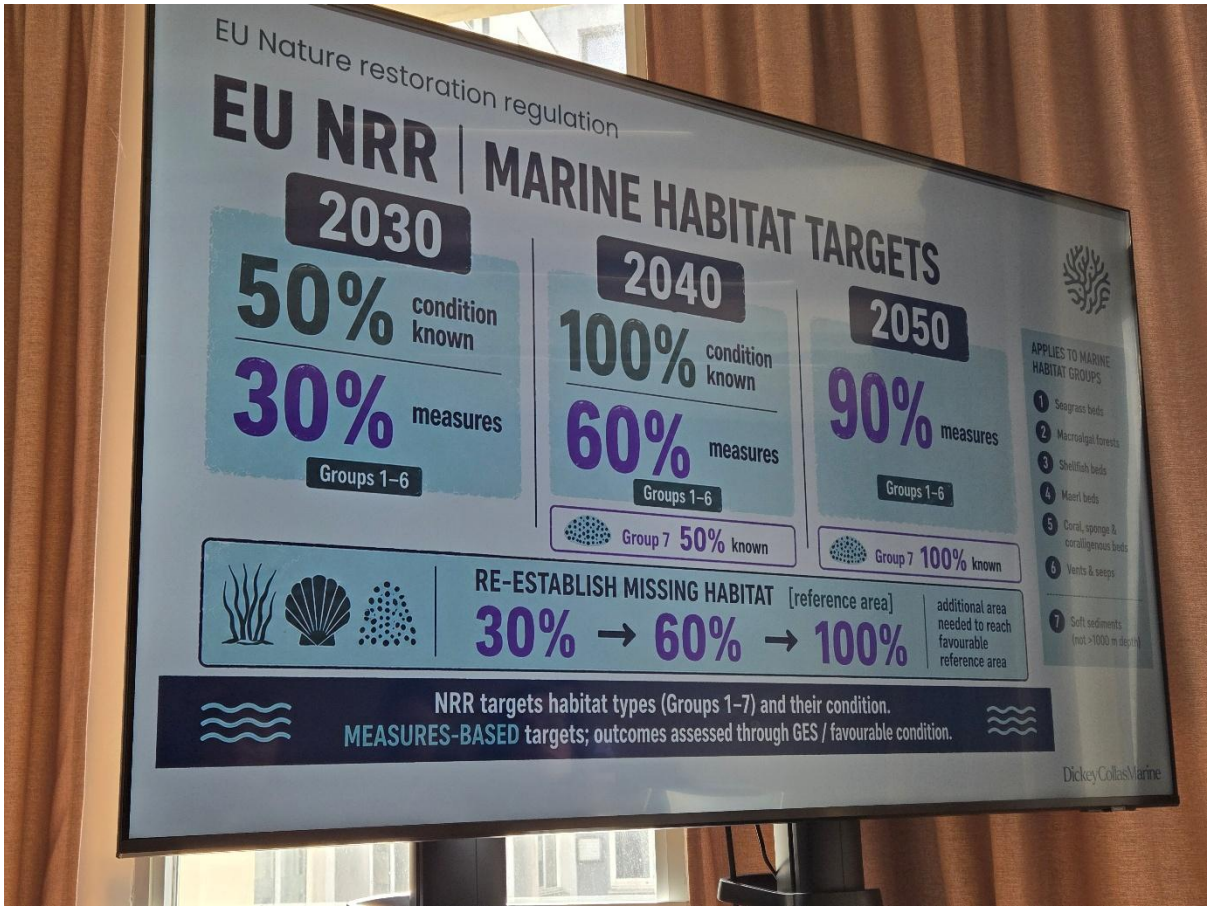
What Counts as Restoration on Working Fishing Grounds? From concepts to practical management.

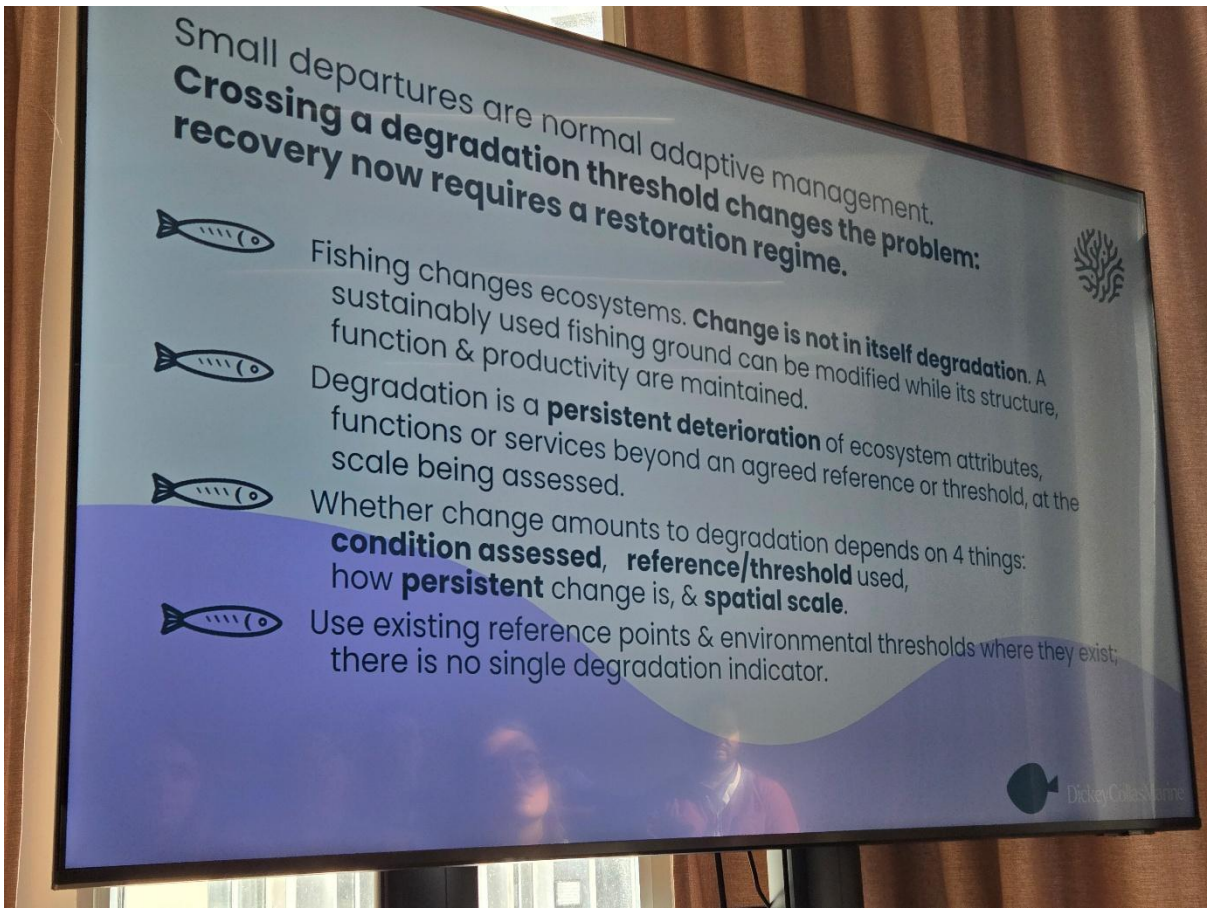
Mark Dickey-Collas

Binding commitments on ecosystem restoration are now impacting the practical reality that most marine space is used, managed, and socially contested. In fished seascapes, “degradation” and “restoration” are often invoked without an agreed reference, without operational limits, and without a conceptual understanding of restoration in productive systems.

This contribution synthesises recent conceptual developments around fisheries and restoration into a framework for “restoring fished seascapes”. It proposes a shared logic for ecological condition in systems that are both productive and changing, distinguishing productivity and ecosystem change from degradation. It translates that logic into operational recovery benchmarks and indicators that can be tracked using existing fisheries and marine data streams. It recommends a co-development approach for agreeing thresholds, decision rules, and review cycles, so that restoration planning recognises fishers’ stewardship options, avoids simply displacing pressure, and clarifies how management responses escalate when risk remains high.

The output is a practical concept-to-management pathway: a small set of condition classes, a decision tree for “what counts”, and a minimum monitoring package linked to management triggers. It is intended to support socially legitimate, ecologically sound transitions where restoration objectives and sustainable fisheries management are treated as interdependent, not competing, goals.





From habitat to harvest: practical restoration measures and reporting evidence that work for fisheries

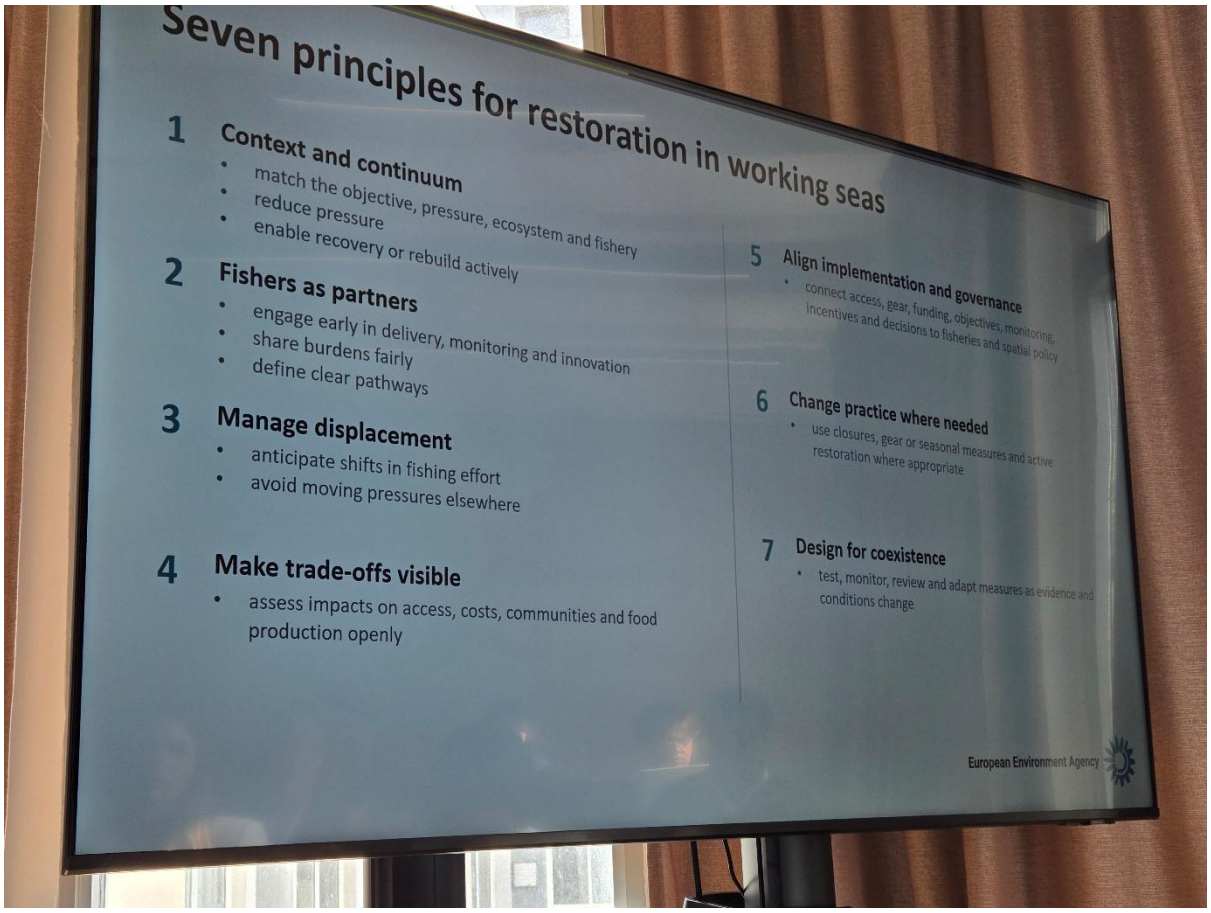
Eirini Glyki

Binding commitments are moving marine restoration from ambition to delivery. GBF Target 2 and the EU Nature Restoration Regulation (NRR) both require substantial progress by 2030, while raising questions for fished systems: how to distinguish change of productive ecosystems from degradation, and how to define “restored” in working seascapes.

This contribution will synthesise the expected outcomes of the April 2026 workshop **“**From Habitat to Harvest: restoration that works for fishers”. The workshop was designed to position fisheries as active contributors to habitat restoration and to clarify how fisheries management can support NRR implementation through practical, workable measures. It focused on productive fishing grounds, mixed-use areas and working seascapes. Participants were fishers, nature restoration planners and researchers thus provide a broad spectrum of views and experiences.

The presentation will distil the workshop-level findings, resulting in a transferable set of insights on opportunities and constraints to deliver and provide evidence of restoration where fishing continues.





Clarifying Marine Restoration Pathways: Disentangling MPAs, Nature-based Solutions, Hybrid Approaches and Grey Infrastructure
Louise C. Flensborg

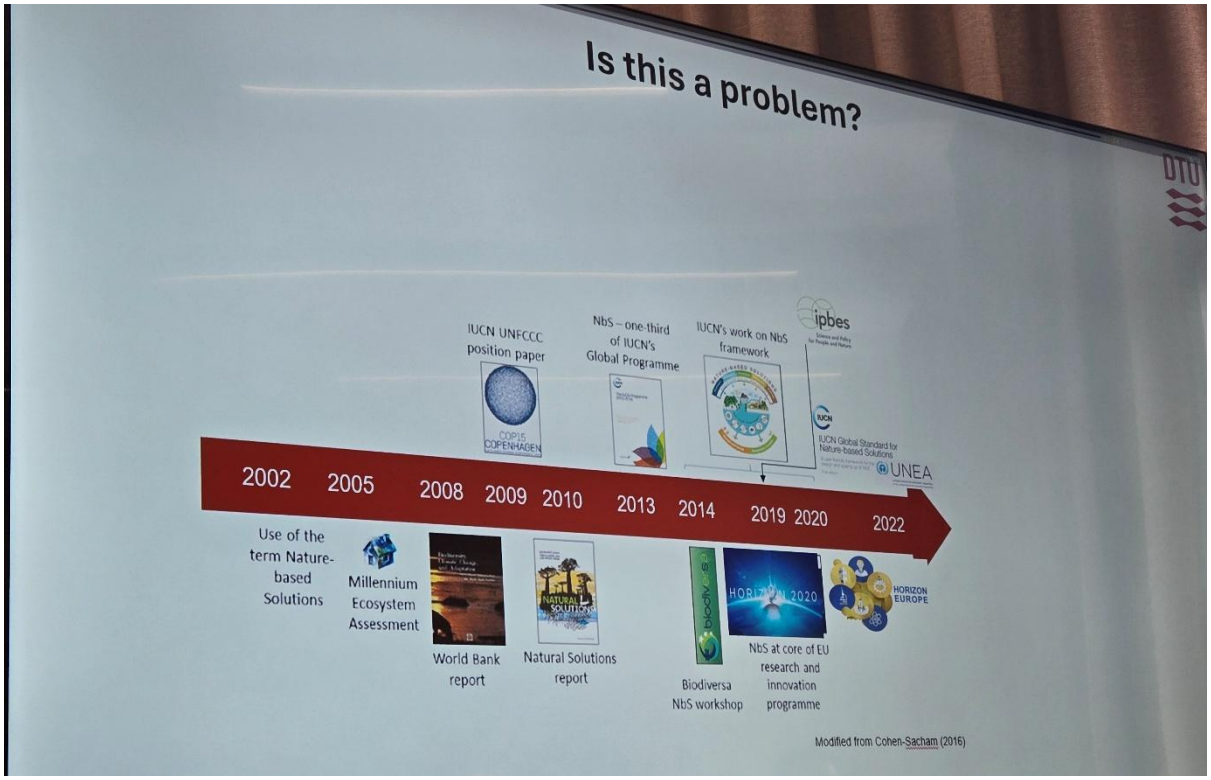
Marine and coastal ecosystems are facing accelerating biodiversity loss and declining ecological condition due to climate change, overexploitation, pollution, habitat conversion, and expanding coastal infrastructure. The scale of degradation demands ambitious and coherent restoration efforts. In response, a range of approaches has emerged, including Marine Protected Areas (MPAs), Nature-based Solutions (NbS), Nature-Inclusive Design (NID), hybrid solutions

combining ecological and engineered elements, and conventional grey infrastructure. Although often grouped under shared sustainability narratives, these interventions differ significantly in objectives, mechanisms, spatial scale, and conservation ambition. Clear distinctions are essential to ensure that actions contribute to genuine ecosystem recovery rather than simply mitigating impacts.

