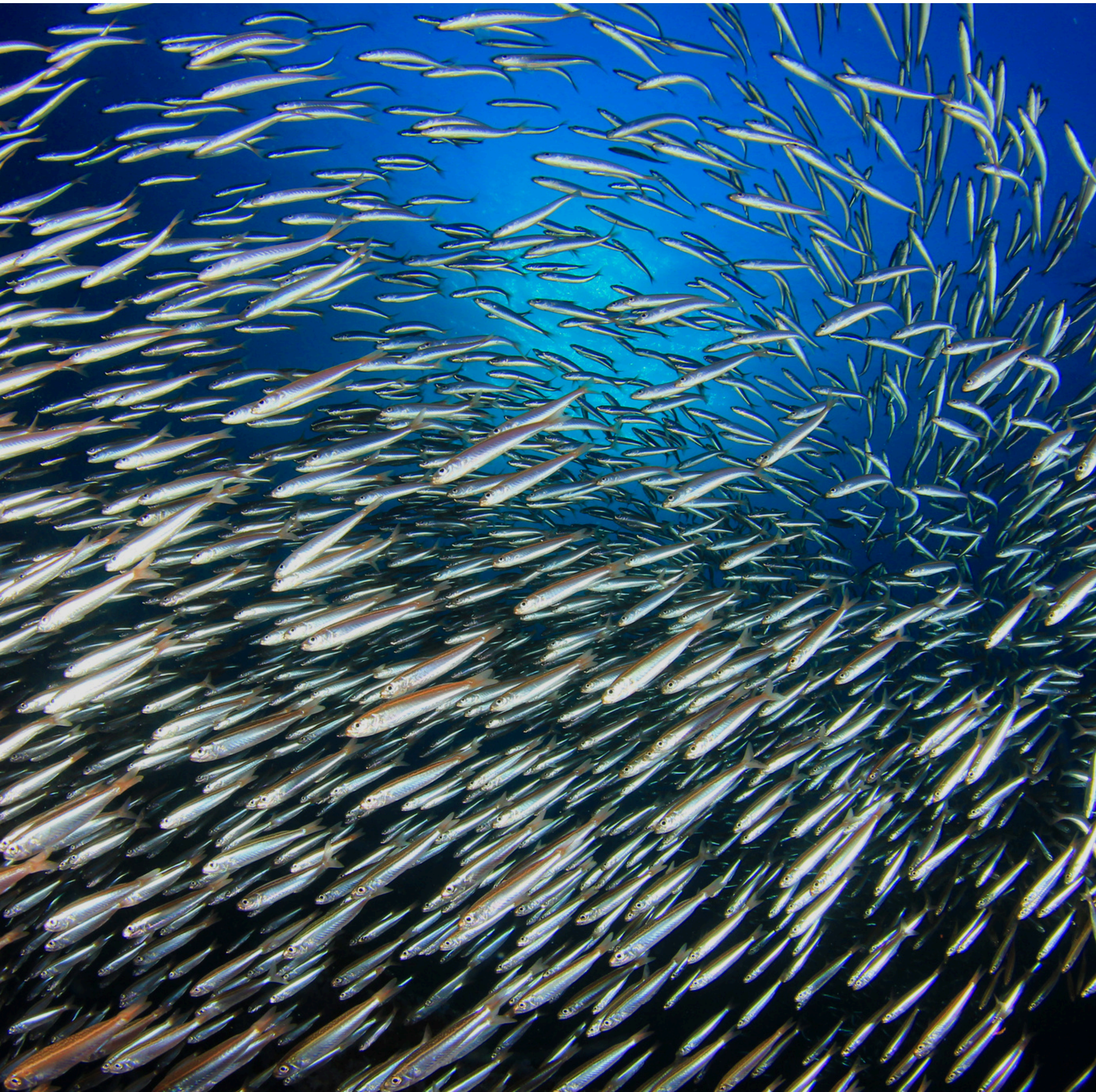
SEAWISE POLICY BRIEF ON

SUSTAINABLE MANAGEMENT UNDER CHANGES TO FISH STOCK PRODUCTIVITY



PURPOSE OF THIS BRIEF

Understanding how environmental and ecological drivers impact fish stock productivity is essential to advance progress towards Ecosystem Based Fisheries Management (EBFM). Developing knowledge on these processes is fundamental to enable improved prediction of how fish stocks and fisheries yields may be impacted under climate change – knowledge critical to ensuring that implementation of EBFM in European waters is fit for the future.

