WORKSHOP TO DEVELOP GUIDELINES ON HOW TO APPROACH THE ECOLOGICAL, ECONOMIC AND SOCIAL TRADE-OFFS BETWEEN OFFSHORE RENEWABLE ENERGY DEVELOPMENTS (WIND FARMS) AND FISHERIES (WKWIND)

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Contents

i Executive summary

This report provides the first drafting of guidelines intended to assist understanding of the trade-offs between offshore renewable energy and fisheries in an ecosystem-based approach. Aimed primarily, but not exclusively, at ICES experts to ensure that when considering trade-offs between the sectors they include all relevant dimensions and aspects to ensure a holistic and systematic approach in line with the overarching guidelines and strategies of ICES.

The guidelines presented in this report are the first draft produced by ICES experts in the Workshop to develop guidelines on how to approach the ecological, economic and social trade-offs between offshore renewable energy developments (wind farms) and fisheries (WKWIND). The workshop is the first step to implement the ICES ORE roadmap and the start of a series of ICES activities to refine and implement the ORE roadmap.

ii Expert group information

Expert group name	Workshop to develop guidelines on how to approach the ecological, economic and social trade-offs between offshore renewable energy developments (wind farms) and fisheries (WKWIND)
Expert group cycle	workshop
Chairs	Angela Muench, UK
	Andrew Gill, UK
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Meeting venue and dates	29 April – 2 May 2024; ICES HQ, Copenhagen, Denmark

1 Introduction

The impact of climate change and energy security concerns have led to globally ambitious plans of most states with maritime waters to extend their offshore renewable energy (ORE) production, in particular offshore wind energy production. Many governments in ICES member countries and elsewhere have developed ambitious plans to use large portions of their marine space for ORE development. These areas currently are used by many other marine sectors, including fisheries, tourism, and transportation. The expansion of ORE effectively industrialises large areas of ocean ecosystems and therewith increases the competition for marine space. Any human activity within the marine space will impact, to some degree, the marine ecosystem. In addition, the activities that are allowed may not be compatible with other activities, hence leading to a need to regulate access to the marine space to limit conflicts. Therefore, governments are required to make decisions on, for example, whether particular economic activities have to be restricted or encouraged, or whether conservation measures or specific management needs to be implemented (often involving spatial or temporal restrictions) to be able to benefit from ORE development and meet their national energy targets. Such decisions involve trade-offs between the allocation of human activities and the achievement of specific targets and are often conducted within the realm of national marine spatial planning (MSP). As a general rule, decisions on trade-offs should increase the total benefits to society and reduce the ecological, economic and social costs.

Deciding on trade-offs between ORE and fisheries requires a sound understanding of the fisheries-related social, economic and-ecological components and their interactions, which can be described by the fisheries social-ecological system (SES) in relation to resource use and the interactions of such systems with local and regional development of ORE (which are also an SES). For instance, ORE infrastructure has localised effects on the habitat, and these localised effects are expected to accumulate for multiple turbines that make up a whole wind farm. At the scale of one or more wind farms there are larger spatial outcomes predicted, and these may change over time. These effects may have beneficial or adverse consequences, which need to be considered in relation to national and regional governance objectives (e.g. conservation goals; energy policy targets; sustainable fisheries). At the same time, the restriction of fishing activity and the artificial reef effects may lead to some benefits in terms of fisheries species occurrence and abundance or marine species refuge. In this case, whether ORE provides a net benefit will depend on the specific context and goals considered. It is evident that the assessment of the interaction between ORE and fisheries is complex and nuanced and therefore this will influence the trade-off assessment. Social and economic aspects, while they add to the complexity of the trade-off assessment, are key to the understanding of the ORE-Fisheries interaction. Therefore, an approach to trade-off assessment should incorporate aspects across the social, economic, environmental and ecological topics, i.e. an integrated and holistic, systems-based approach.

The scale of ORE development regionally is expected to be significant over the coming decades. However, this will not happen immediately, thus effective and continuous learning through the process of planning and decision-making for ORE deployment will greatly help with measures to reduce the negative impacts and promote the benefits, whether economic, social, or ecological. This is a classic case of trade-offs and, as such, it is important to develop guidelines for understanding and assessing these trade-offs so that the right questions are asked, and the right data are collected, which can successfully inform the assessment of trade-offs. This sets the scene for the WKWIND, which is the first activity towards the delivery of the ICES Roadmap.

ICES Roadmap

ICES provides science-based fisheries management advice through the organisation's role in data collection, data management, and science to understand the marine ecosystem. At the beginning of 2024, ICES published the ORE roadmap addressing the need for scientifically informed decision-making for marine spatial planning and to incorporate the increasing spatial conflict between sectors and the impacts on the marine ecosystem (ICES, 2024a). The ORE roadmap lays out four goals of ICES with regards to addressing the development of ORE within fisheries science in an ecosystem-based management framework (ICES, 2020), namely:

1. Advance its scientific capacity to support advice regarding the interactions among ORE developments and marine ecosystems.
2. Design and coordinate data collection networks at the range of spatial and temporal scales needed to monitor, assess, and predict the impacts of ORE development on marine ecosystems.
3. Further the development and application of models, coordinated process studies, and long-term observations supporting ecosystem-based management and the analysis of impacts from ORE development on marine life, fishing activities, and coastal economies at regional and ecosystem scales and at sub-seasonal to decadal scales.
4. Develop frameworks that guide the use of best available information on the interactions of ORE, ecosystem functions and structure, and ecosystem services and provisions.

To start the process of implementing the ORE roadmap, a workshop (WKWIND) was organised for developing ICES best practice guidelines on how to approach the ecological, economic and social trade-offs between offshore renewable energy developments and fisheries. Guidelines usually build upon decades of research and practical applications; therefore, they should be designed as early as possible. Setting out the key elements for guidelines can ensure that the information used within a trade-off assessment is transparent, scientific evidence-based, balanced from a social, ecological, technological, and economic perspective and not dictated by selected stakeholders' perspectives. Therefore, it is important to develop trade-off guidelines for considering what elements should be taken into account so that the right questions are asked, and the right data are collected and analysed, which will then successfully inform the assessment of trade-offs.

WKWIND invited ICES experts representing several of the key WGs to review existing approaches towards assessing the trade-offs that would be relevant when considering offshore renewable energy developments (with an initial focus on offshore wind farms owing to their current predominance in regional seas) and the provisions of wild harvest fish, as well as considering data requirements.

The guidelines are intended to be used predominantly by ICES experts. Therefore, the initial focus of the WKWIND was a review on approaches and data within the ICES context as well as concepts, key elements and processes used within the ICES community. However, national examples were also considered to open up the discussion and ensure that the guidelines will allow a flexible and adaptive approach. Although the workshop was set out to provide guidance on the assessment of trade-offs between offshore renewable energy provision and fisheries, the aim of the guidelines is that they can also be applied to inshore or coastal renewable energy production and therefore should be seen as relevant to marine-based renewable energy trade-off with fisheries resources. Moreover, the guidelines are intended to be applicable to fixed and floating renewable energy technologies.

WKWIND’s aim was to draft guidelines in line with the ICES ecosystem-based management approach, thus guiding how ICES will assess trade-offs by including the economic, social and ecological consequences in a systems-based approach. WKWIND had the following ToRs:

a) Develop guidelines to assess the trade-offs between offshore wind farm developments and fisheries activity and associated social, economic and ecological consequences, taking into consideration:
    i. Defining the spatial and temporal boundaries of the trade-offs to be assessed between fisheries and offshore wind farms.
    ii. Review the existing data and tools relevant to trade-off assessment using information provided by previous ICES workshops (e.g. WKSSFGEO2, WKD6STAKE, WKTRADE4, WKD6ASSESS).
    iii. Developing an approach that allows managers and stakeholders to explore the trade-offs between the extension of energy provision and the provision of wild harvest fish and the respective ecological, economic and social consequences.

b) Propose activities to advance the four priorities identified in the ICES ORE Roadmap for the Provision of Advice on Offshore Renewable Energy.

2 Framing the system

The trade-offs between ORE and fisheries can be usefully framed and mapped out within a system-based approach. This requires a sound understanding of the system components, in relation to resource use and extent of the interactions in a local and regional context. The social-ecological system (as defined by Berkes & Folke, 1998) was considered here as appropriate as it emphasises that humans are an integral part of the marine ecosystem. Drawing strict boundaries between social systems and ecosystems is artificial as there are continuous complex feedback mechanisms between these systems: ecosystems generate goods and services from which humans may benefit, and human use of natural resources impacts ecosystems. The Social-Ecological Systems (SES) framework developed by Nobel Prize laureate Elinor Ostrom and colleagues (McGinnis & Ostrom, 2014; Ostrom, 2007), offers a comprehensive lens through which to understand these complex interactions between humans and ecosystems in relation the use of resources. It also considers governance institutions (formal or informal) and how they shape access to resources to avoid (un)sustainable resource use, which is the basis from which SES was developed.