The EU-funded TRANSEATION project examines how these restoration and protection measures are conceptualized and implemented, synthesizing evidence from 113 peer-reviewed studies. The analysis reveals substantial terminological ambiguity particularly where NbS are conflated with MPAs, NID, hybrid coastal solutions, and wide variation in restoration scale and monitoring approaches. This lack of conceptual clarity and standardized assessment limits comparability weakens evidence-based decision-making, and obscures whether interventions are sufficient to improve ecological status at meaningful scales.

By disentangling these approaches and mapping their scale and intent, the project highlights the urgent need for harmonized definitions, evaluation criteria, and science-based guidance to align marine restoration efforts.





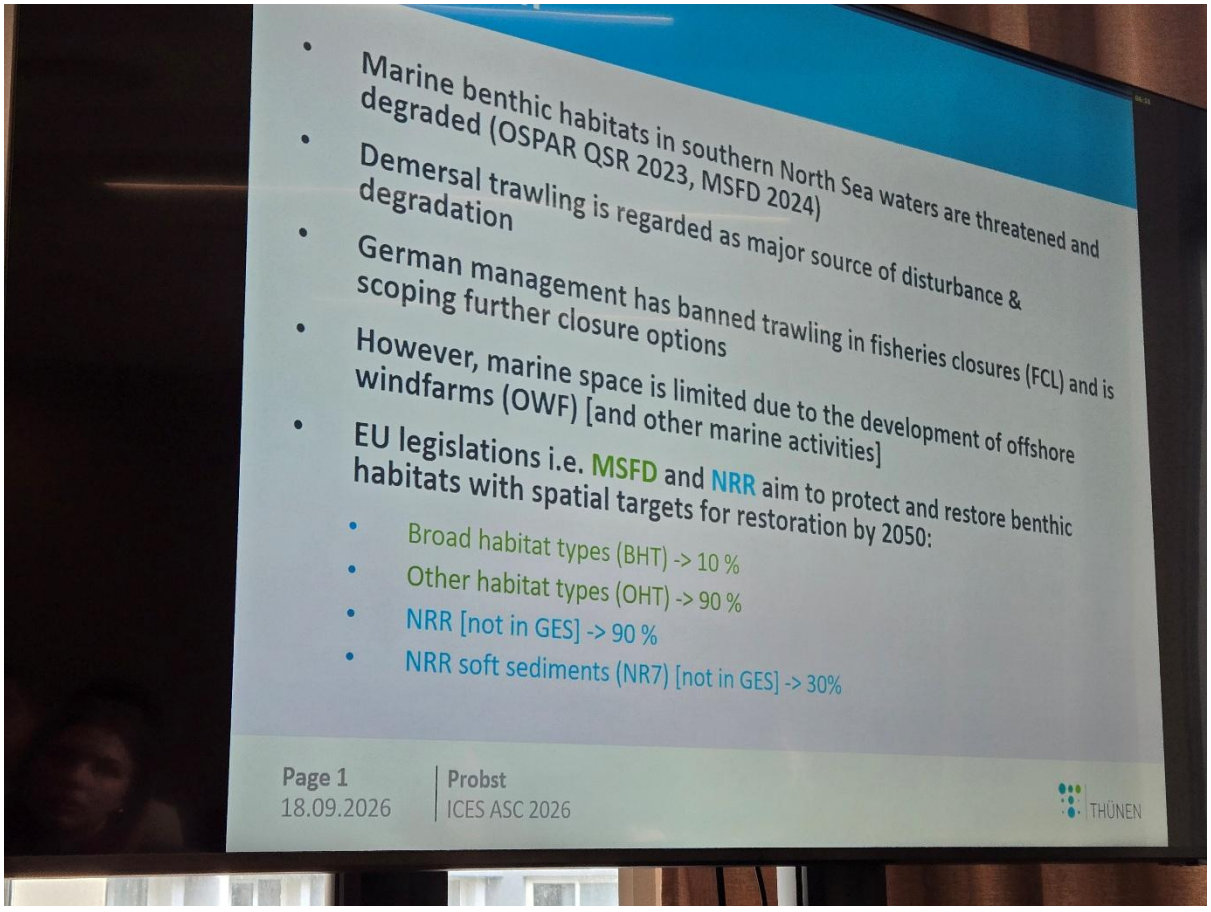


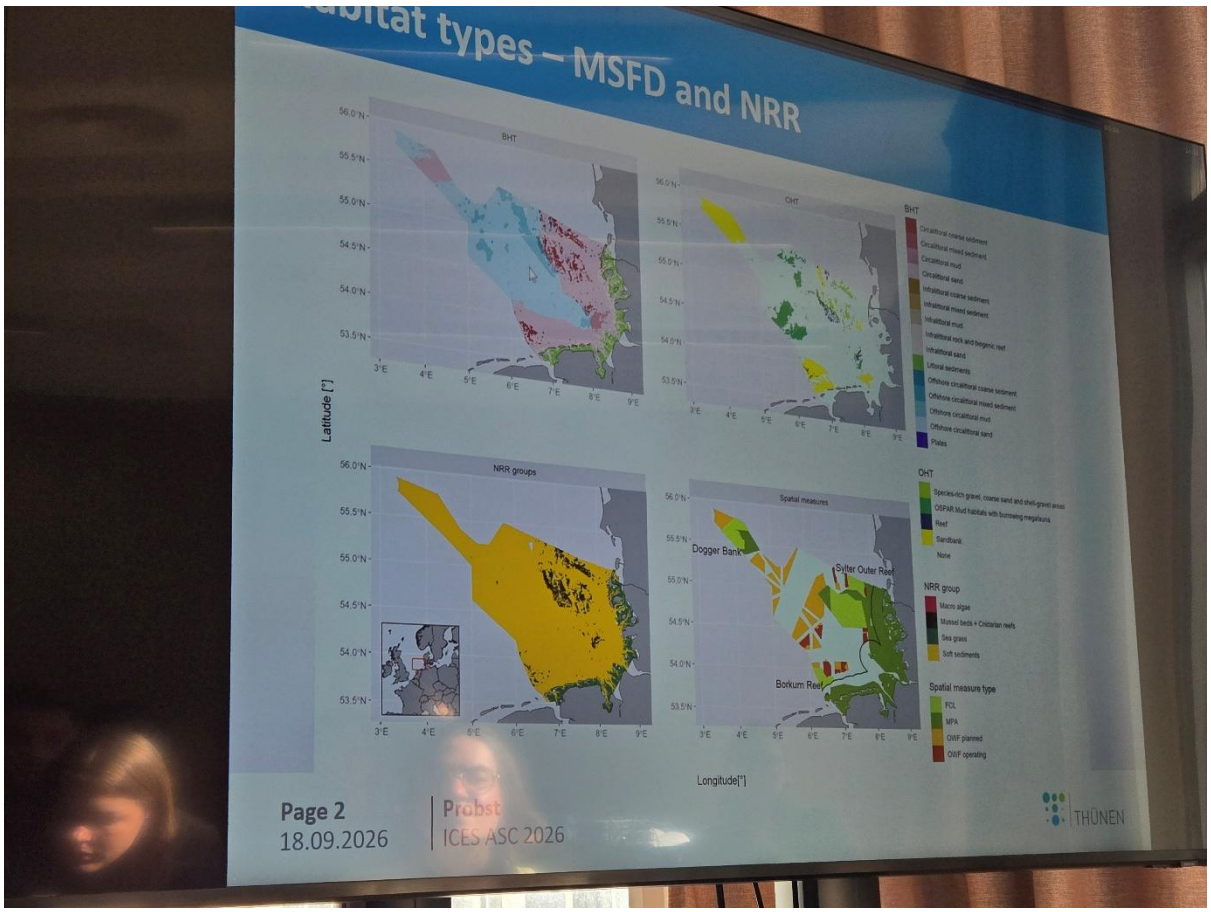
A sea full of measures: EU conservation goals for benthic habitats will require wide-ranging spatial measures

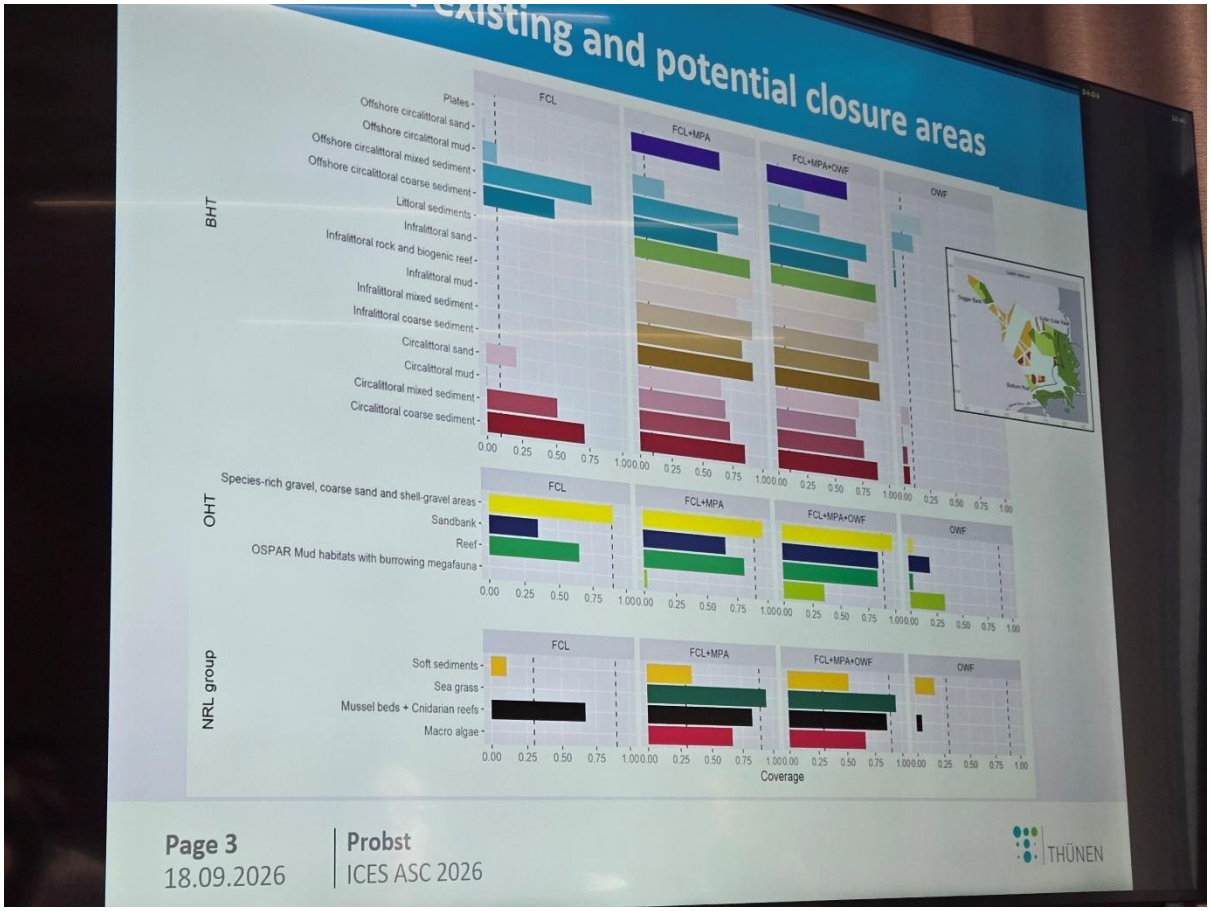
W. Nikolaus Probst

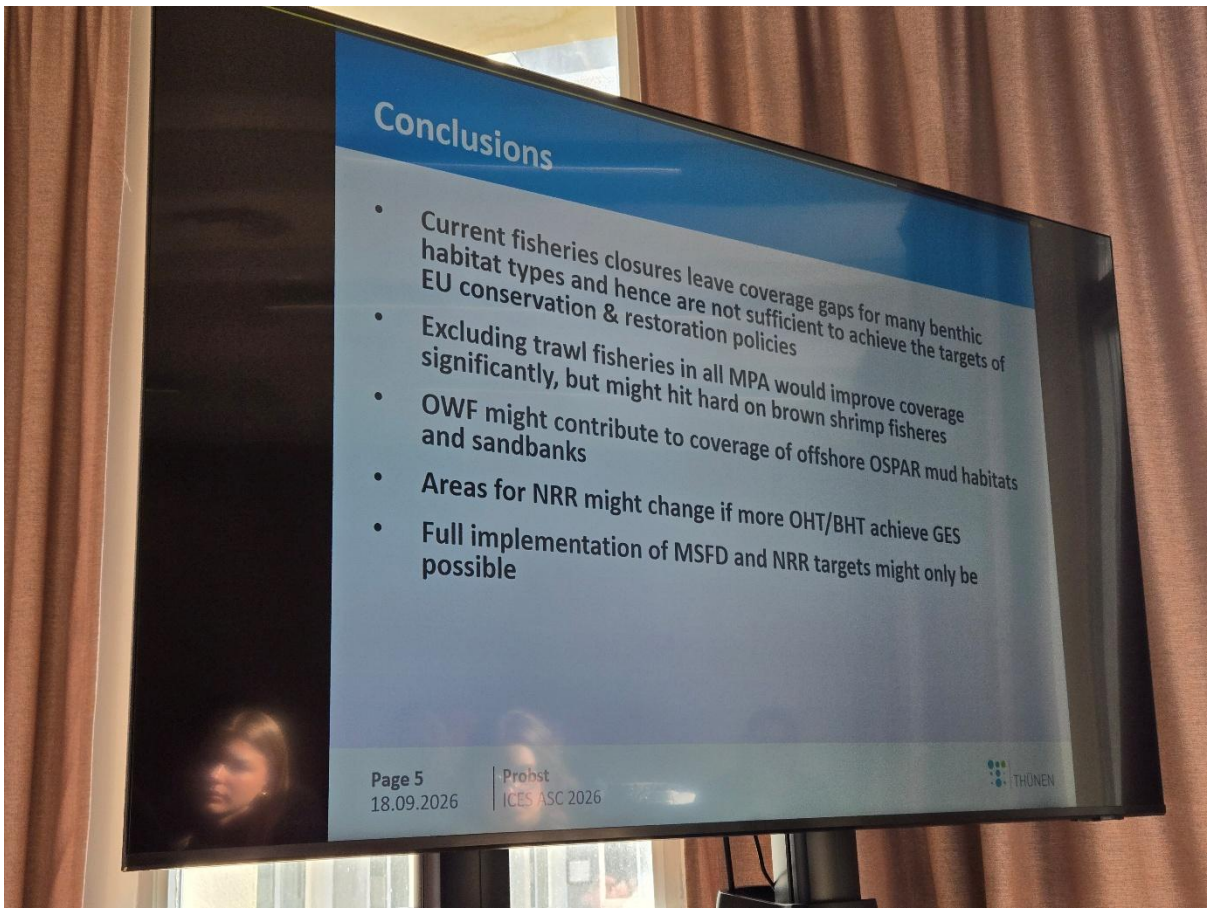
The use of marine space by human activities is continuously increasing, resulting in a competition between human use and spatial measures for marine conservation. The EU Marine Strategy Framework Directive (MSFD) and the Nature Restoration Law (NRL) are two important legal means to implement ambitious spatial conservation targets for benthic habitats within the waters of EU member states. This study analysis how the targets of MSFD and NRL are currently met in the German waters of the North Sea and which areas the full implementation of both legislations might require. The current spatial conservation measures, which ban demersal trawling within certain zones of designated marine protected areas (MPA), are not sufficient to reach the targets of the MSFD and NRL. Extending the exclusion of demersal trawling to the entire area of the MPAs would increase the average coverage for all habitat types/groups from 19 % to 73 % except for offshore sand and mud habitats. These could be further protected, when including areas for offshore wind farms, where trawling is also banned. However, to date it is unclear, if and how these (or other human use) areas could be included legally into spatial conservation regimes. Hence a debate on how to better combine human activities with spatial conservation targets is urgently needed to allow for the achievement of the ambitious MSFD and NRL targets in marine waters of EU member states.