This brief summarises SEAwise's work on enhancing the prediction of long-term trends in fish stock productivity. Our research details the environmental and ecological drivers of recruitment, growth, and mortality dynamics within stocks. It also highlights our use of these findings in the development of enhanced Management Strategy Evaluation (MSE) models – by doing so, providing managers with stronger tools to support more informed and adaptive decision-making under climate change.

KEY POINTS

- SEAwise has modelled the impact of environmental drivers on stock productivity for 55 stocks across the North Sea, Baltic Sea, Mediterranean, and Western Waters region, with temperature identified as the most frequent driver influencing recruitment and growth.
- For 22 stocks, we have integrated these environmentally mediated productivity processes into SEAwise's suite of MSE models.
- When exploring the impact of climate on stock productivity, we projected that stock biomass and catch will decline for 10 out of the 22 commercially significant stocks modelled.
- By modelling modelling predation from marine mammals and predatory fish on commercial fish species, we have developed knowledge on the influence of natural mortality on stock abundance and recruitment.
- We have produced guidelines to support the evaluation of environment-productivity relationships and their inclusion within MSE modelling tools. These guidelines have subsequently been further developed for use as part of an online course to facilitate more systematic uptake of MSE.

KEY RECOMMENDATIONS

- **Incorporate broader evaluations of management strategies systematically**, considering environmental impacts on stock productivity.
- **Employ precautionary approaches when setting catch advice** to account for uncertainty and variability in stock productivity on account of ecological dynamics and climate change.
- **Develop 'worst case scenario' protocols,** drawing on scientific certainty, to support managers in navigating climate-driven declines in stock productivity which cannot be remedied through management change.
- **Base management decisions and catch advice on wider ecosystem considerations**, rather than narrowly on fishing mortality, and document this transparently.
- **Promote use of guidelines that support more systematic consideration of the environmental and ecological effects on stock productivity** within management strategy evaluation, and build on these to develop frameworks to facilitate more standardised inclusion of ecosystem information in fishing opportunity advice.
- Overall, **support continued research geared at improving understanding of the environmental and ecological drivers affecting stock productivity and uncovering long-term trends**.

SEAWISE AT A GLANCE

Involving 24 universities and research organisations from across Europe funded under Horizon2020, the **SEAwise project has worked to deliver the knowledge needed to support fishers, managers, and policy makers in the practical implementation of Ecosystem Based Fisheries Management (EBFM) across European waters.**

Building on the recognition that societal and ecological objectives are interdependent under EBFM, SEAwise has assembled a new knowledge base that captures the social, economic and ecological complexity of European fisheries. Drawing on this to develop predictive models, tools, and ready-for-uptake advice, SEAwise's work enables stakeholders to evaluate the potential trade-offs of management decisions and forecast their long-term impacts.

Through this, SEAwise has laid the foundation for a whole-ecosystem approach to management in Europe – one that would equip both fisheries and management with the resilience needed to successfully navigate future challenges and change.

BACKGROUND

Ecosystem Based Fisheries Management (EBFM) considers commercial species as components existing within a broader ecosystem context. As such, **EBFM requires recognising the ecological and environmental factors that influence stock productivity.**

The productivity of fish stocks – i.e. the rate at which they generate biomass – is constantly changing in response to environmental conditions, such as sea temperature or salinity, and ecological factors, i.e. density-dependence or predation. These variations can involve short term fluctuations, which are generally well covered within management of EU fisheries. However, changes to fish stock productivity can also be longer-term trends, driven by factors such as climate change. Currently, limited ability to predict these trends has made it difficult to infer their impact on fish stocks and the fisheries exploiting them – hindering the ability of managers to identify adaptive and responsive measures that safeguard the health of fish stocks and warrant the continuity of fisheries into the future.

To address this, we must first develop knowledge on the mechanisms or drivers behind changes in productivity. Through integrating these insights into modelling tools, we can generate more detailed insights on stock dynamics and improve our ability to predict plausible futures for these stocks. This work can then provide scientific frameworks to inform managers and stakeholders of potential changes to stock health, supporting prioritisation and decision-making around management measures that may be needed.