2.1 Elements of the framework

The overarching drivers that set the context for WKWIND guidelines to assess trade-offs between fisheries and offshore renewable energy development, were identified as climate change mitigation, energy security and food provision concerns as well as biodiversity conservation measures. A variety of factors will affect how the marine space is used to address these drivers, and this will impact the way trade-offs should be assessed. Therefore, a PESTEL analysis was conducted to systematically identify the factors of importance that should be included in the SES framework. The PESTEL analysis, originally designed for business (Aguilar, 1967), is a strategic tool which looks at Political, Economic, Social, Technological, Environmental, and Legal factors and helps organise factors affecting the use of the marine space into those broad categories. It has recently been used in ICES advice about the adoption of innovative gears (ICES, 2023b) and WKWIND participants agreed PESTEL was appropriate to be used to better understand drivers and barriers with regards to the expansion of offshore renewable energy and its interactions with fisheries.

A list of potential factors that will affect implementation of how marine space is used were identified; Table 1, shows the list compiled. The list should not be seen as exhaustive but rather as describing the multitude of factors and driving forces restraining or motivating the trade-off analysis.

Table 1. List of potential factors using the PESTEL approach which determine the use of marine space to be considered before conducting a trade-off analysis between offshore renewable energy (ORE) and fisheries.

Political	- Subsidies and taxes - Marine spatial planning priorities - Paris agreement - United Nations Biodiversity of Areas Beyond National Jurisdiction Treaty (BBNJ) and other biodiversity policies
Economic	- Economic contribution of the ORE industry and fisheries to the local economy compared to other sectors (alternative uses) - Profitability and technical efficiency of ORE and/or fishing - Changes to investment and operational cost structure (e.g. Existing energy/marine infrastructure; access to energy transmission grids; ports and coastal infrastructure for energy development; shipping lanes / transportation)
Social	- Cultural values associated with fishing communities at local and regional level. - Social acceptability of ORE for coastal residents / communities
Technology developments	- Decreasing investment and operating cost for fisheries and ORE - National decision-making to achieve international objectives
Environmental (Habitat issues/ ecological/ ecosystem)	- Implementation of decarbonisation goals at several levels; emissions of fishing activity/ ORE operations - Knowledge about vulnerable marine habitats - Endangered, Threatened and Protected Species - Structure of benthic/bentho-pelagic habitat - Currents /hydrodynamics (changes in upwelling areas may be particularly critical for fisheries of low trophic level species which are forage species and will affect many other components of the ecosystems (Floeter *et al.*, 2022; Raghukumar *et al.*, 2023) - Contaminants (trace metals, persistent organic pollutants, microplastics) in the sediment - Species abundance and distribution - Trophic web relationships
Legal	- International agreements and directives (e.g. Marine Spatial Framework Directive) - National legislative and regulatory frameworks - Local governance arrangements

2.2 Social-Ecological Systems framework

The participants of WKWIND agreed on the utility of applying a Social-Ecological Systems (SES) framework to enable the systematic examination of the interconnections between the defined social and ecological components, which will provide insights into the underlying drivers, dynamics, and vulnerabilities of trade-offs within a coupled human-environment systems (Partelow, 2018).

The SES framework (Figure 1) is organised into several interconnected components that collectively capture the complex interactions between social and ecological systems. Each 1st tier component is a core subsystem, which consists of multiple tier-2 variables. At tier 1, we find the following components (Guimarães, 2018; Partelow, 2018):

- Resource system (RS): A specific territory or area of resource units that generate benefits. Examples of an RS can be a fishery, a marine protected area, a coastal fishery, the habitat extent of a species or from the perspective of a technical resource system - an offshore wind farm.
- Resource units (RU): The elements of the system that generate benefits. For example: benthic communities, fish, wind.
- Actors: Individuals who influence or are influenced by the RS and the RU. For example: fishers, wind farm operators, coast guards.
- Governance system (GS): The institutions that govern the resource system. These include the government and other organizations involved in management, the specific rules related to resource use, and how these rules are made. The rules are organised in nested levels: constitutional-choice, collective-choice and operational level. To illustrate: The European Common Fisheries Policy and the Marine Strategy Framework are constitutional-choice rules (parts of which stem from United Nations treaties) that lay down the basis of collective-choice rules that are implemented by Member States, for example quota allocations or marine protected areas, which then are further implemented at operational level (e.g., fish producers' organisations who make fishing plans concerning quota). In establishing these rules, advisory boards, environmental NGOs, and other stakeholder organisations also play a role.
- Social, economic and political settings (S): these are contextual factors that have a direct influence on and are influenced by the RS, RU, A and GS.
- External Ecosystems (ECO): the larger ecosystems that directly influence or are influenced by the RS, RU, A and GS.
- Interactions (I): The dynamic relationships and exchanges among the components of a social-ecological system. These interactions can take various forms, such as feedback loops, cross-scale interactions, adaptive interactions, conflict, cooperation.
- Outcomes (O): Results or consequences of interactions and processes within a social-ecological system. These include social outcomes, ecological outcomes, resilience outcomes, resilience outcomes, equity and justice outcomes, and adaptive outcomes.

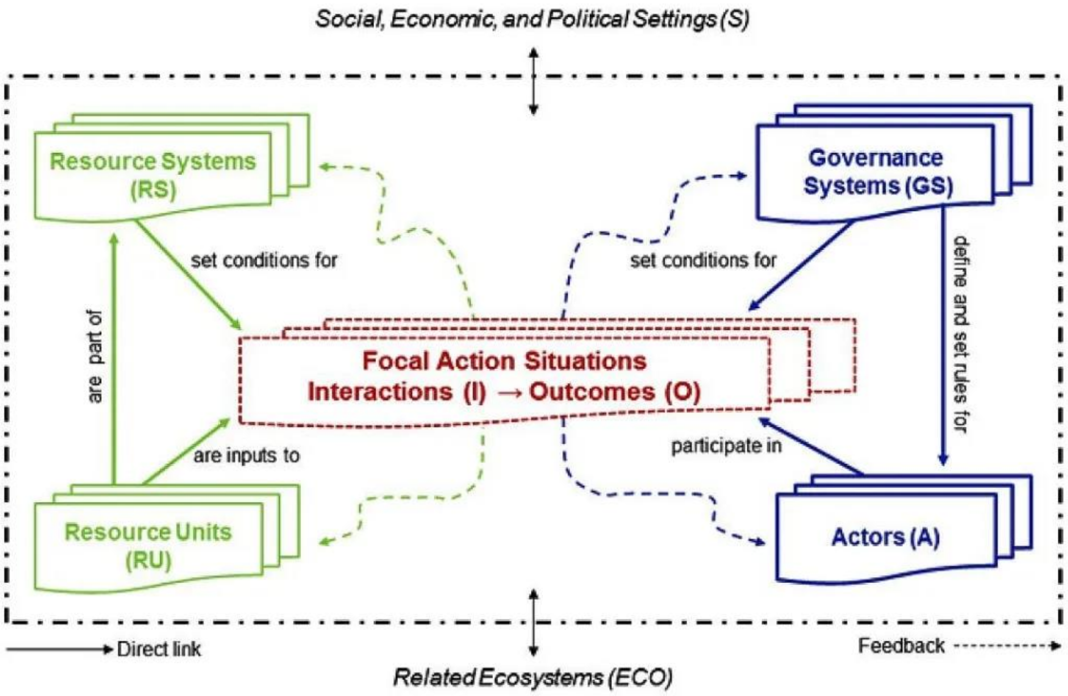

Figure 1. Conceptualisation of the Social-Ecological Systems Framework. Source: (McGinnis & Ostrom, 2014).

Each of the components, represented as coloured boxes in Figure 1, is composed of multiple tiers, with the number of tiers adaptable to the system under consideration. For each tier, components are linked through action situations, examples being the decline or increase of a fish stock or the loss of access to fishing grounds by ORE development. These action situations represent contexts where the actions by the various actors transform inputs into outcomes. Each governance system holds sway over specific groups of actors, thereby shaping the actors' characteristics and the choices at their disposal. The entire array of relevant governance systems and resource systems establishes the parameters within which action situations unfold (Guimarães, 2018).

The uppermost tier of components can be unpacked numerous times when analysing specific SES related questions. The SES components that are most important for a particular study depend on the specific research question of interest (Ostrom, 2011). As part of the diagnostic framework, the tier 1 component includes 56 variables that can contribute to a holistic understanding of a specific question (Table 2). Depending on the type of question(s) to be addressed, the relevant tier-2 variables can be selected and described for the specific case under consideration.

Table 2. Tier-2 variables of Social-Ecological Systems. Source: (McGinnis & Ostrom, 2014).