THÜNEN
A sea full of measures: EU conservation goals for benthic habitats will require wide-ranging spatial measures


Marine benthic habitats in southern North Sea waters are threatened and degraded (OSPAR QSR 2023, MSFD 2024)
Demersal trawling is regarded as major source of disturbance & degradation
German management has banned trawling in fisheries closures (FCL) and is scoping further closure options
However, marine space is limited due to the development of offshore windfarms (OWF) [and other marine activities]
EU legislations i.e. MSFD and NRR aim to protect and restore benthic habitats with spatial targets for restoration by 2050:
Broad habitat types (BHT) -> 10 %
Other habitat types (OHT) -> 90 %
NRR [not in GES] -> 90 %
NRR soft sediments (NR7) [not in GES] -> 30%
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habitat types – MSFD and NRR
BHT
OHT
NRR groups
Spatial measures
Dogger Bank
Sylter Outer Reef
Borkum Reef
Latitude [°]
Longitude[°]
BHT
OHT
NRR group
Spatial measure type
FCL
MPA
OWF planned
OWF operating
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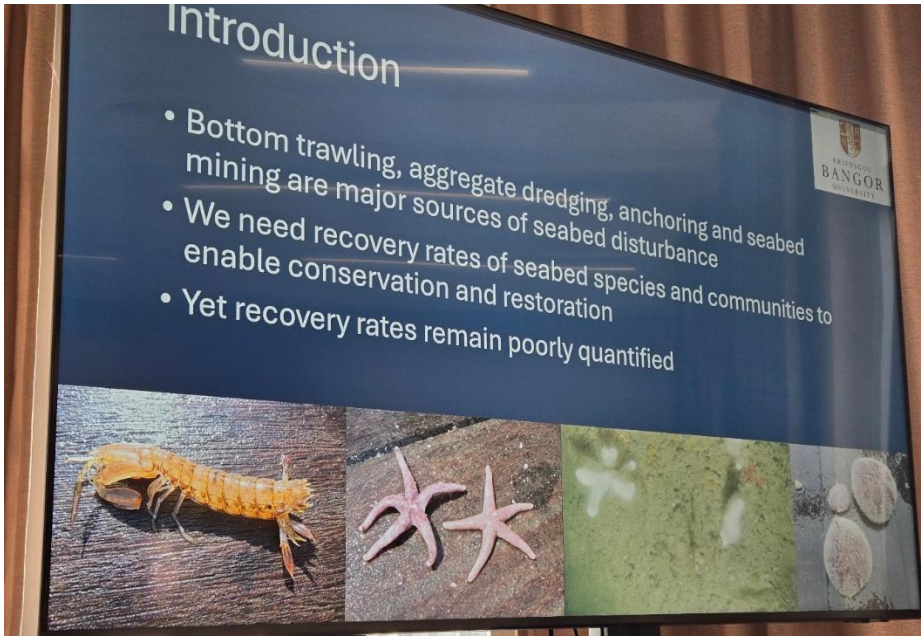

existing and potential closure areas
BHT
Plates
Offshore circalittoral sand
Offshore circalittoral mud
Offshore circalittoral mixed sediment
Offshore circalittoral coarse sediment
Littoral sediments
Infralittoral sand
Infralittoral rock and biogenic reef
Infralittoral mud
Infralittoral mixed sediment
Infralittoral coarse sediment
Circalittoral sand
Circalittoral mud
Circalittoral mixed sediment
Circalittoral coarse sediment
FCL
FCL+MPA
FCL+MPA+OWF
OWF
OHT
Species-rich gravel, coarse sand and shell-gravel areas
Sandbank
Reef
OSPAR Mud habitats with burrowing megafauna
NRL group
Soft sediments
Sea grass
Mussel beds + Cnidarian reefs
Macro algae
Coverage
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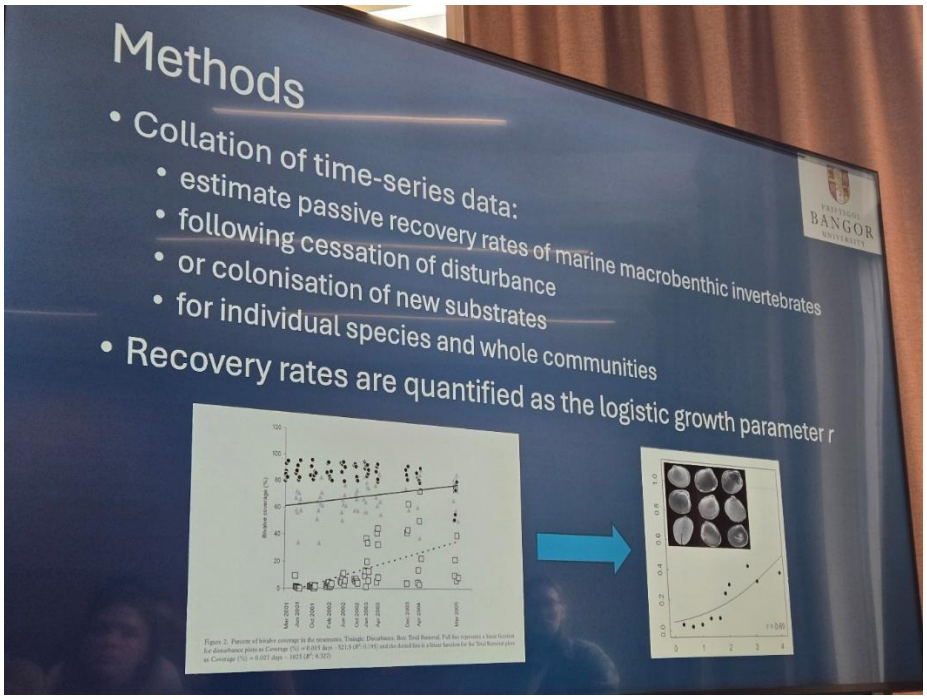


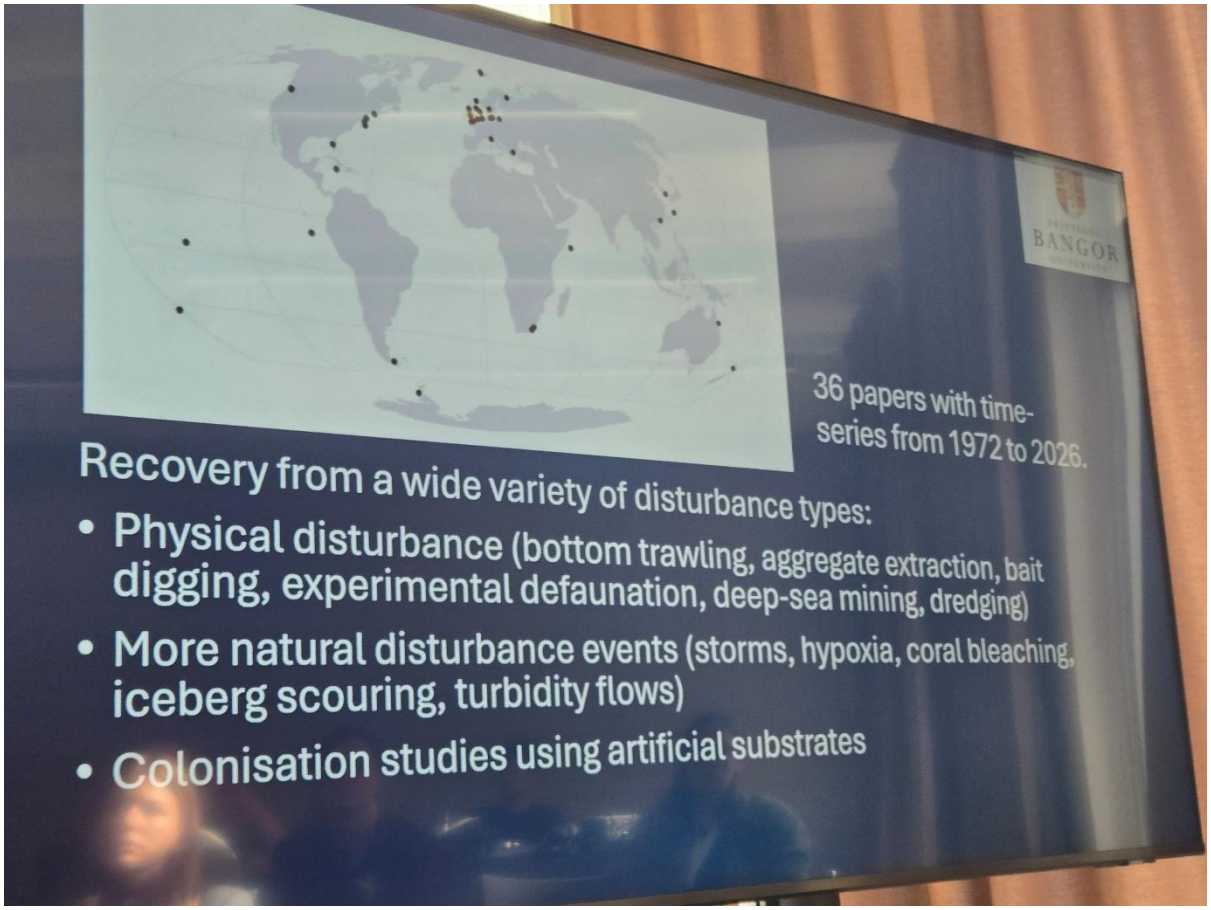
Empirical estimates of recovery after cessation of disturbance for benthic invertebrates
Jan Geert Hiddink

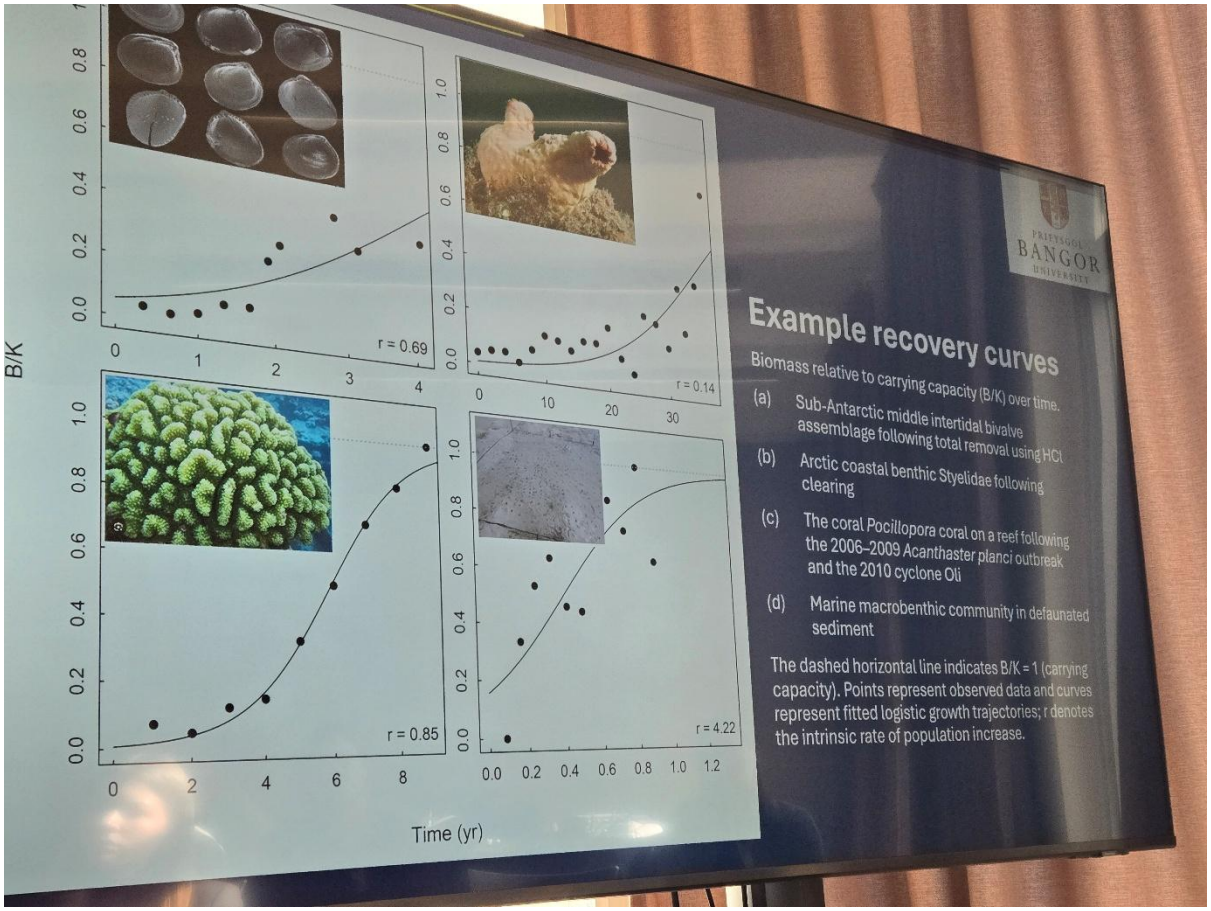
Recovery of benthic invertebrate communities following disturbance is a key process governing the resilience of seabed ecosystems exposed to human pressures such as bottom trawling, aggregate dredging, and emerging activities including seabed mining. Quantifying and predicting recovery rates is essential for conservation planning and for balancing exploitation with the protection of vulnerable habitats. However, robust predictors of recovery remain limited.
Here, empirical time-series data were collated from published studies to evaluate the drivers of passive recovery in marine macrobenthic invertebrates after events or interventions that substantially depleted abundance or biomass, or created newly available substrate. Studies were included across all substrate types, spanning recovery after cessation of disturbance as well as colonisation following the introduction of new substrates, and covering both individual species and whole communities. Abundance and biomass trajectories were extracted and logistic population growth curves were fitted to estimate the logistic recovery parameter *r*.
Recovery rates were highly variable across taxa and settings, but clear environmental patterns emerged. Average recovery rates were significantly higher on sediment compared with hard substrates. Recovery rate decreased with increasing depth and with the spatial scale of the disturbance. Biomass recovered more slowly than abundance, indicating that functional recovery may lag behind numerical recolonisation.
These results demonstrate that recovery rates can be quantitatively estimated from time-series data and strongly structured by environmental context. Slower recovery on hard substrates, in deeper waters, and after larger disturbances provides a basis for improving predictive frameworks for habitat and species recovery. Linking recovery rates to life-history constraints such as maximum lifespan allows advancement of mechanistic prediction of seabed resilience under anthropogenic pressure.


Empirical estimates of recovery after cessation of disturbance for benthic invertebrates
Jan Geert Hiddink


Introduction
• Bottom trawling, aggregate dredging, anchoring and seabed mining are major sources of seabed disturbance
• We need recovery rates of seabed species and communities to enable conservation and restoration
• Yet recovery rates remain poorly quantified

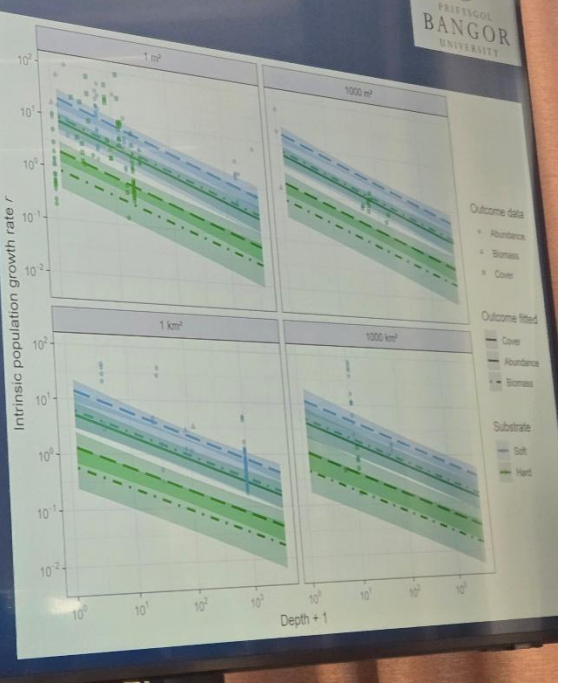

Methods
• Collation of time-series data:
• estimate passive recovery rates of marine macrobenthic invertebrates
• following cessation of disturbance
• or colonisation of new substrates
• for individual species and whole communities
• Recovery rates are quantified as the logistic growth parameter r


BANGOR
36 papers with time-series from 1972 to 2026.
Recovery from a wide variety of disturbance types:
• Physical disturbance (bottom trawling, aggregate extraction, bait digging, experimental defaunation, deep-sea mining, dredging)
• More natural disturbance events (storms, hypoxia, coral bleaching, iceberg scouring, turbidity flows)
• Colonisation studies using artificial substrates


B/K
r = 0.69
r = 0.14
r = 0.85
r = 4.22
Time (yr)
BANGOR
Example recovery curves
Biomass relative to carrying capacity (B/K) over time.
(a) Sub-Antarctic middle intertidal bivalve assemblage following total removal using HCl
(b) Arctic coastal benthic Styelidae following clearing
(c) The coral Pocillopora coral on a reef following the 2006–2009 Acanthaster planci outbreak and the 2010 cyclone Oli
(d) Marine macrobenthic community in defaunated sediment
The dashed horizontal line indicates B/K = 1 (carrying capacity). Points represent observed data and curves represent fitted logistic growth trajectories; r denotes the intrinsic rate of population increase.