This brief summarises SEAwise's work on enhancing the prediction of long-term trends in fish stock productivity. Our research details the environmental and ecological drivers of recruitment, growth, and mortality dynamics within stocks. It also highlights our use of these findings in the development of enhanced Management Strategy Evaluation (MSE) models to improve prediction of stock dynamics under climate change.

Photo credit: Joerg Mangelsen, Pexels

SEAWISE'S MODELLING WORK IN CONTEXT

Various modelling tools exist to support fisheries management, which vary in both their complexity and the ease with which they can be tactically deployed (see figure 1).

Given our intention to deliver ready-for-uptake science, SEAwise has mainly focused its efforts on the development of 'intermediate' multi-species, multi-fleet models. These models sit at the mid-point between complexity and its trade-off against predictive power, producing outputs that take into account some complexity of real-world interactions yet provide relatively certain results. Our work developing these models offers vital insights to support the implementation of EBFM across Europe.

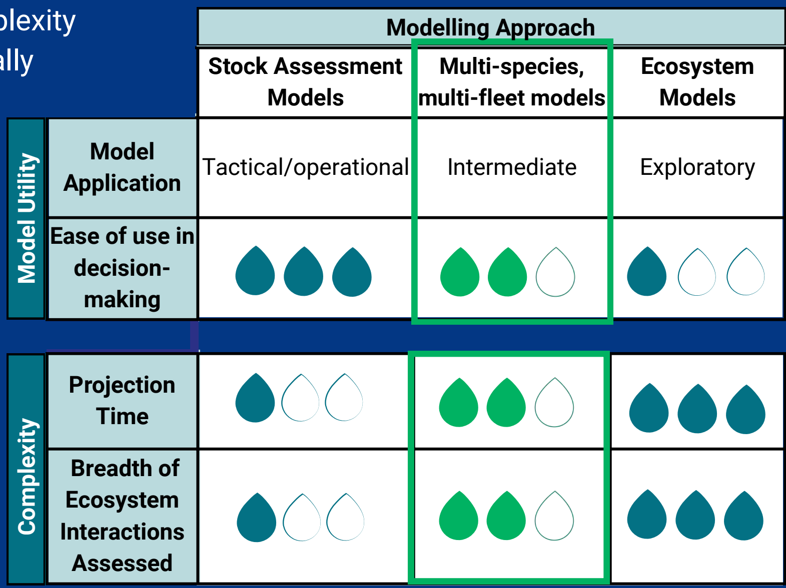


Figure 1. Characterisation of SEAwise's modelling approach according to model utility and complexity. Droplets represent the degree to which models have immediate utility within decision-making processes and how extensively they capture the complexity of ecosystem dynamics now and into the future.

ENVIRONMENTAL & ECOLOGICAL DRIVERS OF FISH STOCK PRODUCTIVITY

Drawing on existing literature and knowledge (1), **SEAwise modelled the impact of environmental and ecological drivers on the productivity of 55 stocks across our 4 case study regions (the North Sea, Western Waters, Baltic Sea, and Mediterranean Sea)** (2-6). We explored drivers including sea temperature (at the sea surface and bottom levels), salinity, and plankton availability, although the full set of drivers explored for each stock varied due to existing knowledge and the availability of biological and environmental data (7).

Across stocks, **we found temperature to be the most frequently identified driver influencing recruitment and growth dynamics** (7). As an illustrative example, for anchovy stocks in the Bay of Biscay (Western Waters region), our modelling, using temperature data from previous seasons, demonstrated that **both mean length at age and mean weight at age declined as sea temperature increased**, among other factors (5, 8). Density-dependence – i.e. the effect on a stock's survival and growth as a result of changes in population density – was also found to be relevant for some of the stocks (7).