Tier-1 components	Associated tier-2 variables
Resource systems (RS)	RS1 – Sector (e.g., water, forests, pasture, fish) RS2 – Clarity of system boundaries RS3 – Size of resource system RS4 – Human-constructed facilities RS5 – Productivity of system RS6 – Equilibrium properties RS7 – Predictability of system dynamics RS8 – Storage characteristics RS9 – Location
Resource units (RU)	RU1 – Resource unit mobility RU2 – Growth or replacement rate RU3 – Interaction among resource units RU4 – Economic value RU5 – Number of units RU6 – Distinctive characteristics RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors A2 – Socioeconomic attributes A3 – History or past experiences A4 – Location A5 – Leadership/entrepreneurship A6 – Norms (trust-reciprocity)/social capital A7 – Knowledge of SES/mental models A8 – Importance of resource (dependence) A9 – Technologies available
Governance systems (GS)	GS1 – Government organizations GS2 – Nongovernment organizations GS3 – Network structure GS4 – Property-rights systems GS5 – Operational-choice rules GS6 – Collective-choice rules GS7 – Constitutional-choice rules GS8 – Monitoring and sanctioning rules
Social, economic, and political settings (S)	S1 – Economic development S2 – Demographic trends S3 – Political stability S4 – Other governance systems S5 – Markets S6 – Media organizations S7 – Technology

Tier-1 components	**Associated tier-2 variables**
Related ecosystems (ECO)	ECO1 – Climate patterns ECO2 – Pollution patterns ECO3 – Flows into and out of focal SES
Interactions (I) *part of Action Situation*	I1 – Harvesting I2 – Information sharing I3 – Deliberation processes I4 – Conflicts I5 – Investment activities I6 – Lobbying activities I7 – Self-organizing activities I8 – Networking activities I9 – Monitoring activities I10 – Evaluative activities
Outcomes (O) *part of Action situation*	O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability) O2 – Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability) O3 – Externalities to other SES

As a diagnostic tool, the SES framework provides a structured approach to identifying key elements and processes shaping the interactions between people and their surrounding ecosystems. It enables scientists, policymakers, resource users and other stakeholders to identify critical components, assess interactions and feedback, diagnose system resilience, identify leverage points for intervention, and inform decision-making and adaptive management. The SES framework provides evidence-based assessments (quantitative and qualitative). It enables stakeholders to anticipate and address potential trade-offs, conflicts, and unintended consequences of interventions. These insights contribute to the design of adaptive management approaches that can respond to changing conditions and uncertainties. Therefore, the framework provides us with an adaptive approach, which enables us to identify all relevant elements and their interactions that will need to be considered with any assessment of trade-offs. Hence, depending on the context different levels of tiers can be considered or not.

3 Considerations for a trade-off assessment

WKWIND connected ICES experts from different scientific disciplines to begin developing the guidelines for the assessment of the trade-off between ORE and fisheries. The aim was to develop guidelines which are aligned with existing ICES values and existing guidelines, such as ecosystem-based management (ICES, 2020), ICES stakeholder engagement strategy (ICES, 2023c) or ICES Framework for Ecosystem-informed Science and Advice (FEISA); (Roux & Pedreschi, 2024).

Early in the workshop, in line with the SES approach proposed in the previous section, participants were asked to provide an initial set of key components that they would expect to see in trade-offs between ORE and fisheries with respect to economic, social, ecological and conservation aspects. This exercise quickly showcased the complexity of aspects to be included. As such, the overarching themes needed for an assessment were discussed and their role in a trade-off assessment identified. These provided an agreed set of the key elements to be considered before setting out to conduct a trade-off assessment. The key elements based on the outcomes of the workshops are set out below.

3.1 First-order and higher-order effects

First-order effects are effects that relate to the current situation, and which are directly observable. For example, a first order effect of closing an area for fisheries could be the immediate reduction in fishing activity and associated production in this area. This reduction could potentially lead to reduced fishing effort overall if not all affected activity can be displaced successfully. The higher-order effects (often referred to as indirect and or induced effects) capture wider changes in the fishing activities and in the ecosystem. For example, displaced fishing activity due to the closure could lead to changes in the ecosystem as a different human pressure would be exerted on the closed area (i.e. less fishing pressure but the presence of ORE infrastructure) and fishing activity could be moving to areas that were not or hardly fished before. Other examples include the effect the displaced fishers may cause on other fishers due to the increased fishing pressure in the areas the fishing fleet was displaced to; or the attraction of predator species if prey fish abundance within a wind farm increases. First-order effects are often easier to assess as they relate to the very short-term, while higher-order effects often only become measurable in the medium to long-term, particularly as they operate over ecological time scales (e.g. it takes time for a marine species population to grow or adapt) and often result from cumulative effects.

3.1.1 Cumulative effects

Aggregated, collective, accruing, and (or) combined changes to the environment that result from a combination of past, present and future human activities and natural processes, represent cumulative effects (Stelzenmüller *et al.*, 2018). Cumulative effects can also be considered as the aggregate effects from the establishment of several wind farms in a region or the accumulation of consequences from individual wind farm developments over space and/or time. Most current scientific evidence relating to offshore wind interactions with the environment looks at local changes or individual effects. To understand whether these effects are similar or different in the context of cumulative effects on the ecosystem and/or the fisheries requires consideration of the spatial and/or temporal scales of the effects. When considering trade-offs there may be a level of cumulative effect where the outcome changes in favour of one aspect over another and as such the trade-off assessment should apply methods that assist with the cumulative considerations. In the hypothetical example of ORE and fishers above, the cumulative effects that follow establishment of multiple wind farms in an area could manifest as follows: 1) fishers are initially displaced from the OSW wind development area; 2) this leads to increased fishing pressure in other areas; however 3) over time fish species recruitment increases from the exclusion of fishing in the wind farm area; and 4) landings then actually increase over the prior state after several years providing net benefit to the fishery. Of course, other scenarios may occur, which highlights the need to consider all the elements that are part of the SES and their interactions and interdependencies, which are required for the trade-off assessment. Future scenarios can be considered using approaches such as Scenario matrices (see Annex 2).

3.2 Transboundary considerations

The scale over which ORE development, fisheries and ecosystems operate will have effects that transcend national and regional geo-political boundaries. The major ORE developers are global companies optimising their investment portfolio based on profit considerations in a global context. Fisheries harvesting a shared stock are often managed regionally and by specific stock area which often covers exclusive economic zones but also waters outside national jurisdictions. The fish species and other ecosystem components do not respect human-defined boundaries; species and habitats reflect the different spatial and temporal scales that ecosystems function over. From a human perspective, marine plans are developed nationally to benefit national society and local communities and to provide space to various marine activities. Owing to the different levels of management and jurisdiction within the marine environment, the benefits or costs of ORE development within the marine space should be evaluated along with the responses of the fisheries resource species and the consequences to the linked fishing activity. ORE development in one area can also have impacts on fisheries in other jurisdictional areas (i.e., through displacement or downstream changes to biological productivity along ocean fronts). Transboundary trade-off considerations are thus required to address the interaction between ORE installed and therefore fixed in one area and fish and fisheries, which may move within different jurisdictional boundaries.

3.3 Life cycle aspects

Life cycle relates to both the stages of the renewable energy development (pre/construction, operation, decommissioning) and the natural history of marine resource species. Both should be included in a systems-based approach to trade-off assessment. This includes not only the changes to the ecosystem resulting from the ORE development but also economic aspects, such as job opportunities and community impacts during the different stages of the development.

Ecological assessments should be targeted towards disentangling the impact of ORE in relation to the different life stages of fisheries species and how this will feed through to the ecosystem, for example trophic changes in the food web. Furthermore, ORE could serve as a reproduction/recruitment ground while in operation, a refuge from traditional fishing leading to local increases in abundance and biomass, which may attract predators into the area. Depending on the changes in the food web, this could potentially provide different fishing opportunities for the fisheries in the vicinity of the ORE. The life cycle aspects should be considered within the context of cumulative assessment too as they are defined by spatial and temporal attributes. The Integrated Ecosystem Assessment (IEA) process (see Annex 2) is particularly suited to considering these challenges with a built-in mechanism to continuously re-evaluate dynamic systems as they move through multiple states.

3.4 Vulnerability

Some areas might be particularly important for ecological, economic, and social factors. Building ORE on spawning grounds or in fragile habitats with protected, threatened or endangered species might have detrimental or even irreversible biological consequences. Restricting access to core fishing areas might be particularly problematic for some fisheries if alternatives are not available. Trade-off assessments should try to identify these areas of ecological, economic and social sensitivity to inform the planning and development process and avoid far-reaching or irreversible consequences.

3.5 Risk and opportunity

ORE development will lead to structural and functional changes in marine ecosystems and the associated social and economic systems at multiple scales. Many of these changes are difficult to predict and a trade-off assessment should incorporate consideration of this as uncertainty. To account for the uncertainty in a trade-off assessment, it is recommended to apply a risk assessment approach that encompasses ecological, economic and social risks, such as the ICES Framework for Ecosystem-informed Science and Advice (FEISA); (Roux & Pedreschi, 2024).

FEISA uses a system of indicators for knowledge development and integration as relevant to stated management objectives (i.e. consolidation of the evidence base in support of EBM). Different types of data and knowledge define measurable qualitative, semi-quantitative, and/or quantitative indicators. The indicators are combined with a risk-based approach for operationalising the indicators into advice (implementation of the evidence-base for EBM into advice products; Figure 2). Such a framework emphasises the development of biological, ecological, and socio-economic indicators, and their practical application in context-based and objective-based risk assessments:

- Context-based risk assessments are used to prioritise human activity sectors and/or components of social-ecological systems for monitoring and management actions. They are generally performed based on experiential knowledge and/or empirical information and are often used for the purpose of risk identification.
- Objective-based risk assessments are probabilistic and used to evaluate the potential consequences of alternative management strategies and options, as well as trade-offs. They require operational objectives to be specified and can be performed empirically or analytically, depending on the availability of mechanistic/process knowledge. Objective-based risk assessments are usually informed (implicitly or explicitly) by experiential knowledge, although rarely recognised as such.