Communities and species

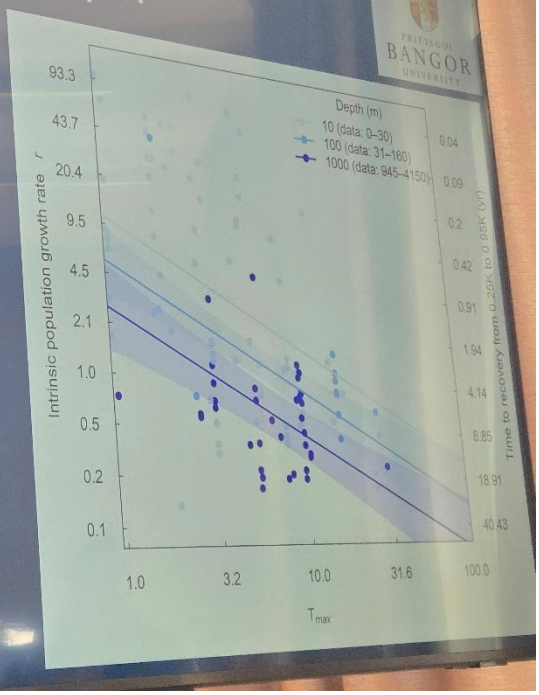
- Sedimentary substrates > hard substrates
- Declined with water depth
- Lower for larger disturbances
- Biomass < abundance, indicating that functional recovery lags behind numerical recolonisation.

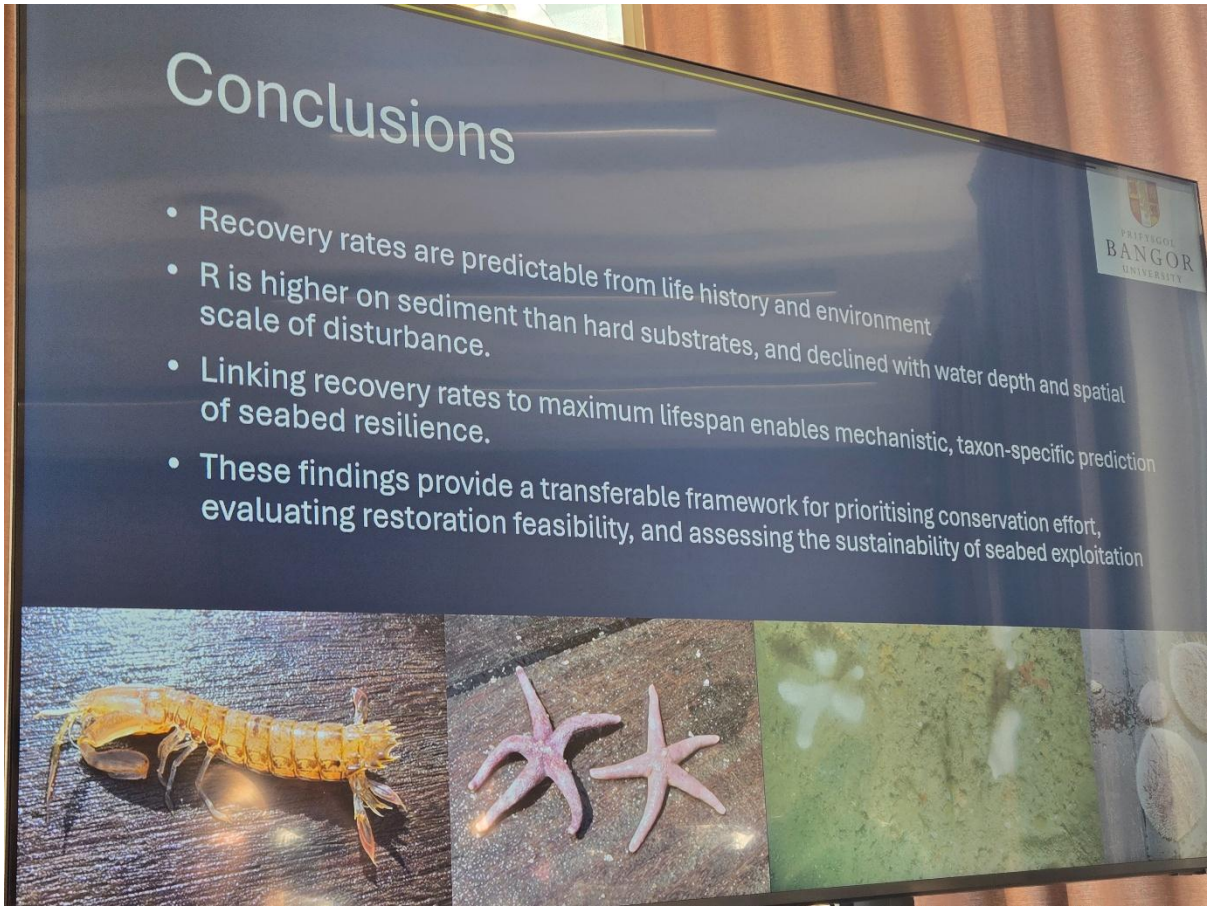


Species: longevity and depth

Recovery rate ~ maximum lifespan

This is consistent with life-history theory and providing a basis for mechanistic, taxon-specific prediction of recovery





AI is a tool, not a sledgehammer – the challenges of universally applying AI and how to improve data transparency
Georgina Vickery

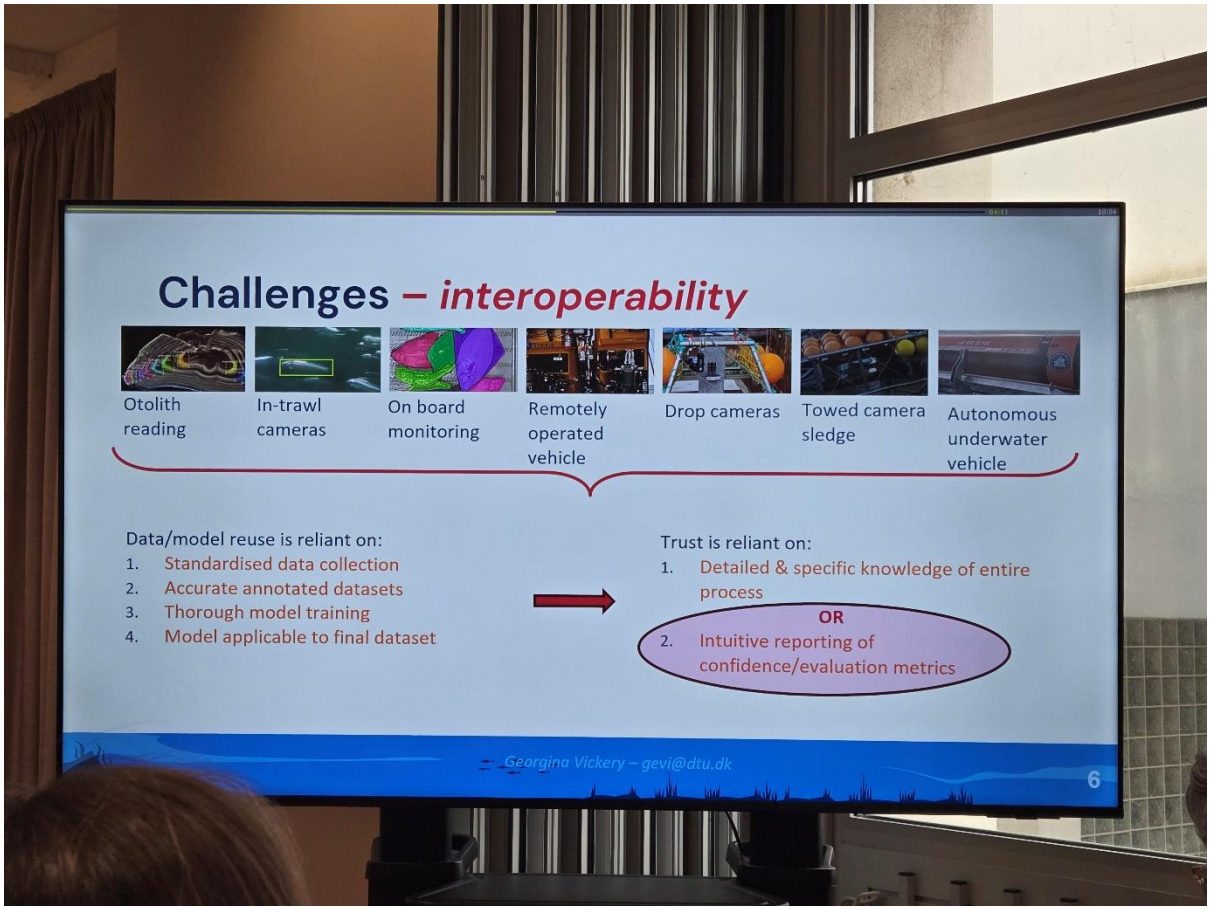
AI in fisheries monitoring is often presented as an immediate solution for improving efficiency and expanding data extraction from underwater video surveys. However, effective AI deployment depends on data quality and relevance to the task. Video from towed or drift cameras, remotely operated vehicles (ROVs) or other equipment existed long before AI, with many time series spanning decades. Therefore these data-rich video transects were optimised for manual processing, resulting in increased biases and uncertainties when coercing AI to extract additional information from these data sources.

This talk explores solutions to retrospectively applying AI to existing data, with discussion on current obstacles to the routine use of AI. The king crab stock assessment by the Institute of Marine Research in Norway was used as case study, whereby AI was applied to forward facing video to extract counts of additional taxa and crab carapace lengths. To address the issues emerging from this processing and facilitate automation of routine surveys, AI models to process acoustic data and imagery from autonomous underwater vehicles (AUVs) were developed. This increase in AI-derived data highlighted the challenge of integrating these species counts and lengths into existing database structures for wider use. Recommendations to facilitate data transparency include developing a systematic identifier, similar to a gear code. As a minimum, this identifier should incorporate model specifications, including detection confidence and evaluation metrics. This would increase interoperability of AI-derived data and facilitate dataset integration.

A final overlooked limitation is the range in methods used to calculate the area surveyed by underwater observation platforms, with the chosen method strongly impacting final density

estimates. A standardised approach is presented in Vickery et al., 2026, which uniquely includes the associated uncertainty. Although not specific to AI, this step is fundamental to integrating AI-derived outputs into stock assessment frameworks.





From AIS pings to behaviour: Practical challenges for marine AI
Hjalti Danielsson

As machine learning is explored for fisheries monitoring, practical challenges emerge during system implementation. We share lessons from developing a Data Analysis Engine (DAE) to model vessel behaviour from AIS, VMS and sometimes catch data, with the goal of detecting potentially IUU-related activity.

In an initial prototype phase using AIS data from multiple fleet types within the Icelandic EEZ, two broad challenges became apparent: how to represent vessel behaviour from AIS transmissions, and how to model that behaviour once represented.

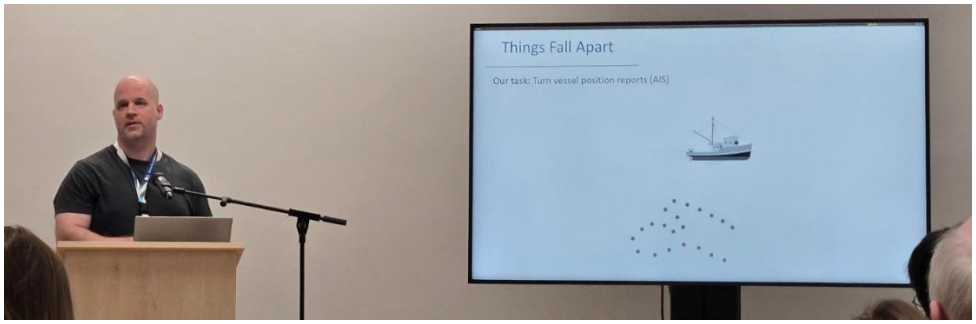
AIS data are irregular in timing and cadence, may contain missing fields, and can arrive out of order. Fixed window segmentation initially produced segments with too little information for trajectory features, or segments mixing distinct behaviours. We therefore adopted adaptive windowing to preserve sufficient context while maintaining temporal coherence.

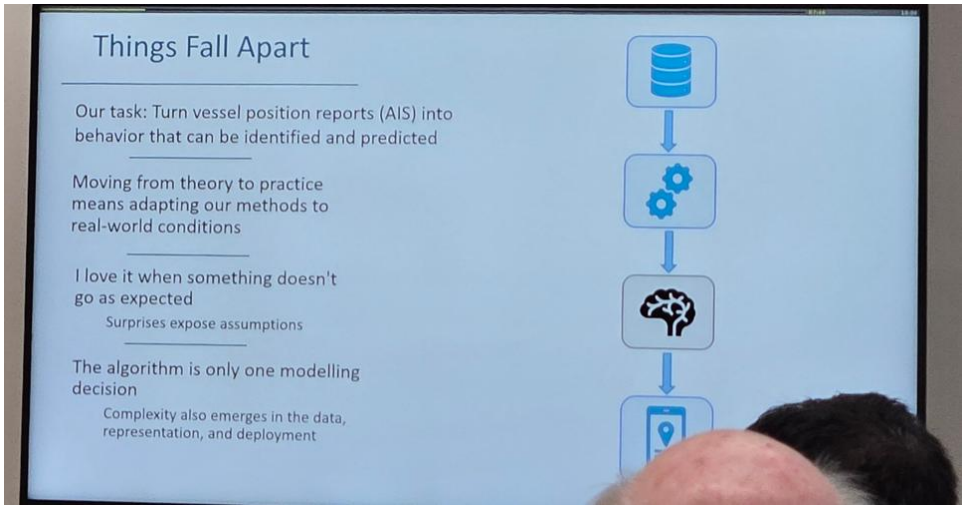
More fundamentally, segmentation required explicit domain assumptions. Translating position reports into behavioural units meant, for example, deciding when a vessel had genuinely changed course rather than momentarily deviated. This required cumulative bearing-change thresholds and rule-based constraints. Segmentation has proven not a mere neutral preprocessing step but a modelling decision that shapes which patterns can later be detected.

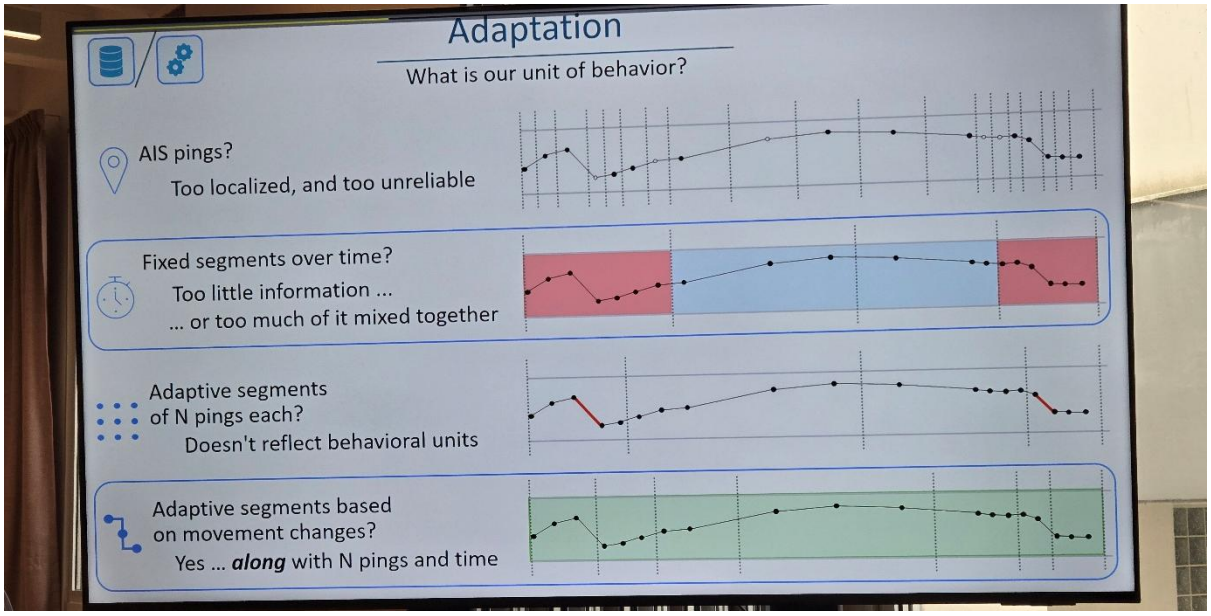
Once represented, behaviour modelling posed its own challenges. Single-algorithm clustering produced excessive "noise" clusters or failed to capture nuance. A multi-stage strategy emerged as a response to observed behaviour in the data: density-based clustering separated structured transit from less structured fishing activity, and Gaussian mixture modelling refined sub-phases within those behaviours.