Photo credit: Benedict Wilson, Mindfully Wired

Photo credit: Spondylolithesis, Canva

CLIMATE IMPACTS ON FISH STOCK PRODUCTIVITY

For 22 of the above stocks, we have integrated these environmentally mediated productivity processes into SEAwise's suite of Management Strategy Evaluation (MSE) models (7, 9). These enhanced models allow for more accurate assessment of stock dynamics through incorporating understanding of the drivers that influence productivity, thereby feeding into our social-ecological systems modelling elsewhere in the project (i.e. 9). As such, our findings emphasise **the importance of incorporating broader, systematic evaluations of management strategies, considering the impact of environmental and ecological drivers on stock productivity.**

To model impacts on stocks driven by climate change, we used a simplified, single-species version of our MSE models, holding fishing practices and technical interactions constant (7).

Overall, we found that stock productivity tends to decline under climate change (7). For 10 stocks (such as North Sea and Celtic Sea cod stocks, Bay of Biscay anchovy, and 3 Mediterranean hake stocks in the Adriatic and Western Ionian Sea), our projections demonstrate a decrease in biomass and catch under climate change, when compared to a baseline 'no climate change' scenario (7).

Given this, our findings emphasise **the need for policymakers and managers to develop protocols for when climate-induced productivity declines are not remediable by introducing or altering catch limitation measures.** Nonetheless, **science provides useful insights on the plausibility of these 'worst case scenarios'**, equipping managers and stakeholders with the knowledge needed to adapt to change before it materialises in the environment.

For a further 5 stocks, however, we projected that under climate change biomass and catch would increase (7). These stocks include North Sea whiting, the Northern hake stock in the Celtic Sea, and 3 Mediterranean shrimp stocks (deep-water rose shrimp, giant red shrimp, and blue and red shrimp stocks) (7). For the remaining 4 stocks, our projections demonstrate either no change (for North Sea haddock and Celtic Sea sole) or unclear change (for North Sea plaice and Celtic Sea megrim) under climate change scenarios (7).

By improving our understanding of climate-driven risks to fish stocks and reducing predictive uncertainty, our modelling enhances the evidence base required to design adaptive, climate-resilient fisheries management policies across EU waters. Additionally, our findings **highlight the importance of a precautionary approach when producing catch advice** – accounting for variability and uncertainty regarding the outlook for certain stocks.

IMPROVED MULTI-SPECIES MODELLING

Fish consumption by marine mammals and predatory fish species is the main driver of 'natural mortality' in commercial fish stocks. Whilst traditional single-species management has often overlooked this, EBFM addresses this explicitly by accounting for predator-prey dynamics to support more holistic, sustainable and informed management decision-making.

SEAwise has developed improved multi-species models to better predict the evolution of natural mortality over space and time across the North Sea and Western Waters regions (10, 11). Beyond this, we explored how to include this information in simpler models, such as MSE and stock assessment models without trophic interactions (11).

Given our research here was predominantly focused on the North Sea region, on account of ample data availability, we outline this here to offer a snapshot of our main findings (10, 11).

Using distributional maps of marine mammals and their prey together with data on marine mammal stomach content, we modelled fish consumption dynamics for harbour porpoise, grey seals, and harbour seals (10). We found that marine mammals can have substantial impacts on the mortality of fished species, with this often characterised by significant variability over space and time (10, 11).

Further, we identified that change in the availability of certain commercial stocks (i.e. sandeel) has knock-on impacts on the predation levels of other stocks, such as herring (10,11). This improved representation of predator-prey interactions in our modelling enables improved prediction of future consumption dynamics which can then be integrated within stock assessments and MSE models (11). Additionally, **these insights can help inform managers in balancing trade-offs to support both the conservation of marine mammals and health of commercial stocks under EBFM.**

SEAwise also modelled the link between productivity and predation by commercial species such as cod, saithe and haddock in the North Sea (11). Our projections reveal that with effort reduction, in response to stock productivity declines, predatory fish such as cod and saithe would be caught less – enabling them to put more pressure on intermediate predators and prey species, ultimately destabilising the system (11). Resultantly, our modelling here highlights that **as mortality on account of fishing decreases, capturing the dynamics of natural mortality becomes essential to perform stock assessment and provide advice.**

Overall, our work here highlights **the importance of basing management decisions on wider ecosystem relationships, rather than narrowly on fishing mortality.**

Photo credit: arlutz73, Getty Images

GUIDELINES FOR THE EVALUATION OF ENVIRONMENT-PRODUCTIVITY RELATIONSHIPS

Improved documentation around the inclusion of ecosystem information within fishing advice is essential to accelerate the implementation of EBFM in a consistent and transparent manner (12). Responding to this, SEAwise has produced guidelines to support the evaluation of environment-productivity relationships and their inclusion within MSE modelling tools (13).