Objective-based risk assessments are performed using empirical data and tools (Figure 1, green labels) or analytical tools where mechanistic understanding is available (Figure 2, blue labels). Context-based risk assessments have an experiential and empirical foundation (green). The distinction between experiential and empirical evidence and risk assessment pathways/methodologies (green space) and mechanistic and analytical evidence and risk assessment pathways/methodologies (blue space) is key to operationalising different indicators and handling different sources and types of uncertainties in advice.

The FEISA framework builds on well-established approaches and is intended to facilitate the integration, utilisation, and translation into advice of the wide range of knowledge/data/information types available in the ICES community and beyond. The framework provides the architecture needed to optimise, expand, and transform existing practice to advance ecosystem-informed science and advice. The framework architecture is designed to support and inform objective-based and/or outcomes-based management decision-making systems.

Considering that changes induced by ORE on ecosystems are often assessed on a case-by-case basis, the evidence base can vary for each case in the type of data available to then assess the consequences of ORE on fisheries. The framework allows for different types of data to be integrated while considering the overall system and acknowledges the uncertainty and risks within the assessment.

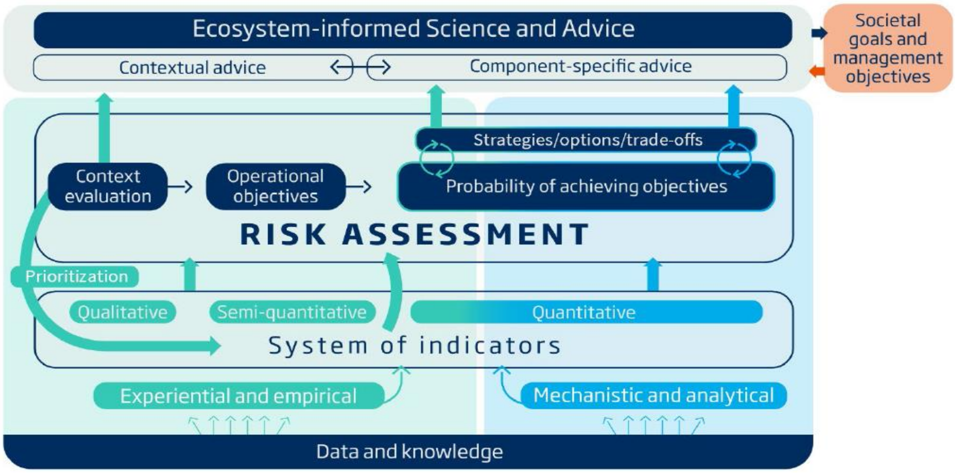

Figure 2. ICES Framework for Ecosystem-Informed Science and Advice (FEISA); (taken from Roux & Pedreschi, 2024).

4 Components of a trade-off assessment

4.1 Definitions

WKWIND brought together experts from a wide range of ICES working groups. At the outset, it was agreed that a common understanding of terminology, within the context of trade-off assessment between ORE and fisheries in an ecosystem-based management approach, is needed as scientific disciplines often use the same words to describe different contexts. Therefore, the WKWIND participants agreed on definitions of several terms to ensure a common terminology before starting to consider the trade-off assessment. Annex 3 sets out the definitions that were discussed and agreed by the WKWIND participants. The list is not meant to be exhaustive but to provide a common understanding for the context of WKWIND and to highlight the importance of common definitions.

4.2 Data

Any consideration of trade-offs and associated quantification is limited by the data available. There are different types of data needed to inform the trade-off assessment between ORE and fisheries in an ecosystem-based context. When conducting a trade-off analysis for ORE-Fisheries specific categories of data are required, namely:

- Fisheries activity data
- Economic data
- Social data
- ORE activity data
- Habitat type (including sediment, benthos, …)
- Ecosystem data (including species, communities, structure and functional attributes)

Annex 4 provides an overview of data sources and availability at the ICES level.

It is important to note that before beginning data collation and subsequent trade-off analysis, the scale of the assessment needs to be determined, in line with the SES approach described above. Boundaries on the time and spatial scales for the assessment need to be set and should be clearly defined before exploring potential data and indicators for the trade-off assessment. The workshop also stressed the need for a robust and objective assessment. Furthermore, it is of importance to understand who the stakeholders and the end users of this assessment are, and that local and operational assessments will require more detailed data than high-level strategic policy assessments. However, any assessment will be dependent on the quality of available data, hence additional data collection and improvement thereof might be needed.

4.3 Stakeholders

WKWIND participants agreed on the need for stakeholder engagement as the work under the implementation of the ICES ORE roadmap continues, but also within the context of trade-off assessments between ORE and fisheries in an ecosystem-based approach. Stakeholders provide a wealth of insights which should be integrated into trade-off assessment, and stakeholder engagement should also contribute to shared acceptance of the outputs of the assessment. The draft ORE trade-offs guidelines should be further developed and validated through input from stakeholder and end-users for these to be relevant and taken up in related science and advice work. It is also recognised that stakeholders will be important in the future as the trade-off work under the implementation of the ICES ORE roadmap continues.

Whilst ICES has a long experience in stakeholder engagement, a vital step in the formalisation of this process took place in 2023 with the publication of the ICES Stakeholder Engagement Strategy (ICES, 2023c). The strategy re-enforces the necessity of stakeholder engagement in ICES activities to ensure all ICES products are relevant to societal objectives, transparent, and include diverse perspectives. The strategy describes the engagement mission and provides guidance for the ICES community on organizing stakeholder engagement. It outlines the key principles of engagement within ICES, listing the scope, context, and rationale for engagement, and defines the roles and responsibilities of both stakeholders and scientists (Figure 3).

Figure 3. ICES Stakeholder Engagement Principles (ICES, 2023c).

Transparency is recognised as a key component to building trust in any interactive process between scientists, policy makers and stakeholders. In ICES transparency is a core tenet of both the ICES stakeholder engagement strategy and the ICES advisory framework and principles (ICES, 2023c). ICES objective of proving evidence-based science and advice needs to account for the ambiguity and complexity in societal objectives. To achieve this, an iterative approach with a high degree of transparency and stakeholder consultation is needed. The stakeholder engagement strategy lays out the mechanism and the roles of the stakeholder (ICES, 2023c).

5 Developing an initial SES framework for identifying (trade-off) interactions between ORE and fisheries

By applying the SES framework to the interactions between ORE and fisheries, policymakers, resource managers, and stakeholders can gain a holistic understanding of the challenges and opportunities associated with these sectors' coexistence. This analysis can inform more integrated and sustainable approaches to marine spatial planning, resource management, and ORE development, ultimately promoting the long-term viability of both ORE and fisheries industries while safeguarding marine ecosystems and coastal communities.

In the context of ORE development and fisheries, an SES analysis might unfold as follows:

Social Actors: Identify the various stakeholders involved in ORE and fisheries. These may include government agencies, ORE developers, commercial and recreational fishers, environmental NGOs, local communities, and indigenous groups.

Ecological Components: Consider the ecological impacts of ORE on fisheries and marine ecosystems. This involves assessing changes in habitat quality, migration patterns, and the abundance and distribution of species resulting from the construction and operation of wind turbines.

Governance Systems and Institutions: Examine the existing governance mechanisms governing ORE and fisheries management. Evaluate the effectiveness of regulations, policies, and decision-making processes in addressing potential conflicts and trade-offs between these sectors. This could involve analysing permits, quotas, zoning regulations, and stakeholder engagement strategies.

Interactions and Feedback: Explore the interactions and feedback loops between ORE and fisheries. For example, consider how changes in fish populations or habitat due to wind farm construction might impact fishing activities, livelihoods, and local economies. Conversely, assess how shifts in fishing practices or regulations may affect the siting, design, or operation of ORE projects.

External Drivers: Take into account external factors influencing the dynamics between ORE and fisheries. This could include market trends, technological advancements, climate change impacts on marine ecosystems, and broader policy objectives, such as energy security related local renewable energy deployment and sustainable fisheries management.

Resilience and Adaptive Capacity: Evaluate the resilience and adaptive capacity of the social-ecological system to cope with potential shocks and uncertainties. This involves assessing the flexibility of governance arrangements, the ability of stakeholders to collaborate and adapt to changing conditions, and the capacity to mitigate and respond to conflicts and unintended consequences.

Within WKWIND, first steps were taken with participants to define the social-ecological system and elements integral to trade-off analyses between ORE and fisheries. However, this overview should not be seen as the final product, but rather as an initial step to showcase how the SES can be applied and help to structure the assessment in line with a holistic approach to trade-offs.

In the workshop, an initial brainstorming exercise resulted in the identification of the different integral elements and concepts that the experts in the room thought were essential to include into the trade-off analysis for ORE and fisheries (Figure 4; see also Annex 5). The elements were clustered in a plenary session and then delivered to a sub-group in order to work these initial thoughts and issues into a concrete Social-ecological framework which will be here used as an example to showcase the various elements to be included into a trade-off assessment and how an SES can be used to structure the assessment (Figure 5).