Finally, we observed differences between offline development and real-time use. Offline, irregular data can be examined and interpolated in detail. In real-time, however, decisions must be made more quickly and often with less contextual information available at that moment. While correction and imputation remain possible, the constraints are narrower, requiring clearer thresholds and more cautious decision rules as we move from analytical development to live system use.

Our experience highlights three insights: (1) representation and segmentation choices can influence performance as much as algorithm selection; (2) in our case, unsupervised modelling required combining methods to capture different types of behaviour; and (3) AIS-based systems demand domain-informed iteration due to irregular transmissions and context-dependent behavioural definitions. By sharing these lessons, we aim to support more transparent and context-aware marine AI development.







Where Science Meets Experience: Local Ecological Knowledge through modular interviews, in Small-Scale Fisheries of Southwest Portugal

Carina Duarte

In Portugal, 90% of the fishing fleet corresponds to small-scale vessels (<12 meters). Nonetheless, data scarcity and absence of proper fishing effort estimates increase Small-Scale Fisheries' (SSF) vulnerability to ocean grabbing (appropriation of maritime space and control of its resources). In this study we developed a semi-structured modular interview (16 modules, 174 questions ~1hour interview per fisher) to analyze fishers' Local Ecological Knowledge (LEK) to: (i) map fishing grounds and biodiversity, (ii) assess socioeconomic challenges, (iii) determine fishing patterns under pressures, and (iv) explore science-fishing community collaboration for adaptive management. Data was collected across two fishing ports in southwest Portugal (Setúbal and Costa da Caparica) through 31 interviews, assembling information on 1) fishers demographics, 2-4) vessel, species and gear characteristics, 5) fishing grounds, 6-7) economical aspects, 8-10) problems affecting SSF, 11) spatial conflicts, 12-13) climate change perception, 14-15) solutions and 16) participatory mapping. Fisher's average age was 53.2 years, and in 93% fishing was a family tradition whereas 94% rely exclusively on fishing. Fishers using trammel nets (58%) primarily targeted sole (31%) and cuttlefish (29%), while gillnet fishers (32%) aimed for surmullet (42%) and mullet (33%). Major challenges include low first sale price (84%) and crew shortages (87%). In 90% of the interviews, the main spatial conflict involved recreational fishing (90%) and the bivalve dredge fishery operating in the same fishing grounds (80%). Regarding climate change, fishers perceived an increase of sea temperature (64%) as their primary environmental concern. The community interviewed considered it important to cooperate with scientists, namely through involvement in projects (96%) and indicated the need to access scientific results (76%). Our approach allows us to collect essential data for sustainable SSF management, enhancing resilience and providing adaptive governance in the context of environmental and socioeconomic pressures, adaptable to other areas and fleets.

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Where Science Meets Experience: Local Ecological Knowledge through modular interviews, in Small-Scale Fisheries of Southwest Portugal

Carina Martins Duarte

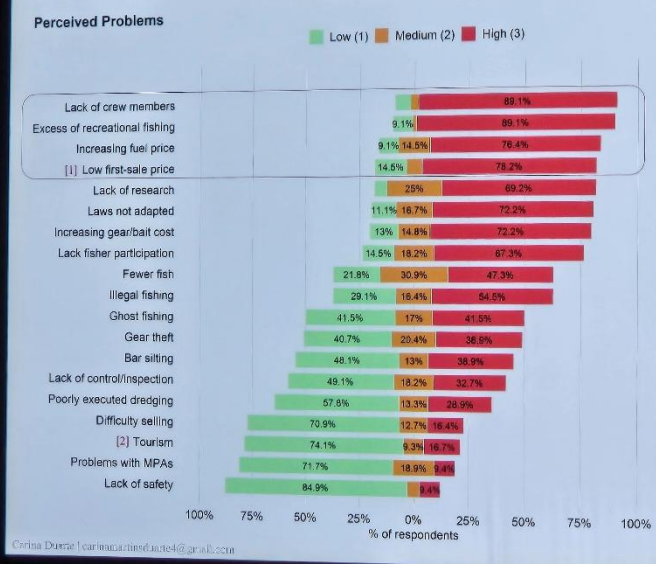
David Maurício[1], Ana Moreno[1], Miguel Gaspar[1], Mafalda Rangel[2], Marta Rufino[1,3]

Portuguese Institute of Sea and Atmosphere (IPMA)[1]
Centre of Marine Sciences (CCMAR)[2]
Centre of Statistics and its Applications (CEAUL)[3]



2026

What do fishers see as the main problems?



[1] *"Atlantic mackerel costs 0.20€/kg at the auction and 5€/kg at supermarkets" – Fisher 6 from Setúbal*

[2] *"During the beach season, we have more restricted hours for fishing with the beach seine because of tourism" Fisher 1 from Costa da Caparica*

Membership differences

Low first sale price

Kruskal-Wallis $p<0.05$

Fishers from cooperatives rate it lower than fishing associations or non-associated fishers

Fishing port differences

Tourism

Kruskal-Wallis $p<0.05$

Costa da Caparica fishers rate it as a higher problem than Setúbal fishers

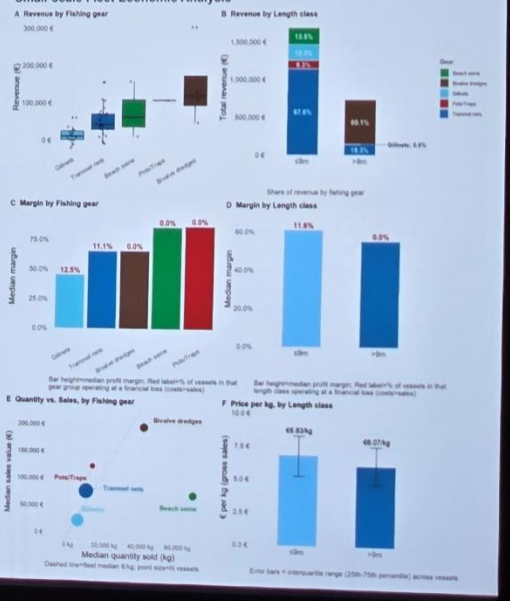
No other significant difference was found

Carina Duarte | carinamartinsduarte4@gmail.com

Economic Analysis: Profitability vs Costs

Which vessels and gears perform best?

All figures are anual totals per vessel. ***Revenue****= gross sales value;* ***Median margin****= % of revenue kept as profit (net revenue ÷ gross sales);* ***Loss margin (red%)****=% of vessels in that gear that lost money that year*



Bivalve dredges are the standout gear

- Highest revenue (A), 65% margin with zero loss-making vessels (C), and 80% of all >9m revenue (B); highest mean sales per quantity sold (E)

Risk is concentrated in the fleet's most common gears

- Trammel nets (68% of ≤ 9m revenue) and gillnets present the lowest margin and highest lost rates (11; 12%)

Biggest vessels are not automatically more efficient or more profitable?

- ≤ 9m vessels earn a better price per kg but carry more risk (11% operate at a loss vs, 0% for >9m (D)

Highest cost for all gears: *fuel is the largest single cost category, ≈ 48% of total annual cost per vessel*

Note: Pots/Traps represent one single fisher, and longline/hand and pole was taken out due to lack of data

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Posters:



MARINE OBSERVATION SYSTEM: BUILDING FISHERMEN-ORIENTED LOGBOOKS IN THE ADRIATIC SEA USING A BOTTOM-UP APPROACH WITH SMALL-SCALE FISHERMEN

Igor Celić[1], Gianluca Coidessa[2], Luca Di Nicola[3].

1. National Institute of Oceanography and Applied Geophysics - OGS, Italy
2. Consorzio Piccola Pesca dei Compartimenti Marittimi di Monfalcone e Trieste - CO.GE.PA. Trieste (TS), Italy
3. Infoteam, Pescara (PE), Italy

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Non-invasive, fishermen-driven digital logbooks to monitor small-scale fisheries and ecosystem change in the Adriatic Sea

Small-scale fisheries are increasingly under scrutiny for their ecological impacts and socio-economic role, but remain under-represented in scientific assessments due to persistent data and coordination gaps. The new **EU Fisheries Control Regulation** (EU 2023/2842) introduces mandatory **digital reporting** and **vessel geolocation**, offering opportunities to improve data quality while raising concerns about top-down implementation and the adequacy of self-reported data, especially in small-scale fleets. **Monitoring tools** are often designed without sufficient involvement of fishers and are perceived mainly as enforcement instruments. The **Marine Observation System** addresses this by **co-designing** a **digital logbook** for the **Adriatic small-scale fishery**, using a bottom-up approach that treats monitoring as both a data source and an operational service for fishers.

Figure 1: MarObsSys Smart digital logbook

Objectives

The project aims to deliver and test a fishermen-oriented digital logbook that integrates routine catch monitoring with non-invasive image-based acquisition of catch properties using machine learning. The logbook is conceived to provide structured catch information and simple analyses directly to fishers, while generating consistent time series to document ecosystem changes and support management in the Adriatic Sea.

- **Co-design a digital logbook** usable and accepted by small-scale fishers.
- **Replace** or complement **paper logbooks** with structured real-time catch data.
- Use **non-invasive**, image-based **sampling of catches** to infer species, size and weight through AI.
- Provide **onboard summaries** and simple analyses to **support fishers' decisions**.
- Create consistent **time series on catches and effort** to track ecosystem change and support management.

Experimental procedure

Figure 2: Pilot case – Marano Lagunare small-scale fleet

Testing the digital logbook on **small lagoon vessels** was challenging due to space limits and changing conditions.

The pilot was carried out with the voluntary participation of small-scale fishing vessels in the northern Adriatic, in close collaboration with the CO.GE.PA consortium and the **Marano Lagunare fleet**. Fishers were first involved through interviews, focus groups and surveys to define requirements for the digital logbook, focusing on ease of use at sea, integration with existing practices, added value beyond regulatory compliance, and benefits for business management and sustainability. During the at-sea phase, the Smart e-Logbook rugged tablet application was used on board to compile a digital logbook for each **fishing operation**. For every haul, fishers recorded operational parameters and used the tablet camera to acquire images of catch boxes.

The assisted workflow supported fishers in determining GPS position and **FAO/GSA quadrant**, identifying **species** via Machine-Learning-based image analysis, assigning **commercial size classes** and estimating numbers and retained weight from box volume. Additional details (skipper, vessel ID, gear) were entered directly in the app, and records were validated on board, including number of boxes, retained weight and discards.

Collected data were sent to a cloud infrastructure, stored and processed, and then visualised through a **web analytics platform** with reserved access for participating fishers. The resulting image dataset, however, was strongly unbalanced across species and highly variable in size and weight, so training was limited to the three dominant species and size/weight prediction was excluded, highlighting the need for larger, more balanced and protocol-driven datasets in future work.

Results

Validating a fishermen-oriented digital logbook and AI pipeline in real small-scale fishery operations

The results are based on a **pilot study** in which the Smart e-Logbook and AI pipeline were deployed and tested directly **on board small-scale** lagoon fishing vessels **under real operating conditions**.

Figure 3: Monitoring and recording panel of fishing operations

MarObsSys validated the proposed approach for digitalising small-scale fisheries logbooks, reaching **Technology Readiness Level 6** within 12 months and demonstrating the Smart e-Logbook and cloud back-end in real operations. The system met all core objectives on prototype development, cloud integration and improved on-board data collection efficiency, with a **100% adoption** rate during the main pilot period versus a **60% KPI target**, indicating strong acceptance and ease of use among fishers. A Machine Learning–based computer-vision module for automatic species recognition from box images was designed and prototyped. Due to the limited and unbalanced image dataset, the model did not reach the planned **70% accuracy**, especially for size estimation, but tests confirmed the soundness of the methodological set-up and the feasibility of integrating image-based recognition, providing a solid basis for further refinement as more data become available. The cloud platform ensured secure, structured management of positional data, catches, images and landing declarations, improving interoperability with **EU electronic reporting standards** and reducing errors and effort compared to paper logbooks.

Overall, the project delivered concrete results consistent with the planned SMART objectives and targeted TRL, while highlighting that extended multi-season deployments will be needed to fully validate the AI components and expand species coverage.

Figure 4: Data analytics platform dashboard for fleet managers

Conclusions

A digital logbook for small-scale fisheries can be fully adopted when it is designed first as a useful tool for fishers, not only as a control device. The MarObsSys pilot demonstrates that this approach **improves the quality and timeliness of catch and effort data** while fitting real operational constraints.

Open FAIR data on Zenodo platform:
https://zenodo.org/communities/marobssys

Acknowledgments

iNEST – Interconnected North-East Innovation Ecosystem - National Recovery and Resilience Plan (PNRR) – Mission 4, Component 2 – Investment 1.5. - Measure or action: Cascade funding call for enterprises – "MARITIME, MARINE AND INLAND WATER TECHNOLOGIES: TOWARDS THE DIGITAL TWIN OF THE UPPER ADRIATIC" – Spoke 8

Not All Fish Are Equal!



*Labrus mixtus

A Comparison of Cancer Risk and Pollution Effects

Randel Kreitsberg, Richard Meitern, Ciara Baines, Tuul Sepp
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Department of Zoology, Institute of Ecoloy and Earth Sciences, University of Tartu, Estonia
UNIVERSITY OF TARTU

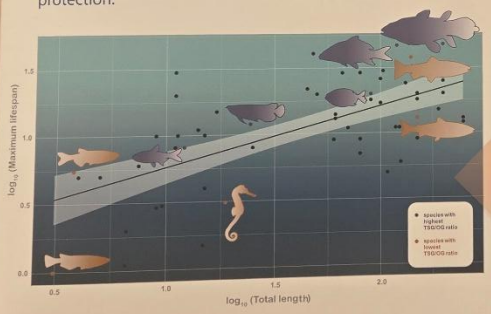
Background:

Aquatic ecosystems are heavily affected by anthropogenic pollution, resulting in a variety of physiological effects, lesions and abnormalities, including cancer.

Numerous protective mechanisms have evolved across a wide range of fish species, e.g.:

- Biotransformation of pollutants to eliminate toxic chemicals.
- Apoptotic cell death to hinder tumour formation.

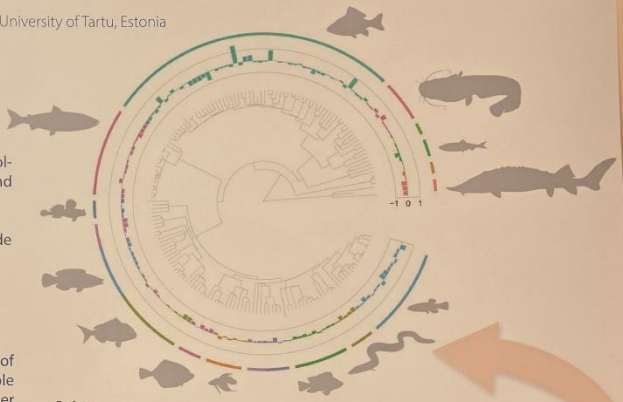
In our studies *(check the references below!)* we used decades of data accumulated in databases to reveal possible species-specific patterns in toxicant sensitivity and cancer protection.



We asked whether:

- Phylogenetics can explain toxicant sensitivity in fish.
- Traits related to metabolic function, ecology and life history predict differences in toxicant sensitivity between species.
- There is a relationship between life history traits (longevity, body size) and the number of cancer-related gene duplications.