These guidelines were developed over the course of a joint ICES-SEAwise workshop held in Spring 2024, bringing together over 56 participants from both within the SEAwise project and beyond (Europe and the US) (13). Through comparison of SEAwise work against that of colleagues, and by placing it in a more general context, participants collectively produced guidelines and methodological guidance on the integration of environmental considerations in MSE models (13).

Through co-design by workshop members, these resultant guidelines are scientifically robust and fit-for-purpose for use within advisory frameworks and to meet policy and management needs across EU fisheries (13). Resultantly, **these guidelines support more systematic consideration of the environmental and ecological effects on stock productivity within management strategy evaluations.**

Photo credit: Ricardo Nel, Pexels

Building on this, SEAwise in collaboration with ICES held a 3-day, online course in November 2024 – delivering presentations and tutorials developed from the guidelines and drawing upon SEAwise case studies. More recently, these guidelines and materials were consolidated into an open-access online course delivered by SEAwise (**linked here**) – enabling the insights developed here to be drawn upon even following the project's completion in September 2025.

CONCLUSIONS

Understanding the effects of environmental and ecological drivers on the productivity of fish stocks is key to advancing practical operationalisation of EBFM. Improving our knowledge of and accounting for these processes is central to improving stock assessments, and predicting how stocks and yields may be impacted in the future, e.g. under climate change.

Beyond fishing mortality, SEAwise's research highlights the importance of **incorporating wider ecosystem considerations into management decisions, and provides guidance to support broader evaluation of management strategies, incorporating environmental and ecological impacts on stock productivity.**

Our scientifically robust and fit-for-purpose guidelines facilitate more systematic analysis of these ecosystem considerations, and their impact on stock productivity, within management strategy evaluation. With uptake, these guidelines indirectly support the more standardised inclusion of ecosystem information in advice on fishing opportunities, and the identification of Harvest Control Rules (HCRs) that are robust to changes in productivity.

REFERENCES

1. Savina-Rolland, M., et al. (2022). SEAwise Report on the key drivers of stock productivity and future environmental scenarios. Technical University of Denmark. https://doi.org/10.11583/DTU.21269295
2. Melià, P., et al. (2023). SEAwise Report on improved predictive models of recruitment under different environmental scenarios. Technical University of Denmark. https://doi.org/10.11583/DTU.24948081
3. Melià, P., et al. (2024). SEAwise Report on improved predictive models of recruitment under different habitat scenarios and incorporating experimental results. Technical University of Denmark. https://doi.org/10.11583/DTU.28049477
4. Ibaibarriaga, L., et al. (2023). SEAwise Report on improved predictive models of growth, production and stock quality. Technical University of Denmark. https://doi.org/10.11583/DTU.25053296
5. Ibaibarriaga, L., et al. (2024). SEAwise Report on improved predictive models of growth, production and stock quality under different habitat scenarios and incorporating experimental results. Technical University of Denmark. https://doi.org/10.11583/DTU.28049597
6. Savina-Rolland, M., et al. (2023). SEAwise Report on effects of environmental and ecological factors on stock productivity for online tool. Technical University of Denmark. https://doi.org/10.11583/DTU.25610955
7. Savina-Rolland, M., et al. (2024). SEAwise Report on effects of environmental and ecological factors on stock productivity for online tool. Technical University of Denmark. https://doi.org/10.11583/DTU.28079417
8. Taboada, F. G., et al. (2023). Shrinking body size of European anchovy in the Bay of Biscay. *Global Change Biology*, 30, e17047. https://doi.org/10.1111/gcb.17047
9. Travers-Trolet M., et al. (2024). SEAwise Report on how integration of ecological indicators in multispecies-multifleet management evaluation models changes impacts of management strategies on fished stocks. Technical University of Denmark. https://doi.org/10.11583/DTU.28079390
10. Neuenfeldt, S., et al. (2023). SEAwise report on improved predictive models of natural mortality. Technical University of Denmark. https://doi.org/10.11583/DTU.26075416
11. Neuenfeldt, S. et al. (2024). SEAwise Report on improved predictive models of natural mortality under different distributional scenarios and incorporating experimental results. Technical University of Denmark. https://doi.org/10.11583/DTU.26068735
12. Trenkel, V., et al. (2023). The rationale for heterogeneous inclusion of ecosystem trends and variability in ICES fishing opportunities advice. *Marine Ecology Progress Series*, 704, 81–97. https://doi.org/10.3354/meps14227
13. ICES (2024). Joint ICES-SEAwise Workshop to Quality Assure Methods to Incorporate Environmental Factors and Quantifying Ecological Considerations in Management Strategy Evaluation Tools (WKEcoMSE). *ICES Scientific Reports*, 6(72), 48 pp. https://doi.org/10.17895/ices.pub.26661457