The elements of the system were further transferred from the SES framework into a tabular form (Table 3; see Annex 5 for graphical version) to elucidate specific details needed to conduct a trade-off analysis using SES.

Figure 4. Brainstorming exercise to identify aspects to be considered as crucial within a trade-off assessment between ORE and fisheries.

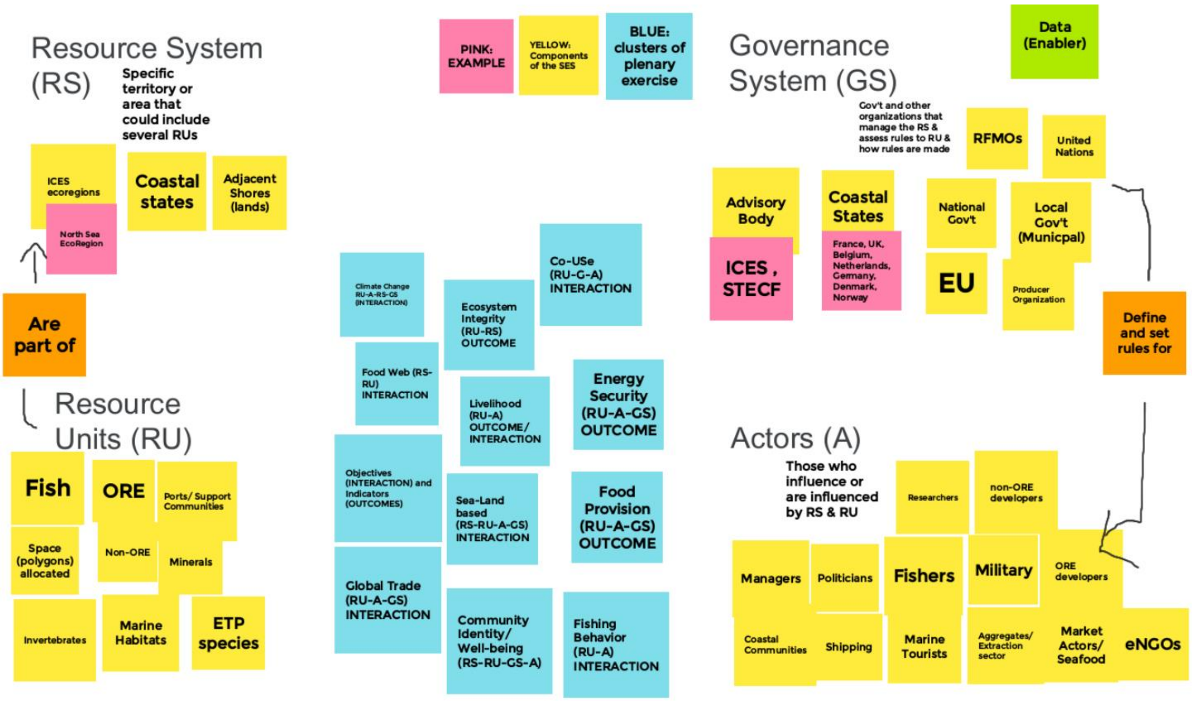

Figure 5. An initial example resulting from the brainstorming of the workshop depicting the elements (yellow) of the Social-ecological system (SES). Blue squares indicate larger concepts that are results of interactions and outcomes among the different system elements.

Table 3. Initial approach of transferring brainstorming examples into SES table - mapping the detailed elements of SES for ORE and fisheries to be used in a trade-off assessment.

Resource System (RS)	**Resource Unit (RU)**	**Spatial characteristic**	**Temporal characteristics**	**Interactions**		
				With	**Type**	**Outcome**
Tier 1						
Human constructed facility (RS4)	Several Offshore wind parks (RU7)	Regional extent	Operation	Fish	Attraction/ Alteration +/-	Distribution and abundance of fish populations
Human constructed facility (RS4)	Cables between offshore wind parks and coast	Spatial lines	Operation	Fish	Attraction/ Alteration +/-	Distribution and abundance of fish populations
…						
Tier 2						
Human constructed facility (RS4)	Offshore wind park (RU7)	Local extent	Operation	Fish	Attraction/ Alteration +/-	Distribution and abundance of fish (schools/shoals)
Human constructed facility (RS4)	Cables between wind park and coast	Spatial lines	Operation	Fish	Attraction/ Alteration +/-	Distribution and abundance of fish (schools/shoals)
…						
Tier 3						
Human constructed facility (RS4)	Single offshore wind turbine (RU7)	Spatial point	Operation	Fish	Attraction/ Alteration +/-	Movement and location of fish individuals
Human constructed facility (RS4)	Cables between turbines	Spatial lines	Operation	Fish	Attraction/ Alteration +/-	Movement and location of fish individuals
…						

6 WKWIND in relation to ICES ORE Roadmap

The ORE roadmap outlines a role for ICES in addressing knowledge gaps through topical expert groups, a coordinated approach to the data acquisition, engagement, prioritisation, and capacity-building required for an ecosystem-based approach to understand the outcomes of ORE developments within the marine environment. The ORE roadmap (set out in January 2024) identified four priority goals to advance the data, science, and advice objectives identified in this roadmap, and support the achievement of ICES goals around ORE. The four goals are:

1. Evaluation of the trade-offs between ORE developments and other sectors, starting with fisheries and biodiversity; developing of best practice guidelines for marine spatial planning.

2. Development and publication of guidelines and standards for monitoring and assessment in the ORE sector at the temporal and spatial scales needed to support ecosystem-based management.

3. Creation of ecosystem-based management science and approaches to support the sustainable development of offshore renewable energy, in support of national government, regional, and industry needs.

4. Assessment of the impact of ORE developments on fishery and ecosystem observation surveys, fisheries management advice, and recurrent ICES advice; development of solutions to meet the objectives and advance the goals identified in the roadmap.

Goal 1: WKWIND was the first activity towards the delivery of the ICES Roadmap for Offshore Renewable Energy (ORE). In the development of the WKWIND workshop structure, it was decided that goal 1 could best be progressed by developing guidelines that would help direct ICES and external users in the evaluation of trade-offs between ORE developments and other sectors (see above). The scope of this is so broad that limits are needed; that is, without a specific site or region in mind the trade-off question is too broad.

This WKWIND report presents an agreed approach of how to set the appropriate systems context and the key elements required for a trade-off framework and how to create the bounds for the analysis. The trade-offs with biodiversity were not developed in detail in the workshop, but rather integrated within the social-ecological system.

WKWIND determined the following guidelines:

- Frame the system which is under consideration for the trade-off through identification of the elements. A useful approach to enable framing is a Social-Ecological Systems framework, which first requires identifying the key elements of governance, stakeholders, resources and their extent, and second consideration of the interactions between these elements of the framework.
- Aspects that should be included in the trade-off assessment, besides the identified interactions are:
    - First-order and higher-order effects
    - Cumulative effects
    - Transboundary considerations
    - Life cycle aspects
    - Vulnerability
    - Risk and opportunity

- Essential components of the trade-off assessment include:
    - Definitions and terminology standardised
    - Data availability
    - Stakeholder engagement considerations

A foresight exercise involving researchers and stakeholders and/or a case study would further advance Goal 1. The exercise would take the outline guidelines and apply them to the case study, which would have defined limits that will bound the SES.

In terms of developing best practices for marine spatial planning; the workshop recognised that engaging with WGMPCZM is an essential step. We envision these guidelines as becoming a step in the MSP process; that is, a best practice to include the guidelines that will eventually be developed in any MSP involving areas for offshore energy development.

Goal 2: It was identified that progress toward this goal was a top priority. WGOWDF has identified a similar TOR. However, there is significant work yet to be done in identifying the scope and related activities. Participants stressed the importance of working directly with stakeholders including ORE industry, as any monitoring and data collection efforts are precipitated by access, which the OSW industry controls (although there is variation by country). An external mandate would be extremely helpful in gaining access to data but does not exist in most countries currently. It was noted that an effort in the UK was undertaken to develop standards and guidelines for project-specific monitoring. In the past, there was a mismatch in the responsibilities of environmental contractors working for ORE companies (for licensing/ permitting) and the intention for regional monitoring by scientists. ORE companies currently have little incentive to facilitate regional monitoring, or even the ability to combine data from multiple projects for regional studies. Working collaboratively with the industry starting early as possible would help to enable planning and appropriate data collection for the trade-off analysis. In addition, efforts to increase the availability of spatially resolved fishing effort and catch data to support the assessment of first- and higher-order effects of ORE on fishing activity was also stressed. This likely needs coordination across steering groups within ICES.

One opportunity that was noted was in the importance of the study of hydrodynamics, advection, mixing, and their relationship to primary productivity. Negative impacts on these physical and ecological systems could be potentially catastrophic for the marine ecosystem, but there is currently extreme uncertainty around these impacts. The types of monitoring and evaluation required for permitting and licensing do not contribute to the understanding of these processes. A role for ICES could be to demonstrate the importance of coordinated regional monitoring and assessment of hydrodynamics, primary productivity, and associated ecosystem impacts.

Goal 3: There was consensus that ecosystem-based management approaches are essential to incorporate, but there is ongoing work in many WGs and WKs that is directly applicable. The guidelines in development for this report show how different ecosystem-based approaches fit into the framework. Sessions will be convened at future ASCs under HAPISG (Human Activities, Pressure and Impacts Steering Group) and HUDSG (Human Dimension Steering Group).