Databases used:
ECOTOX; FishBase; AnAge; WRiMS; Ensembl; COSMIC



Order

- Acipenseriformes
- Atheriniformes
- Clupeiformes
- Characiformes
- Siluriformes
- Cypriniformes
- Salmoniformes
- Gobiiformes
- Perciformes
- Eupercaria
- Centrarchiformes
- Pleuronectiformes
- Anabantiformes
- Ovalentaria
- Mugiliformes
- Cichliformes
- Anguilliformes
- Cyprinodontiformes

Main results:

- Closely related species differ markedly in sensitivity to toxicants.
- Fish species with higher maximum length are more sensitive to toxicants.
- Fish longevity is connected positively to tumour suppressor gene/oncogene ratio.

Take home message!

We believe that comparative studies with fishes could be a largely unexplored treasure trove for understanding the evolution and ecology of physiological mechanisms, such as the ones connected to pollution sensitivity and cancer risk!

References:

Toxicant sensitivity study: Kreitsberg et al., 2025. Comparative analysis of toxicity sensitivity and functional traits in fish. Aquatic Toxicology, 285, 107432.

Cancer protection study: Baines et al., 2022. Comparative study of the evolution of cancer gene duplications across fish. Evolutionary Applications, 15 (11), 1834-1845.



We greatly appreciate the work and support of our good colleagues in Thünen Institute of Fisheries Ecology, Germany, and the crew of RV Walther Herwig III.

Acknowledgements:
Studies were funded by Estonian Research Council grants no.: PSG653 and PRG1137.

Estonian Research Council

MAPPING THE KNOWLEDGE ON MARINE CONTAMINANTS AND BENTHIC HABITATS : A SNAPSHOT OF THE RESEARCH FIELD

N. Dorey[1], F. Quemmerais[2], T. de Bettignies[1,3], C. Détrée[2]

1 PatriNat · 2 OFB · 3 GBE

European context that called for a knowledge review

Nature Restoration (EU)

- Binding targets
- Risk assessments requires knowledge

How much knowledge is there on the effects of diffuse **contaminants** on **benthic habitats** ?

N = 27,909 **publications** records from Web of Sciences → metadata

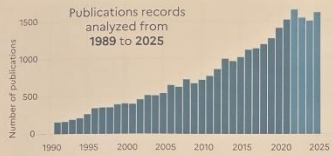
No reading, sorting or critical appraisal Bibliometrix* (R) Text-mining (R)

Which contaminants ?

JRC list** = **2,700 substances**

- 1,200 substances grouped in 51 categories
- 1,500 single substances

When were the papers published ?



A growing field but publication rates are slowing down since the 2020s in the EU



Which benthic habitats ?

Nature Restoration Regulation

7 Groups of Habitat Types

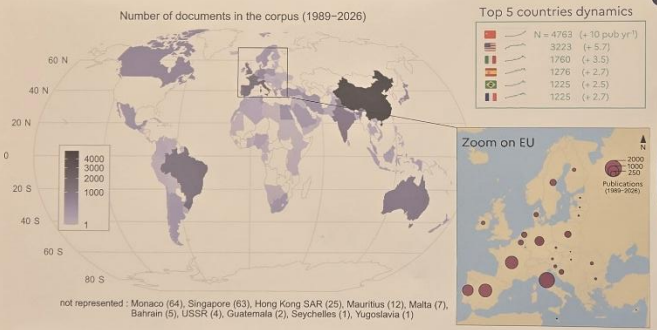
+ phylogenies & diving guides

+ expert discussions

110 benthic search words

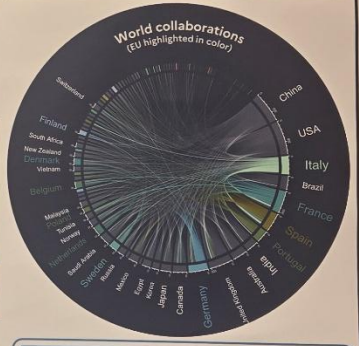
Includes habitats and organisms

Which countries studied this subject ?



not represented : Monaco (64), Singapore (63), Hong Kong SAR (25), Mauritius (12), Malta (7), Bahrain (5), USSR (4), Guatemala (2), Seychelles (1), Yugoslavia (1)

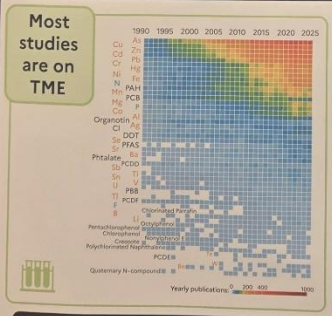
Who collaborates together?



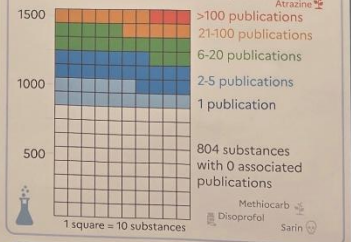
What did the publications study ?

804 substances unknown effects

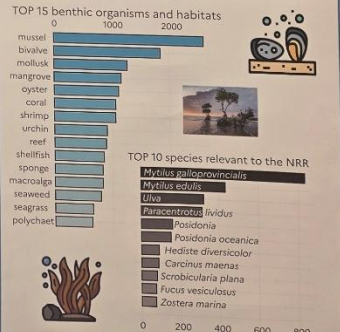
Most studies are on TME



Number of publications associated with each of the 1,500 « single substances »



A majority of the studies are on bivalves



Who is funding the research ?

The **National Natural Science Foundation of China** (NSFC) represents **5.7 %** of all acknowledged funding bodies.

✓ The **EU** represents **3.6 %**, mostly via ERDF, FP, ESF, INTERREF, MSCA fundings.

- Rapidly growing research: focused research efforts on historical pollutants (TME) and bivalves
- This type of knowledge on the effect of marine contaminants is crucial to inform **policymaking**

Identified research gaps :

- > 50% unknown substances
- under-represented benthic habitats (vs. single species)

This work and further review work will be used for national recommendations in pollution risk evaluations and integrated in spatial risk models.

narimane.dorey@gmail.com

* **Bibliometrix :** Aria, M., & Cuccurullo, C. (2017). Bibliometrix : An r-tool for comprehensive science mapping analysis. *J. Informetr.*, *11*(4), 959-975.

** **JRC list :** Tornero, A. M. V., & Hanke, G. (2017). *Potential chemical contaminants in the marine environment : An overview of main contaminant lists.* https://doi.org/10.2760/337288

GTH photo credits. **G1**: Cymodocées Cala Rossa © Boudouresque (OFB), **G2**: Kimmerlahalia © Xavier Turpin / OFB, **G3**: Moulière Calanques Marseille © Foltête / OFB, **G4**: Banc de Hyalinoecia (de) 4000 mètres © B. Duchêne (OFB), **G5**: A11_CHerMarine © M.Thomas, **G6**: Opengrown Deep Slope 4000 mètres © NOAA Ocean Exploration, **G7**: Fond sableux mer d'Iroise © B. Duchêne (OFB)

tools?

Annual Science Conference

ECOSYSTEM-WIDE IMPACTS OF CONTAMINANTS: EVALUATING PCB BIOACCUMULATION IN A MARINE FOOD WEB



Hem Nalini Morzaria-Luna[1], Alaia Morell[2], Raisha Lovindeer[3], Chloe Sprague[4], Isaac Kaplan[5], Alberto Rovellini[4], Chris Harvey[5], Javier Porobic[6], Beth Fulton[6], Lakshitha Premathilake[7], Su Kyong Yun[7], Tarang Khangaonkar[7], Joel Baker[2]

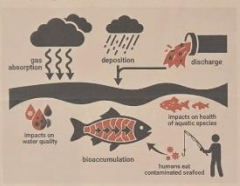
We applied an end-to-end Atlantis ecosystem model capable of assessing species-specific toxicology, chronic impacts of contaminants, effects on higher trophic levels, and the rate of recovery. Our work expands on other food web bioaccumulation models by comprehensively assessing direct and indirect effects.

1 SIMULATION SETUP

We explored the impacts of Polychlorinated Biphenyls (PCBs) in Puget Sound (Washington State, USA), a coastal fjord. PCBs are persistent legacy contaminants banned in the 1970s.

Atlantis is an end-to-end deterministic 3-dimensional ecosystem modeling framework that simulates uptake and decay of contaminants, and non-lethal and long-term biological impacts.

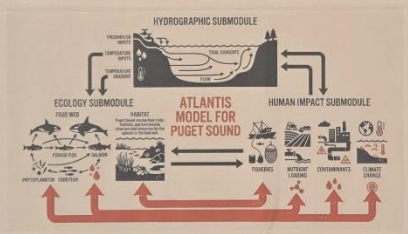
PCB pathways and effects



Atlantis repository

Contaminant equations Lovindeer et al. 2025

Learn more



Simulation:

- 30 years
- Forced by PCB concentrations in sediment, phytoplankton, zooplankton, and the water column and sediment from a physical-biogeochemical hydrodynamic model.
- Direct uptake by bacteria, zooplankton, seagrass and macroalgae
- Other groups acquire PCBs from consumed prey or maternal transfer.
- PCB concentrations impact growth, fecundity, and mortality following the equations in Lovindeer et al. 2025

2 FUTURE WORK

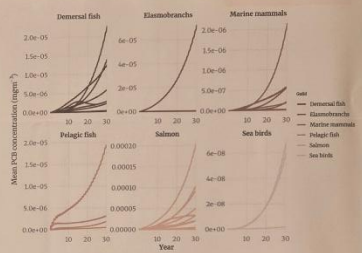
- Include inital conditions that reflect current environmental concentrations
- Assess cumulative impacts of co-occurring legacy and emerging contaminants
- Evaluate risk to human health from PCBs in seafood

Contact: hmorzarialuna@lltk.org

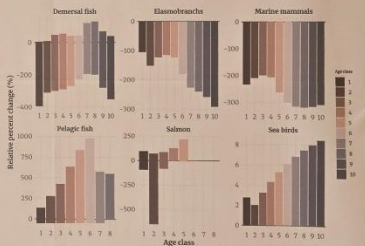
LONG LIVE THE KINGS

3 RESULTS

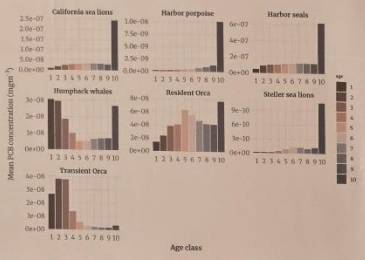
PCBs transferred across the food web



PCBs led to ecosystem change over time by reducing the number of predator groups



Marine mammals reduced their body burden through maternal transfer



4 ACKNOWLEDGEMENTS

This project was part of the Puget Sound Integrated Modeling Framework awarded to Puget Sound Institute at UW-Tacoma by Allen Family Philanthropies grant #202203-13143. Computing resources were provided by the UW eScience Institute and through a NOAA-Microsoft Cooperative Research and Development Agreement.

1 2 3 4 5 6 7

PUGET SOUND INSTITUTE · UBC · UNIVERSITY of WASHINGTON · noaa · CSIRO · Pacific Northwest NATIONAL LABORATORY

European Commission

Where to find the data?
Scan to access publicly available FDI data (csv and shape files)

The Fisheries dependent information (FDI)

Database supporting sustainable EU fisheries

Zeynep Pekcan-Hekim; Anna-Marie Winter; Jordi Guillen
EU Commission, Joint Research Center (JRC), Ispra, Italy

Why we need fisheries dependent data?

EU Common Fisheries Policy (CFP)

- Provides a framework for the sustainable management of fishing fleets and the conservation of marine resources.
- Requires that all management decisions and proposals are grounded in sound scientific advice.

To ensure the best available scientific advice, there is a need for harmonized, reliable, and accurate fisheries-dependent data.

The **EU Data Collection Framework (DCF),** establishes the legal and operational foundation for collecting, managing, and using fisheries data under the CFP. The **EU Multiannual Program (EU MAP),** outlines specific data requirements, mandatory surveys by sea basin, and thresholds for data collection.

EU countries submit data annually in predefined formats in response to the **EU DCF data calls** issued by the European Commission. **Fisheries Dependent Information (FDI)** has been a fundamental dataset collected under this framework.

Coverage of the FDI data

- Logbook data from 22 coastal EU countries
- Data since 2013 (Figure 1)
- EU waters and Outermost regions, European fleets operating exclusively in non-EU waters (international waters and third countries including those with fishing partner agreements) (Figure 2)
- 10 different data tables (Figure 3)
- Fleet segment level (year*supra-region*fishing technique*vessel length class)
- Métier information (Recommended by RCGs)
- Spatial landings and effort data in c-square 0.5*0.5 degree resolution or rectangle type, latitude and longitude information (Figure 2)

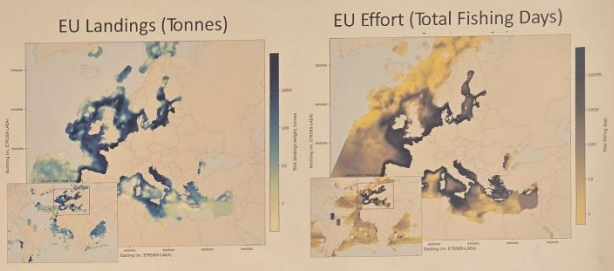


Figure 2. Spatial landings (tonnes) and effort (fishing days) reported in the Fisheries Dependent Information (FDI) from 22 coastal EU countries)

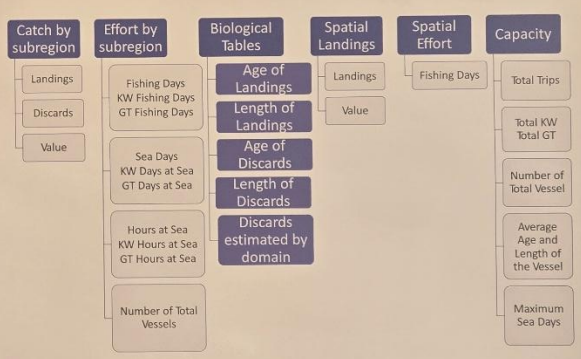


Figure 3. The Fisheries Dependent Information (FDI) data tables

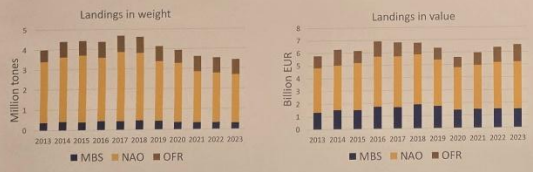


Figure 1. The EU landings weight (left) and value (right) reported in FDI by sea basin NAO (North Atlantic Ocean), MBS (Mediterranean and Black Sea), and OFR (Other Regions) for the period 2013-2023.

Where is the data used?

- For advisory and regulatory processes led by the European Commission (DG MARE) and the Scientific, Technical and Economic Committee for Fisheries (STECF)
  - Routine calculation of quota top-ups and fishing opportunities concerning the exemptions of the landing obligation
  - Supporting the action plan to protect and restore marine ecosystems (e.g. assessing the impact of bottom trawling in marine protected areas MPAs)
  - Evaluation of the implementation of the Western Mediterranean Sea Multi-Annual Management Plan
  - Supporting the Maritime Strategy Framework Directive (MSFD)
- ICES Working Groups (WGNSSK, WGMIXFISH-METHODS , WKD3Lists)
- Scientific research
  - Investigating the fuel use patterns in fisheries (Sala et al. 2022)
  - Fishery performance indicators for assessing ecological sustainability of wild-caught seafood products (Grati et al. 2025)

Acknowledgements: We thank Georgia Kakoulaki for the maps and Silvia Garbossa and Antonella Zanzi for their valuable contribution.

Science for policy
Scan the QR code to visit:
Joint Research Centre
https://joint-research-centre.ec.europa.eu

CONTACT INFORMATION
European Commission — Joint Research Centre (JRC)
Contact/s: Zeynep Hekim, Anna-Marie Winter, Jordi Guillen
E-mail: zeynepph@gmail.com, Anna-Marie.winter@ec.europa.eu

References
Sala, A., et al. Energy audit and carbon footprint in trawl fisheries. *Sci. Data* 9(1), 428 (2022).
Grati F. et al. Fisheries performance indicators for assessing the ecological sustainability of wild-caught seafood products in Europe. *Environ. Sustain. Indic.* 26, 100632 (2025).