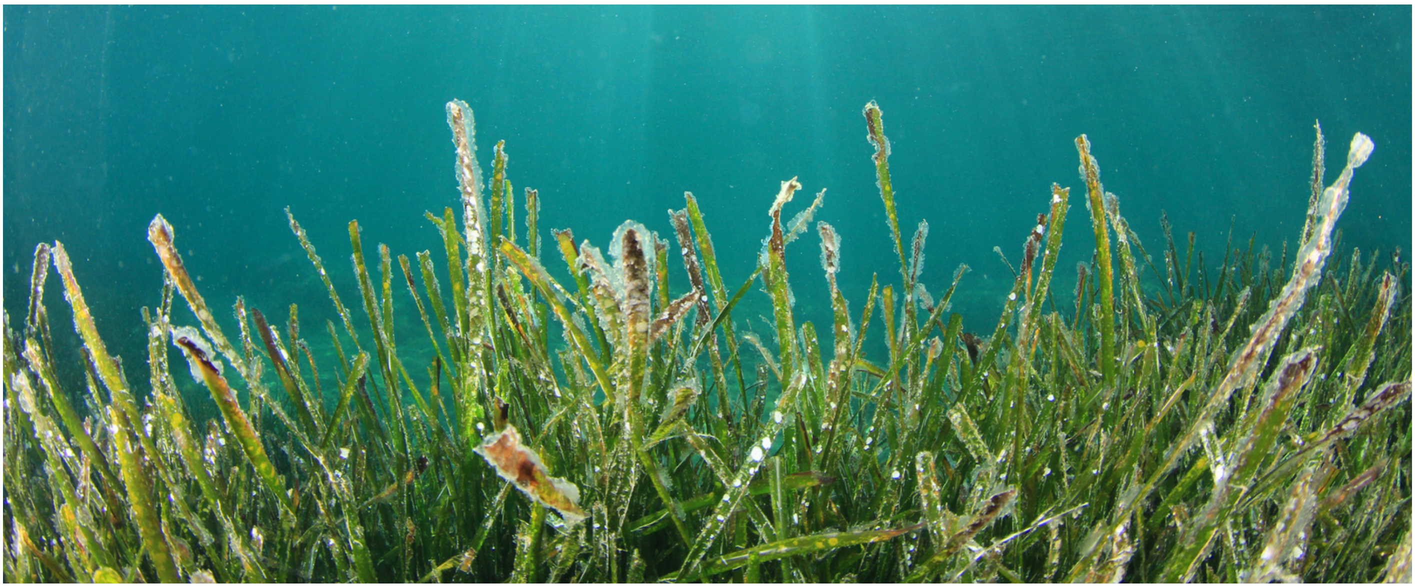


Photo credit: richcarey, Getty Images

This policy brief has been produced as part of **SEAwise's work theme on 'Ecological Effects on Fisheries'.** For further information on this work and to dive into our findings in-depth visit: https://tinyurl.com/SEAwiseEcoEffectsOnFisheries.

This Work Theme was led by Dr. Marie Savina-Rolland, IFREMER, France, as part of the broader SEAwise project coordinated by Prof. Anna Rindorf, Technical University of Denmark (DTU).

This brief sits as part of a broader series of six policy briefs offering an overview of SEAwise's research, coinciding with the culmination of the project in September 2025. These briefs can be found here: https://tinyurl.com/SEAwisePolicyBriefs.

info@seawiseproject.org **seawiseproject.org** **SEAwise Project**

MINDFULLYWIRED

SEAwise has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101000318