Goal 4: WKWIND did not directly advance Goal 4. WGOWDF has a ToR (and a manuscript accepted for publication at ICES JMS) directly related to this goal. The USA has been working strategically on this goal and has developed a survey mitigation strategy and several survey-specific mitigation plans. The chairs of WGOWDF and Pia Schuchert (EOSG Chair) have discussed convening a workshop later this year. This would include chairs of all EOSG working groups, the chairs of the FRSG, chairs of priority WGs within FRSG, and other identified scientists.

It is recognized that increases in MPAs, 30 by 30 goals, and no-take areas are a parallel issue and make this question more complicated but also must be taken into consideration. In both cases, we expect productivity to be enhanced for some species (but likely not all, and may be negative), and for the changes to be location-, technology-, and species-specific. To assess these impacts, scientifically-sound surveys must be conducted.

There was a suggestion to consider adding a statement to recurring ICES stock assessment advice about the impacts that ORE is likely to have on future surveys, stock assessment uncertainty, and the provision of fisheries advice to elevate the issue to the minds of those in the fisheries management realm.

Finally, any trade-off assessment relating to the co-existence of sustainable offshore wind and sustainable fisheries in ICES Ecoregions should be considered in relation to how it meets specific Sustainable Development Goals (SDGs) targets (see Annex 6).

7 Recommended next steps

The next steps following on from WKWIND are recommended:

- Engage with WGMPCZM on the WKWIND report after finalization. (Goal 1)
- Apply the systems approach developed in the workshop to a case study (with data) to further advance the development of guidelines. This may be as a part of a follow-on workshop or done by involved participants of WKWIND. (Goal 1, 3)
- Engage with WGOWDF on their ToR related to Goal 2. (Goal 2)
- Convene session under HAPI at ASC 2024. (Goal 3)
- Develop draft ToRs and convene a workshop explicit to Goal 4 led by WGOWDF and EOSG. (Goal 4)
- Consider adding a statement to recurring ICES stock assessment advice about the impacts that ORE is likely to have on future surveys, stock assessment uncertainty, and the provision of fisheries advice. (Goal 4)
- Provide a point of contact within ICES for researchers and stakeholders interested in being involved in specific next steps identified here, referencing the ICES Stakeholder Engagement Strategy and other ICES guidelines. (all Goals)

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WKWIND resolution

Workshop to develop guidelines on how to approach the ecological, economic and social trade-offs between offshore renewable energy developments (wind farms) and fisheries (WKWIND)

The workshop aims to review approaches to assess the trade-offs between offshore renewable energy developments (initial focus on offshore wind farms) and the provisions of wild harvest fish by assessing the economic, social and ecological consequences. WKWIND will provide the first steps for developing ICES best practice guidelines on how to assess trade-offs to enable sustainable marine management.

WKWIND will be chaired by Andrew Gill, UK; Angela Muench, UK; and Sean Hayes, USA; and will meet at ICES HQ, Copenhagen, Denmark, 29 April – 2 May 2024 to:

a) Develop guidelines to assess the trade-offs between offshore wind farm developments and fisheries activity and associated social, economic and ecological consequences, taking into consideration:

    i. Defining the spatial and temporal boundaries of the trade-offs to be assessed between fisheries and offshore wind farms.

    ii. Review the existing data and tools relevant to trade-off assessment using information provided by previous ICES workshops (e.g. WKSSFGEO2, WKD6STAKE, WKTRDAE4 , WKD6ASSESS).

    iii. Developing an approach that allows managers and stakeholders to explore the trade-offs between the extension of energy provision and the provision of wild harvest fish and the respective ecological, economic and social consequences.

    (Science Plan codes: 6.6, 6.4, 3.5)

b) Propose activities to advance the four priorities identified in the ICES ORE Roadmap for the Provision of Advice on Offshore Renewable Energy
(Science Plan codes: 1.1, 1.9, 2.1, 2.5, 2.7, 3.1, 3.2, 4.1, 5.3, 6.1, 6.2, 6.3, 7.1).

Prior to the workshop, the Chairs will prepare material to address the ToRs. This group will also ensure the completion of the workshop report, and operational TAF (Transparent Assessment Framework) products for further consideration by ICES EGs. WKWIND will report by 1 June 2024 for the attention of ACOM and SCICOM.

Supporting information

Priority	High, it is intended to prepare ICES for expected future EU and national advisory requests on ORE and ecosystems interactions, on assessing the trade-offs between existing/ proposed marine wind farm developments, fisheries and biodiversity. The outputs and advice will feed into ongoing efforts to provide strategic guidance that will feed into sustainable management and marine spatial planning with respect to achieving fisheries, marine offshore renewables and biodiversity sustainable development objectives.
Scientific justification	Climate change and energy security have created an urgent global effort to develop renewable energy. Offshore wind energy and other offshore and marine renewable energy technologies provide many countries with the ability to generate renewable electricity within their borders. As a result, rapid and large-scale offshore renewable energy (ORE) development is now underway, at an unprecedented pace and magnitude. To achieve the ICES Vision and Mission

	in the face of rapid growth in offshore renewable energy, ICES has four goals as set out in the ICES ORE Roadmap, namely: i. To advance the ICES scientific capacity to support advice regarding the interactions among offshore and marine renewable energy developments and marine ecosystems. ii. To facilitate an international effort to design data collection networks at the range of spatial and temporal scales needed to monitor, assess, and predict the impacts of offshore and marine renewable energy development on marine ecosystems. iii. To advance development and application of models, coordinated process studies, and long-term observations supporting the analysis of impacts from offshore and marine renewable energy development at regional and ecosystem scales and at subseasonal to decadal scales. iv. To develop frameworks that guide the use of best available information on the interactions of offshore and marine renewable energy, ecosystem functions and structure, and ecosystem services and provisions. In addition, ICES has received a draft request for advice from the European Commission on the assessment of ecosystem interactions and trade-offs between offshore wind developments and fisheries. This and the need to develop capacity and flexibility within the advisory process to address advice requests at short notice necessitates organising a workshop to explore and prepare data and example advisory products to meet this and future advice needs.
Resource requirements	ICES Data Centre and secretariat support.
Participants	Scientific leadership will be provided by the ORE WGs (WGMBRED, WGOWDF, WGORE), with input from experts representing WGFBIT, WGSFD, WGBIODIV, WGMPAS, WGMPCZM, WGECON, WGSOCIAL. Expected attendance by some 20–25 members and guests.
Secretariat facilities	Data Centre, Secretariat support and meeting room
Financial	No financial implications.
Linkages to advisory committees	Direct link to ACOM and SCICOM.
Linkages to other committees or groups	Links to WGSFD, WGFBIT, WGECON, WGSOCIAL, WGOWDF, WGMBRED, WGORE, WGMPAS, WGMPCZM, WGBESEO, HAPISG and HUDISG.
Linkages to other organisations	The work of this group is closely aligned with similar work in OSPAR, and HELCOM.

Annex 2: Example of other approaches to assist the assessment of trade-offs

Several approaches could potentially be used to explore hypothesised trade-offs between fisheries and ORE in a systems-based approach. Depending on the context of the trade-off assessment, one approach might be better suited than another, as each of them has their advantages and disadvantages. Hence, the context and the aim of the trade-off should define the approach to be used. In the ICES context, the SES was decided to be the best way forward to identify the elements of the system and their interactions and interdependencies that will influence the potential outcomes of trade-offs. Hence the workshop set the context with the SES approach, however it was acknowledged and discussed that other approaches were complementary to the SES. These approaches have overlapping similarities and could be integrated into a more comprehensive analysis in the future. The following approaches are some examples and should not be seen as an exhaustive list but rather to highlight different approaches that could inform the future trade-off assessments, depending on the evidence requirements.

Integrated Ecosystem Assessments

Integrated Ecosystem Assessments (IEA) are a science-based process for conducting ecosystem-based management. ICES has a history of using IEA (see work under ICES Steering Group for Integrated Ecosystem Assessment). The advantage of using the IEA method as a tool to inform trade-offs, which could be applied in the context of ORE development and fisheries, is it ensures best available science is used to assess the ecosystem elements and therefore inform decisions. IEA can complement single-sector approaches and provide a systems-oriented approach to assess and monitor the social-ecological system. The process allows identification of all components of an ecosystem, including human needs and activities so that managers can balance trade-offs as well as assessing the risks of implementation. The IEA approach (Figure 6) is a flexible process that is not prescriptive about the tools used to implement the process. Many qualitative and quantitative tools can be applied. The process is represented in a loop as it is designed to receive regular feedback to enable adaptive management as human and environmental aspects of the system evolve, hence evolves with stakeholder engagement (NOAA, nd).