© European Union, 2026



Arc'hantael Labrière
SLU
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Frozen fish: smaller than you think

Shrinkage effect of freezing on herring and sprat in the Baltic Sea

WHY

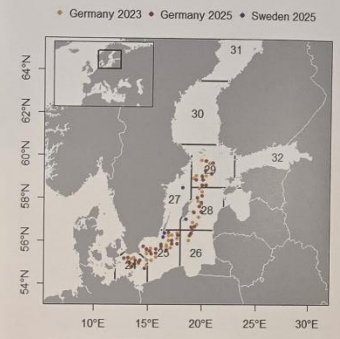
Stock assessments and life-history models combine length-weight data from both fresh and frozen fish. Freezing conservation however alters measurements, leading to freezing-induced bias currently not accounted for.

METHODS

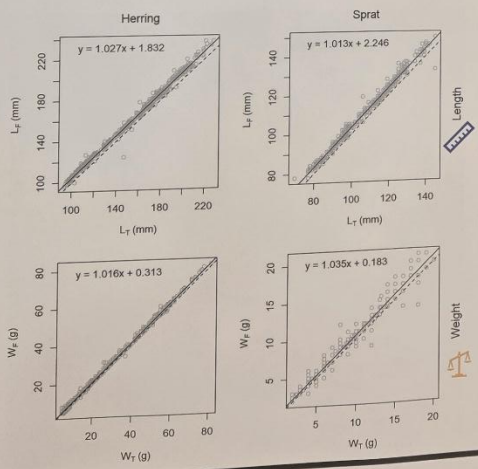
Fish were collected during three hydroacoustic scientific surveys in May 2023 and 2025 by Germany and Sweden. A total of 520 herrings (*Clupea harengus*) and 434 sprats (*Sprattus sprattus*) were sampled. Fish were measured to the nearest millimetre and weighted to the nearest gram. Clupeids were frozen at -18°C for six different freezing durations.

TAKE HOME MESSAGE

Fish shrinkage is not linear overtime and differs between species. Herring shrinks more in length than sprat (2.7% vs. 1.7%) whereas sprat shrinks more in weight than herring (3.5% vs 1.3%). Investigate your frozen fish's shrinkage!

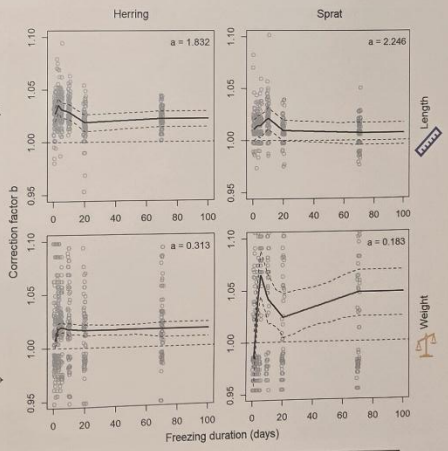


Baltic Sea ICES subdivision. Coloured dots represent haul locations for each survey.



← Relationship between thawed (T) and fresh (F) length (L) and weight (W) for herring and sprat. The solid line represents the fitted linear regression, and the dashed line represents a 1:1 relationship.

Effect of freezing duration on shrinkage in length and weight for herring and sprat. →



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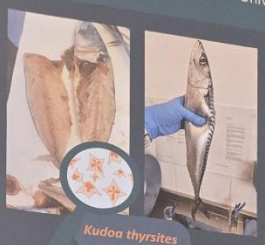
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Link to the published open access article

WHEN MACKEREL TURNS TO JELLY: OCCURRENCE AND PREVALENCE OF *KUDOA THYRSITES*

[1]Atlantic Technological University (ATU), [2]Bord Iascaigh Mhara (BIM), [3]Institute of Marine Research (IMR) | *viktoria.kiralyova@research.atu.ie

Királyová V.*[1]; O'Dwyer K.[1]; Talbot A.[1]; Gallagher M.[2]; Giulietti L.[3]; Brophy D.[1]



?

What is the occurrence of 'jelly flesh'?
Are larger individuals more affected?
Is there a difference between autumn and winter fishery?
Is there a difference between the number of 'jelly flesh' cases and *K. thyrsites* detection?

Atlantic mackerel (*Scomber scombrus*) is one of the most valuable wild caught fish species across the Northeast Atlantic region. The myxozoan parasite *Kudoa thyrsites* has been previously associated with post-mortem myoliquefaction, also called 'jelly flesh' in mackerel caught around Norway[1], the Faroe Islands[2] and Scotland[3]. Despite the economic importance of mackerel for Ireland, with a value of over €80 million, there was no official record of 'jelly flesh' occurrence until 2026[4]. Given mackerel's economic importance, it is vital that a baseline study is conducted to assess the status of *K. thyrsites*. Establishing such a baseline will provide essential data to evaluate the potential risks posed by this parasite to the quality and marketability of Irish mackerel.

DATA COLLECTION

'Jelly flesh' occurrence



34,500 mackerel were inspected for signs of 'jelly flesh' as part of routine quality control at a processing plant

Seafood processors

2024 - 2026
Winter / Autumn fishery

Commercial landings

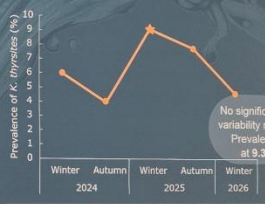
Port samplers collected **276** muscle samples, which were screened for the presence of *K. thyrsites* using qPCR

***K. thyrsites* prevalence**

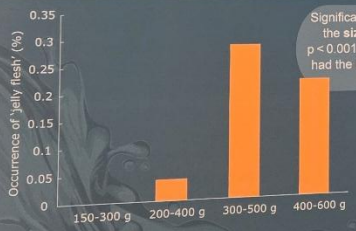
SEAFOOD PROCESSORS



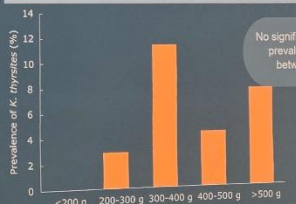
No significant difference between autumn and winter fishery. Significant interannual variability ($\chi2$ test, $p < 0.001$). 'Jelly flesh' occurrence peaked at **0.35%** during the **winter season of 2025**.



No significant difference in interannual variability nor between fishing seasons. Prevalence of *K. thyrsites* peaked **at 9.3%** in the **winter of 2025**.



Significant difference between the **size classes** ($\chi2$ test, $p < 0.001$). **300-500g** size class had the highest occurrence of 'jelly flesh'.



No significant difference in the prevalence of *K. thyrsites* between size classes.

COMMERCIAL LANDINGS

TAKE HOME MESSAGE

1. Low occurrence of 'jelly flesh' **< 0.2%**
2. Larger individuals >300 g are more likely to develop 'jelly flesh'
3. The prevalence of *K. thyrsites* in mackerel from commercial landings was higher than the occurrence of 'jelly flesh' recorded by seafood processors
4. Both occurrence and prevalence peaked in winter 2025
5. Information provided by seafood processors is **vital** for multi-annual monitoring



Atlantic mackerel is one of the most valuable pelagic species across the wider Northeast Atlantic, understanding the distribution and impact of *K. thyrsites* has significance beyond Ireland alone. An effort to document and monitor the occurrence of 'jelly flesh' and the prevalence of *K. thyrsites* will therefore not only safeguard Ireland's mackerel industry but also contribute to regional fisheries management, supporting the long-term sustainability of one of the Northeast Atlantic's most important shared resource.



Shouldn't be harmful!!!
Only try at your own risk!!!

Acknowledgement
I would like to acknowledge James Griffin and Eugene Mullins for their efforts in collecting the data presented.
This research is conducted in collaboration with BIM and the Marine Institute and is funded through the European Maritime, Fisheries and Aquaculture Fund.

Ollscoil Teicneolaíochta an Atlantaigh
Atlantic Technological University
MARINE AND FRESHWATER RESEARCH CENTRE
BIM Ireland's Seafood Development Agency
Foras na Mara Marine Institute
Rialtas na hÉireann Government of Ireland
Co-mhaoinithe ag an Aontas Eorpach
Co-funded by the European Union

SILENT CURRENTS: GENDER BIAS BELOW THE SURFACE OF FISHERIES SCIENCE

Lucía Arranz1, Margarita Rincón3, María Soto1, María José Juan Jordá1, Diana González1, Lucía Rueda1, Maria Grazia Pennino2. 1.Instituto Español de Oceanografía (IEO-CSIC), 2.Institut de Ciències del Mar (ICM- CSIC), 3.Joint Research Centre (JRC)



INTRODUCTION

Gender equity in science and international governance has gained attention, however disparities persist, particularly within fisheries science and decision-making bodies (Shellock et al., 2022; Giakoumi, et al., 2021).

QUESTION

Is gender bias persistent in participation and leadership roles within the scientific assessment groups of Regional Fisheries Management Organizations (RFMOs)?

HIPOTHESIS

Gender bias is more persistent on leadership roles than in participation roles in assessment groups of RFMOs

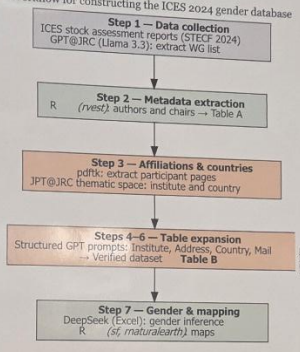
"Beneath the surface, gender bias continues to shape who speaks for the ocean. Recognizing and reversing these silent currents is key to equitable science and sustainable seas."

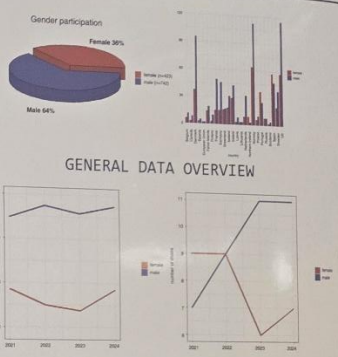


MATERIAL, METHODS AND RESULTS

Initial data from reports: participation (2021-2024) in the International Council for the Exploration of the Sea (ICES) Advisory Committee on Fishery Management , focusing on the composition of its **stock assessment Working Groups (WGs).**

Data base construction: participants and chairs from ICES stock assessment relevant working groups, using a multi-step workflow combining R coding and artificial intelligence (AI) (Fernandez-Machado, 2025).





GENERAL DATA OVERVIEW

GENDER TRENDS OVER TIME

CONCLUSSIONS

•Overall underrepresentation: Women remain underrepresented across all years.
•Country-level trends: Mild weakening of male dominance but still a clear overall imbalance.
•Convergence participation: only Spain and Portugal.
•Female trajectory: Decreased from 38.9% (2021) to 37.5% (2024), with the lowest values in 2022 (34.5%) and 2023 (34.2%).
•Male trajectory: Maintained a consistent majority (61–65%) with a peak in 2022 (65.5%) and modest normalization afterward.
•Leadership concern: The number of female chairs has dropped significantly, highlighting persistent inequality in decision-making positions.
•Slight improvements in some groups and countries, male remains the dominant gender across most working groups and leadership roles. The period 2021–2024 reflects a landscape of slow convergence but enduring male predominance, underlining the need to address gender equity in marine science and governance.
Despite incremental progress in some countries and working groups, men continue to dominate both participation and leadership within ICES scientific groups.
The 2021–2024 period reflects slow convergence but enduring male predominance, emphasizing the need for institutional measures to promote gender equity in marine science and governance.

KEY MESSAGES

- Women remain underrepresented in fisheries science leadership
- Men outnumber women nearly 2 to 1 in ICES scientific groups
- Female participation shows small gains but fragile progress
- Leadership gap widens — fewer female chairs since 2022
- Equity is not just about participation — it's about power
- Invisible barriers shape who speaks for the ocean
- AI and open data can expose the silent gender currents

FUTURE

Future Directions / Ongoing Work
- Expand the analysis beyond ICES to include other tRFMO scientific bodies (ICCAT, IOTC, IATTC, WCPFC).
- Assess intersectionality — explore gender alongside career stage, discipline, or geography (e.g., Global North vs. Global South).
- Investigate drivers of disparity: publication productivity, mentoring, institutional culture.
- Evaluate policy impact — link gender representation to outcomes in advice quality or inclusivity of management recommendations.
- Build an automated monitoring dashboard using AI (e.g., R + GPT pipelines) for annual gender-balance tracking in marine science.
- Develop policy briefs for ICES, FAO, or RFMOs with measurable equity targets.

Early-Stage Researchers
- Mentorship matters: visibility and role models can accelerate equity.
- Collective action: form or join Women in Marine Science and Diversity in RFMOs networks.
- Data transparency: push for gender-disaggregated data in all RFMO reports.
- Skill empowerment: promote training in data science, leadership, and negotiation for young women.
- Allyship: encourage male colleagues to support equitable participation and challenge bias in meetings.

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Improving the robustness of MSY-based harvest control rules for low-productivity, long-lived fish stocks

Wendell Medeiros Leal[1,2], Régis Santos[1], Michael F. Sigler[3], Tobias K. Mildenberger[2]

[1]Institute of Marine Sciences – OKEANOS, University of the Azores | [2]National Institute of Aquatic Resources (DTU AQUA) | [3]Shoals Marine Laboratory

TAKE-HOME MESSAGE

Using B_{MSY} as the biomass threshold, maintaining an explicit biomass limit, and incorporating precautionary uncertainty buffers provides a practical pathway for managing low-productivity, long-lived fish stocks within existing MSY-based advice frameworks.

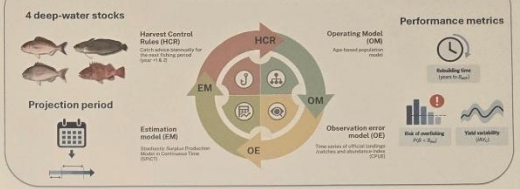
Lower risk of overfishing | Shorter rebuilding time | Limited impact on yield

WHY IS THIS A PROBLEM?

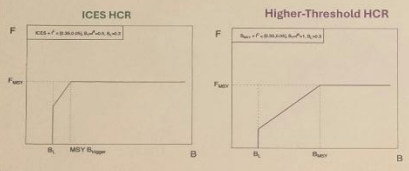
- **Late maturity** — Long lifespan
- **Low natural productivity** — Limited resilience
- **Slow recovery** — Long rebuilding

Conventional MSY-based HCRs may reduce fishing pressure only after biomass has already fallen far below the management target.

HOW DID WE TESTED IT?



WHAT MANAGEMENT RULES WERE TESTED?



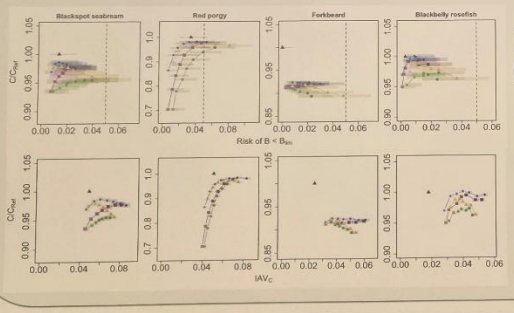
HCRs configurations evaluated

HCR configuration	Threshold (B_T)	Biomass limit (B_L)
ICES	$0.5B_{MSY}$	$0.3B_{MSY}$
Higher-Threshold	B_{MSY}	$0.3B_{MSY}$
ICES-noBL	$0.5B_{MSY}$	No limit
Higher-Threshold-noBL	B_{MSY}	No limit

Uncertainty buffer (f^c) tested: 0.35 | 0.30 | 0.25 | 0.20 | 0.15 | 0.10 | 0.05



WHAT DID WE FIND?



WHAT DRIVES HCR PERFORMANCE?

EFFECTS OF INDIVIDUAL HCR COMPONENTS

1 BIOMASS THRESHOLD — Act earlier

0.5 B_{MSY} (ICES threshold) → B_{MSY} (Higher threshold)

- ↓ 13–22% lower B_{lim} risk (long-term)
- ↑ ~3% higher yield (long-term)

Earlier reductions in fishing mortality improve performance.

2 BIOMASS LIMIT — Keep a limit

No B_L (No biomass limit) → B_L = 0.3 B_{MSY} (Explicit biomass limit)

- ↓ Lower B_{lim} risk across all 4 stocks
- ↑ ~2% yield gain | Modest effect on yields.

An explicit biomass limit adds protection when stocks are depleted.