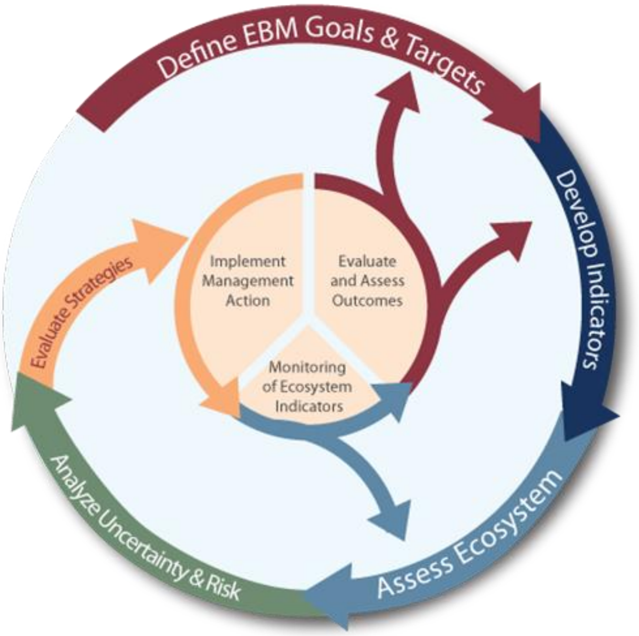


Figure 6. The NOAA Integrated Ecosystem Assessment (IEA) Loop.

Using Integrated Ecosystem Assessments to assess trade-offs of the fisheries and offshore wind social ecological system (an example from the USA)

An example of an IEA, from the USA perspective, was presented in the context of trade-off analyses that are needed as ORE development rapidly expands. The Gulf of Maine Fisheries and Floating Offshore Wind IEA (FishFlOW) project is an ongoing collaborative project between NOAA Fisheries, the Responsible Offshore Development Alliance, and the University of Rhode Island. In collaboration with fishing communities, research scientists, managers, and developers, FishFlOW aims to:

1. Map key links and interactions between offshore wind development, fisheries, and the environment;
2. Identify priority concerns, key indicators and gather data that can help measure the current conditions and future effects from offshore wind through these linkages;
3. Assess and report on and monitor indicators, risks, and tradeoffs over time;
4. Ensure the project's products are applicable to the decision-making process and circulated through existing management pathways.

The purpose of using the IEA method is to ensure all components of the system, including human dimensions, are incorporated into decision making. FishFlOW is in the early stages of the IEA process and has begun developing a conceptual model of the social-ecological system as an initial first step. Public comments submitted by the fishing community were analysed using content analysis methodology and key themes and sub-themes identified from the text. A preliminary conceptual model was developed from those themes and sub-themes and presented to the fishing community and researchers in the Gulf of Maine region. Through workshops with these groups, the preliminary model was ground-truthed by: 1) identifying what was missing in the model; and 2) identifying the priorities of information needs and indicators from stakeholder perspectives. The team will also work one-on-one with wind developers to gather similar information. The current conceptual model as of May 2024 is shown in Figure 7 and it is intended to identify data and indicators that can be used to assess trade-offs. The model presents a base model, but sub-models can be used to assess one or more impacts that can feed into the evidence base for determining trade-offs. Anticipated products of FishFlOW include a list of indicators and available data, which as highlighted in the main report text is essential for conducting a trade-off assessment.

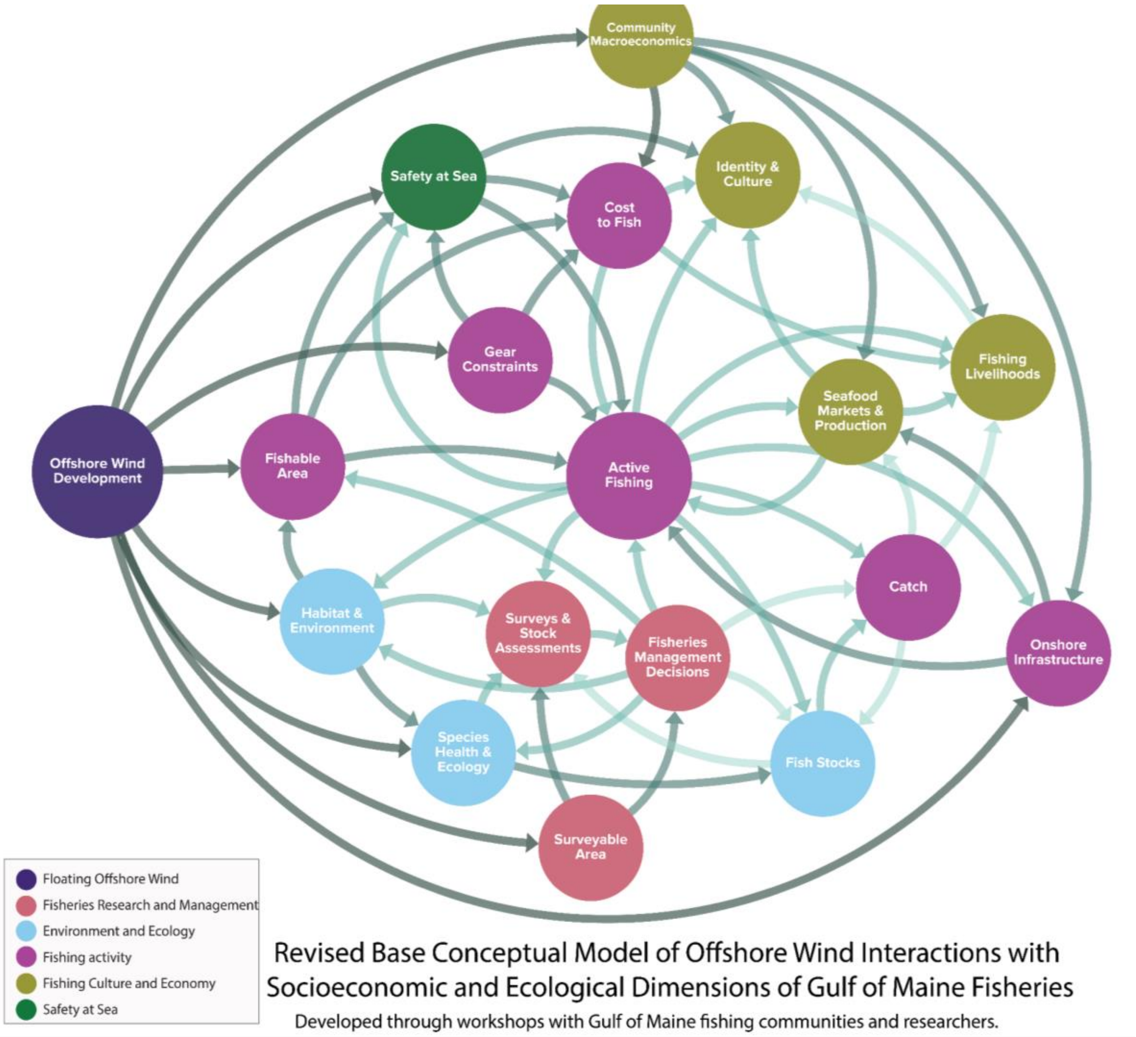


Figure 7. The base conceptual model of offshore wind interactions with socioeconomic and ecological dimensions of Gulf of Maine fisheries.

Scenario planning matrix

Another approach that is likely complementary to the IEA framework described above and the SES framework described in the main report text is Scenario Planning (SP), which helps when considering a long-term perspective. The concept was introduced into resource management as a framework to support decisions under uncertain and uncontrollable conditions (Peterson *et al.* 2003). SP provides a structured process to explore alternative future conditions under a range of assumptions to manage risk and prioritize actions. This has been used increasingly in the terrestrial (Miller *et al.*, 2022) and marine environments (D. Borggaard *et al.*, 2019; D. L. Borggaard *et al.*, 2020; deReynier, Y. *et al.*, 2023) to consider the impacts of climate change on ecosystems and human impacts. For marine environments, it has been used to anticipate future changes and challenges to both endangered species and commercial fisheries. NOAA fisheries currently maintains a scenario planning webpage as part of its Protected Resources Science Toolkit.

Scenario planning is neither a prediction, nor a forecast, but rather works to define a range of potential futures (scenarios) and tries to anticipate what risks and opportunities might emerge within and across them. This helps managers prepare for a range of futures and to navigate potentially paralyzing uncertainties, manage risk, and evaluate/prioritize management actions associated with adapting to, and managing for, climate change.

This future thinking has many benefits. It provides the capability for early and broad risk identification, giving managers a greater flexibility to react quickly in a changing world through the identification of options. Early planning allows the development of decisions and plans that would be suitable across some or all futures and often the generation of innovative ideas. And much like the IEA framework and the SES framework above, when conducted with diverse groups, SP can also provide increased alignment towards a common vision. That said, SP is not prescient and may not anticipate all future scenarios. Nor is SP analytical, in a mathematical sense, and thus does not fully execute a trade-off analysis/conclusion. Rather, it is essentially an expert elicitation of what the future may hold and strives to leave managers more prepared for uncertainty and better informed on the competing decisions and trade-offs they will face.