3 UNCERTAINTY BUFFER — Add precaution

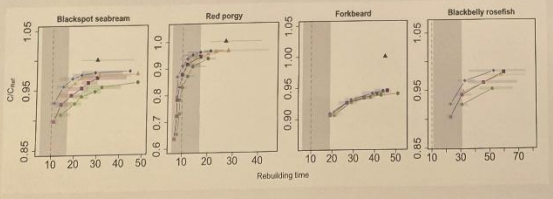
Less precautionary ← 0.35 0.30 0.25 0.20 **0.15** 0.10 0.05 → More precautionary

Best balance

- ↓ ~60% lower B_{lim} risk (vs. f^c = 0.35)
- ↓ <5% yield loss (on average)

f^c = 0.15 provides a strong balance between conservation benefit and yield cost.

HOW LONG DOES RECOVERY TAKE?



REBUILDING TIME MATTERS

RISK TELLS US WHETHER A STOCK CROSSES A THRESHOLD. REBUILDING TIME TELLS US HOW LONG THE CONSEQUENCES PERSIST.

1 CONVENTIONAL ICES HCR — Slower or no rebuilding

B_T = 0.5 B_{MSY} | B_L = 0.3 B_{MSY} | f^c = 0.35

- ✕ No rebuilding within the projection period (low-productivity stocks)
- Longer recovery times (when rebuilding occurred)
- Prolonged period below management targets

FASTER RECOVERY

2 MORE PRECAUTIONARY HCRs — Faster and more consistent rebuilding

B_T = B_{MSY} | B_L = 0.3 B_{MSY} | f^c = 0.05–0.15

- Rebuilding achieved for 3 of 4 stocks (within the projection period)
- Shorter recovery times (up to ~50–80% faster)
- Higher and more stable biomass trajectories around or above B_{MSY}

MANAGEMENT IMPLICATIONS

Simple adjustments to MSY-based harvest conttol rules can improve outcomes for slow-recovering stocks.

1. **ACT EARLIER** — B_T = B_{MSY} — Reduce fishing pressure sooner.
2. **KEEP A LIMIT** — B_L = 0.3 B_{MSY} — Protect depleted stocks.
3. **BALANCE PRECAUTION** — f^c ≈ 0.15 — Balance risk and yield.

→ Adapt MSY-based HCRs to the limited resilience of slow-recovering stocks.

OKEANOS | UAc Universidade dos Açores | DTU | fct Fundação para a Ciência e a Tecnologia | AZORES FISHERIES

Contact: wmed@aqua.dtu.dk

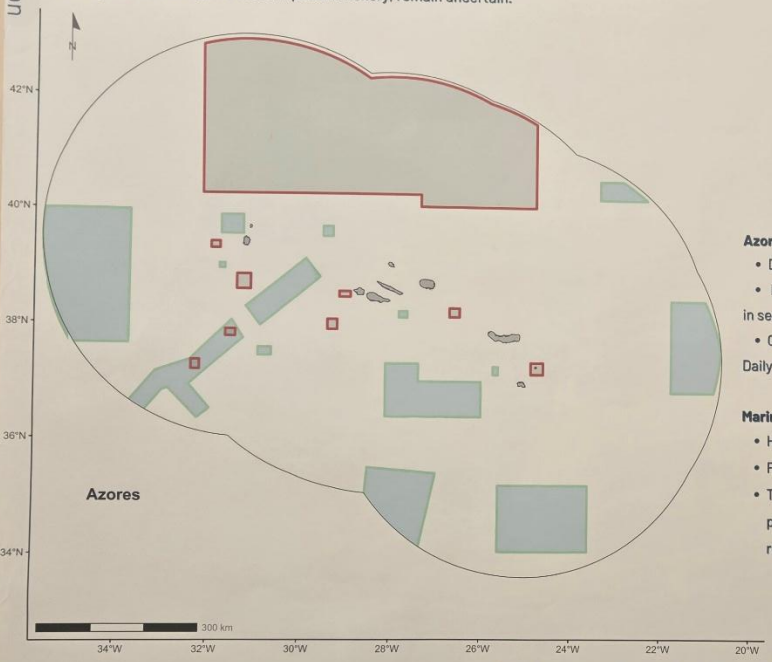
Implications of the largest marine protected area network in the North Atlantic for a highly mobile tuna fishery

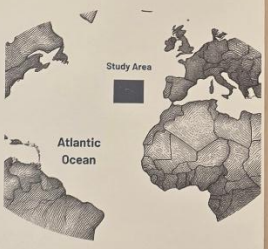
Osman Crespo-Neto, Wendell Medeiros-Leal, Régis Santos

1.Institute of Marine Sciences - OKEANOS, University of Azores, Horta,Portugal;
2. National Institute of Aquatic Resources (DTU Aqua), Kg.Lyngby, Denmark.

Introduction

In 2024, the Azores established the largest network of MPAs in the North Atlantic, covering 287,000 square kilometres, which constitutes **30% of its exclusive economic zone (EEZ)**. This network includes fully and highly protected areas, with emphasis on deep-water habitats. However, the implications of this new spatial management framework for the **pole-and-line tuna fishery**, one of the region's most important fishery, remain uncertain.





Methods

Azorean Fisheries Observer Program (POPA)

- Data between 2015 and 2024
- Hourly effort - Acctual time spent in searching for fish clues
- Catch per unit effort:

Daily total Catch in kg per hour for each species

Marine Protected Areas - MPAs

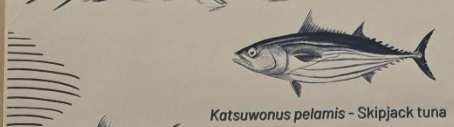
- Higlhy Protected Areas -
- Fully Protected Areas -
- Total of 287,000 Km² MPAs, with 50% fully protected, where no extraction of natural resources can take place.

Results

Fishing performance over the last 10 years in areas overlapping established MPAs

Species	Protection	Total Catch (Kg)	% Total Catch	Euros per Year (€)	Mean CPUE (Kg/hour)
Skipjack	Fully	319,534.5	2.5	36,612.83	**1,431.36**
	Highly	103,647.0	7.22	-	1,256.22
	Not_Protected	4,885,233.6	90.3	-	711.29
Bigeye	Fully	70,259.0	6.02	57,258.92	**3,825.48**
	Highly	202,648.0	1.95	-	2,042.89
	Not_Protected	2,532,760.0	92	-	307.23





Katsuwonus pelamis - Skipjack tuna



Thunnus obesus - Bigeye tuna

By quantifying the spatial exposure of a dynamic tuna fishery to specific marine protected areas, we found that some **fully protected areas have a disproportionately high influence on CPUE.** Consequently, restricting access to these areas could result in greater economic impacts than suggested by catch reductions alone, given the lower operational costs and higher fishing efficiency associated with high-CPUE grounds.

Overall, these results highlight the importance of accounting for ecological, economic, and social dimensions when designing protected areas for highly migratory species.

fct Fundação para a Ciência e a Tecnologia

UAc Universidade dos Açores

The role of English subtidal seabed sediments in organic carbon storage, impact of human activities, environmental pressures and potential management options: **an evidence review**

Centre for Environment, Fisheries & Aquaculture Science

Carolyn Graves & Ruth Parker
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There has been recent focus on the impact of human activities on seabed organic carbon (OC) stores and the potential to manage these activities to protect or enhance carbon storage. This has become a UK policy priority due, in part, to the lack of consensus on elements of the relevant evidence base. **A community workshop was convened with experts from across Europe to evaluate evidence to date, identify gaps in knowledge, and highlight key next steps.**

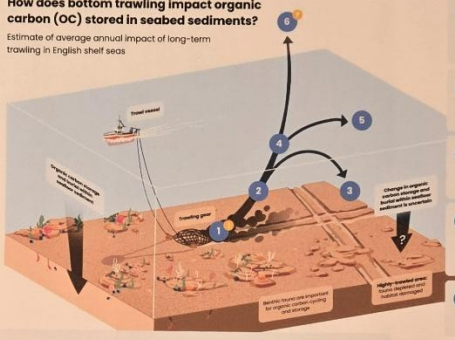
UK shelf seabed sediments are estimated to **store 240–524 Mt OC** in the upper 10 cm: **1–5 times the carbon emitted annually** as CO_2 by the UK. The main human activities/pressures which impact sediments and potentially affect OC storage include demersal trawling, infrastructure development, and climate change. The extent of disturbance from trawling is large, however only a small fraction of disturbed OC is resuspended in the water column and not all of this is expected to be remineralised to CO_2 and emitted to the atmosphere, though other mechanisms can also lead to enhanced remineralisation of OC after disturbance. Infrastructure projects (e.g., cables, pipelines, offshore energy) affect smaller areas but disturb deeper into the seabed. Climate change is expected to reduce OC inputs to subtidal sediments and accelerate its degradation.

Management options focus on limiting disturbance of the most vulnerable carbon stores, such as restricting certain activities in reactive carbon hotspots, although trade-offs with biodiversity and the risk of displacement must be considered. Adjusting the timing of activities, since seabed disturbance during warmer months increases the likelihood of carbon degradation and CO_2 release, may also be effective. Modifying practices, such as adapting fishing gear to reduce seabed contact or incorporating lifecycle planning into infrastructure development, also has potential to minimise impacts on seabed carbon.

Key evidence gaps include refined maps of sediment carbon, understanding of carbon reactivity and degradation processes, and availability of predictive models for management and climate scenarios.

How does bottom trawling impact organic carbon (OC) stored in seabed sediments?

Estimate of average annual impact of long-term trawling in English shelf seas

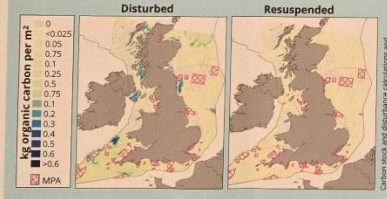


1. **Organic carbon is disturbed from sediments by trawling gear**
   34% of carbon stock annually
2. **Some carbon is resuspended**
   1.9% of stock, **5.7%** of disturbed
   Resuspended material had previously settled on the seabed and is moved back into the water column.
3. **Some resuspended organic carbon is transported and redeposited**
   1.5–1.9% of stock
   79–100% of resuspended
4. **Some resuspended organic carbon is degraded in the water column**
   Less than **0.4%** of stock,
   less than **21%** of resuspended
   Organic matter is broken down, releasing dissolved CO_2
5. **Some dissolved inorganic carbon stays in the water column**
   Less than **0.4%** of stock, % of degraded unknown
6. **Some inorganic carbon may be emitted to the atmosphere as CO_2**
   Much less than **0.4%** of stock; % of degraded unknown
   It is not known how much CO_2 ends up being emitted into the atmosphere

How big is the carbon stock?
Amount of organic carbon contained in upper 10 cms of seafloor sediment beneath English shelf seas
83 million tonnes OC

How much of the stock is reactive?
Reactive carbon has the potential to become CO_2
21%
18 million tonnes OC

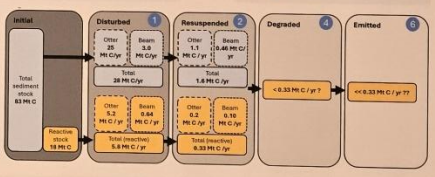
Spatial distribution of seabed organic carbon impacts



Carbon stock and disturbance calculations and mapping by Richard Healdeen, Cefas. Contact Richard.healdeen.gov.uk

Benthic **fishing pressure** was quantified based on the ICES dataset[1] compiled to support the OSPAR assessment of benthic impacts of fishing activity[2]. The predominant bottom impacting fishing gears in the UK are otter and beam trawls. The mean swept area ratio in the surface sediment layer (top 2 cm) was calculated for each 0.05° by 0.05° grid-square all years (2009-2020) assuming null values in the annual data represented the absence of fishing activity. Trawling pressure data were combined with a **seabed carbon density** map[3] (500 m by 500 m resolution) gear-specific depths of sediment **disturbance**[4] and **resuspension**[5,6] were applied. Seabed **carbon lability** was estimated based on thermogravimetric analysis[7,8] of ~ 1,000 samples extrapolated across the study area using classification by EUNIS level 3 habitat type[9] and UKSeaMap[10] sediment substrate.

Our full **evidence review** is now available online:



The evidence review workshop was funded by Defra Marine & Fisheries and facilitated by Cefas. Thanks to and acknowledgement of the contributions and expertise of all Evidence Review co-authors:

Cefas co-authors:

John Aldridge, Richard Heal, David Hughes, Claire Mason, Claire Powell

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[1]University of St Andrews; [2]Plymouth Marine Laboratory; [3]Joint Nature Conservation Committee; [4]Natural England; [5]University of Essex, [6]Bangor University; [7]University of Leeds; [8]NatureScot; [9]Agri-Food and Biosciences Institute; [10]University of Aberdeen; [11]Heriot Watt University; [12]Natural Resources Wales; [13]British Geological Survey; [14]University of East Anglia

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Clare Bradshaw[1], Mark Chatting[2], Mark Coughlan[2], Markus Diesing[3], Christian Lønborg[4], Barry O'Neill[5], Sarah Paradis[6], Lucas Porz[7], Samuel Rastrick[8], Justin Tiano[9], Wenyan Zhang[7]

[1]Stockholm University, Sweden; [2]University College Dublin, Ireland; [3]Geological Survey of Norway; [4]Aarhus University, Denmark; [5]DTU Aqua, Denmark; [6]ETH Zurich, Switzerland; [7]Helmholtz-Zentrum Hereon, Germany; [8]Institute of Marine Research, Norway; [9]WMR IJmuiden, The Netherlands

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Cefas

WORLD-CLASS AND INTERDISCIPLINARY EXCELLENCE RESEARCH

Are we ready to be wrong?

On ICES Science Advice, Quantification and Ethical Lens for Stakeholder Engagement

Min Hyung Kim[1,3], Dorothy Jane Dankel[3], María del Mar Delgado-Serrano[2], Marcela Brugnach[1]

1 BC3 Basque Centre for Climate Change, Spain
2 Universidad de Córdoba, Spain
3 SINTEF Ocean, Climate and Environment, Norway

01 –Core dilemma

In between **institutional reliance on quantitative models** and the imperative for **stakeholder engagement and knowledge co-production in complexity:**

What does credibility of science advice mean? Is there an Inclusion Paradox?

Ethical implication:
What does it mean to use precise numbers in science advice when the underlying problem is complex and uncertain?

Are we ready to be wrong? (Kim & Dankel, 2025)

02 – Working research questions

How does relying on **quantitative** knowledge to secure **credibility** and **impartiality** constrain an organization's capacity for **knowledge co-production** and **epistemic plurality**?

What does this mean for the credibility of science-policy interface advice under deep **uncertainty**?



Photo credit: Min Hyung Kim (Getxo, Spain)

03 – Working conceptualization: Inclusion Paradox

Working definition:

Contexts in which science-policy organizations publicly pursue **stakeholder engagement** and **knowledge co-production**, yet stakeholders still experience **epistemic marginalization**.

This can arise because the underlying boundaries of what counts as **'credible'** or **'impartial'** knowledge remain strictly anchored in conventional scientific-technical and model-based quantification languages of knowing.

Builds from: the foundational insights of the **participation paradox** (Craps et al., 2004) and structural asymmetries in climate governance (Brugnach et al., 2017), demonstrating that formal participatory processes can, under certain conditions, lead to expert-lay power dynamics and communication hurdles.

Extends To:

Examining the specific aspect of **science advice** and its **credibility** in uncertainty and complexity.

- On how institutional reliance on scientific-technical and quantitative modeling ⟹ Systematic exclusion of relational, qualitative, and local ways of knowing

Epistemic filter?

- Highlighting the need for institutional **reflexivity** regarding epistemic space boundary-work while **re-imagining impartiality and credibility** toward **epistemic justice** (Fricker, 2003, 2007; Kim & Dankel, 2025) and diversity through an institutional capacity for mutual listening, trust, and respect.

04 – Case in point: ICES Science advice and Stakeholder Engagement Strategy (2023)

ICES needs to provide impartial marine science advice.
+
The marine governance today demands stakeholder engagement and knowledge co-production.

When we are engaging stakeholders on deep uncertainty and complexity:

- What is credible science advice?
- What does impartiality mean?

Re-defining Epistemic Space?
Reflexive Credibility and Impartiality



Questioning core concepts
Can 'impartiality' expand to hold co-produced knowledge?

Fostering reflexive, safe spaces
Can diverse ways of knowing coexist on mutual trust and respect?



The model. Advice built in code and confidence intervals.
The table. Knowledge argued over, in a room, by people.
The sea. Where the numbers are supposed to hold.
The fleet. Those who live with the ocean — and know things it cannot model.

Photos credit: Dorothy J. Dankel

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