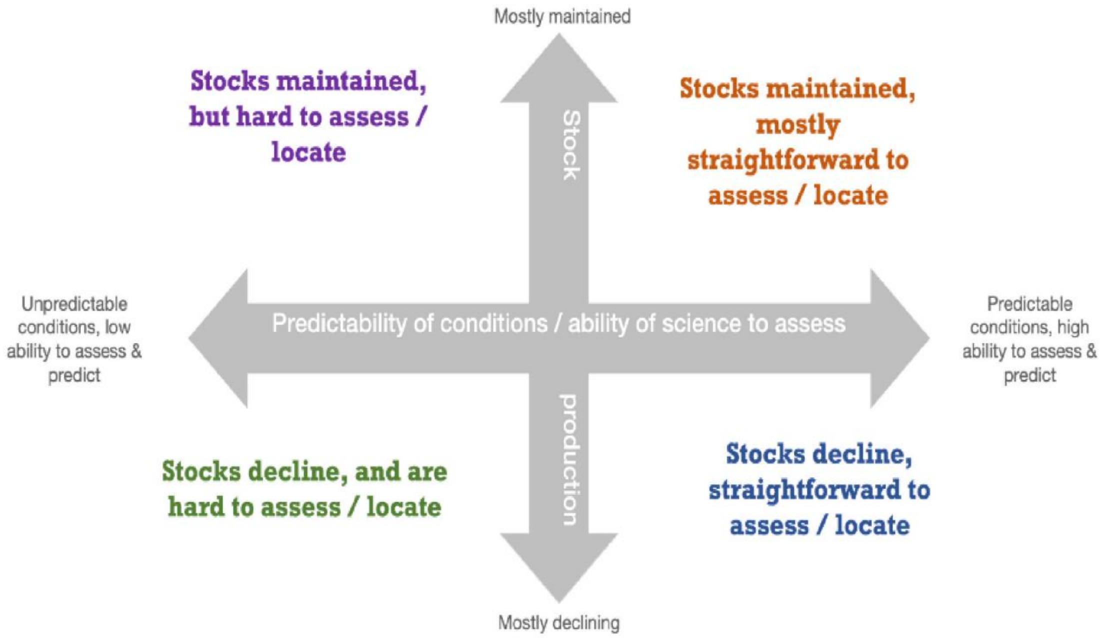
There are five key steps to implement the process once you have organized a work group.

1. Clarify the focus and goals of the investigation (scope & time horizon)
2. Research to identify factors likely to shape the future (drivers)
3. Combine drivers to create a scenario framework
4. Craft a plausible, challenging story for each scenario
5. Use the scenarios for strategy, innovation, risk, vision-setting

During the workshop - an example was shared from the United States Mid-Atlantic Fishery Management Council that addressed two core questions about the future.

1. What happens to stock production/species productivity by 2040 as climate change continues? Does it result in declining productivity (alongside worsening habitat, and low rates of species replacement), or is productivity mostly maintained (with adequate habitat and sufficient levels of species replacement)?
2. How unpredictable are ocean conditions, and how well is science able to assess and predict stock levels and locations by 2040? Do conditions become far more unpredictable, where existing science is clearly unable to provide much useful information, or are conditions sufficiently predictable to allow science to provide mostly accurate information about stocks and location?

From this they developed a matrix with four quadrants (**Error! Reference source not found.**) based on a range of foreseeable futures developed during a 2-day workshop with 75 stakeholders and refined with follow up webinars with additional stakeholders. Each quadrant was given a name and extended narratives on the main themes for each were produced based on the likely conditions of that potential future. While managers cannot be sure which future will occur, it helps them to anticipate a likely range of challenges that they need to build capacity to address and thus steer a course towards a best possible outcome.



OCEAN PIONEERS "Weird weather and crazy conditions." That's what fishing operators and fishery managers are facing in 2040. Life on the ocean is remarkably different compared to 20 years ago. Climate change has prompted more investment in alternative energy and aquaculture. Seasons and locations of fisheries change unpredictably, and traditional science is unable to make accurate assessments. Despite this, fishermen report they are encountering plenty of seemingly healthy stocks. Ocean pioneers thrive in these turbulent conditions. Success doesn't come easy - it requires taking risks (such as investments in new data-gathering technology), deep pockets and an ability to ride out the storms of uncertainty. There are shifts in social and cultural connections and those who are able to work together and adapt can often improve their economic outcomes.	**CHECKS AND BALANCE** Good science, smart collaboration and tolerable conditions allow East Coast fisheries to cope with the challenge of climate change in 2040. But nothing is easy: stocks shift and expand their ranges, while busier coasts and new offshore activity create accessibility challenges for both commercial and recreational fishermen. Investments in habitat protection and restoration begin to reverse decades of damage and loss. Science capacity is boosted, delivering improved ocean monitoring, real-time catch reporting and population monitoring. A prosperous ocean economy leads to competition (e.g., between fisheries and aquaculture) but also collaboration (e.g., as fisheries science is boosted by data-gathering sensors on wind energy installations). Changing management approaches help usher in more extensive opportunities and economic benefits for fisheries.
COMPOUND STRESS FRACTURES Several sources of stress have led East Coast fisheries to breaking point by 2040. Shifts in ocean currents and extreme weather events have tipped ecosystems out of balance. Major storms lead to more pollution and degraded habitats. Healthy stocks are scarce. Low abundance leads to reduced harvests and protected species regulations close several fishing grounds. Science is unable to help, as stock assessment data cannot cope with such a changeable and volatile ecosystem. Even fishermen's local ecological knowledge is unreliable or irrelevant. Trust between stakeholders is in short supply, illustrated by fractious debates over the siting of offshore wind installations. Operators are forced to shift to lower trophic level species, and government support is needed to save a few selected fisheries.	**SWEET & SOUR SEAFOOD** "The science is good, but the news is bad." In 2040, climate change is affecting ocean and stock conditions in ways long predicted by scientists. Stocks have shifted their range while productivity and abundance have declined for most relevant species. Better forecasting techniques help fishermen prepare for marine heatwaves and localized die-offs. Aquaculture provides a much-needed alternative as wild-caught seafood declines, and better science ensures that any pollution dangers are minimized. There are signs of a few smart management decisions (such as limits on newly arriving species) and adaptation from fishing operators, but most management approaches have not adapted to the tougher conditions of today, and those on the horizon.

Figure 8. Example of a 2x2 scenario planning matrix from US MAFMC climate scenario planning exercise. Axes and the core interactions between a range of stock productions and assessment capacity under a changing marine environment is above and brief narratives of what conditions are likely to emerge under the 4 range of condition interactions.

Annex 3: Definitions

The following is a list of definitions of words used often within the context of trade-off analysis between ORE and fisheries in an ecosystem-based management approach. This list is not meant to be exhaustive but to provide a common understanding for participants of WKWIND and to highlight the importance of common definitions.

Benthic Communities - an area where a group of marine organisms live and interact with each other on, near, or within the seafloor (Miracosta, 2024).

Biodiversity - biodiversity, or biological diversity, is the term given to the variety of life on earth. It's an all-encompassing term to describe the genetic diversity that makes each individual life form unique, the diversity of different organisms that occur throughout the world and the rich diversity of ecosystems or landscapes that occur across the globe. Biodiversity policy also recognises the profound impact that human activities have had, and continue to have, on the world's ecosystems.

Change - in the context of trade-off analysis, it was agreed that change can mean something positive, negative or neutral. It can be used to describe short-term alterations but also long-term changes as well as to referring to net- and overall changes. Hence, change encompasses a wide range of dimensions to be included and should not focus solely on the negative aspects.

Communities – a group of people living in the same place or having a particular characteristic (practice) in common. An example of a place-based community of people associated with fishing and processing of fish products on shore. An example of a practice-based community are fishers who target the same stock using the same gear, but who do not necessarily are from the same port. In reality, place-based and practice-based communities show overlap. For a more detailed discussion on how a fishing community can be defined see (ICES, 2021).

Ecological engineering-Adapting structure in such a way that it helps nature but doesn't affect the function of the structure.

Ecosystem function - is the capacity of natural processes and components to provide goods and services that satisfy human needs, either directly or indirectly (de Groot *et al.*, 2002).

Ecosystem processes – are the physical, chemical, and biological processes that link organisms and their environment. These may include biogeochemical/nutrient cycling, energy flow, and food web dynamics.

Ecosystem service – are the direct and indirect contributions ecosystems () provide for human wellbeing and quality of life (they produce natural capital stocks). This can be in a practical sense, providing food and water and regulating the climate, as well as cultural aspects such as reducing stress and anxiety.

Fisher(s) - Person(s) who catch(es) fisheries resource species either as a job or for sport.

Fisheries - Group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area (e.g. the Dutch flatfish-directed beam trawl fishery in the North Sea) (*ICES Glossary*, 2024)

Fishery resource species - Any species that predominantly inhabit aquatic habitats and are captured by humans (Adapted from Gartside & Kirkegaard (2009) and Pinto *et al.* (2018)).

Food webs – A conceptual model of how species in a marine ecosystem are connected through trophic interactions (what eats – what etc.).

Habitats - includes the physical habitat formed by living organisms (biogenic), and from physical features such as sand, mud, or rocks (geogenic) and other factors such as ocean depth, hydrodynamics, salinity, and seafloor morphology.

Nature-based solution -Use of natural features and processes to solve a problem.

Nature-inclusive design -integrates into existing designs to create suitable habitat for local populations.

Social-Ecological systems (SES) approach - are based on the concept that humans are a part of—not separate from—nature

Trade-off – is a quantitative evaluation of the costs foregone by different sectors in a marine social-ecological system with different, potentially competing, objectives (e.g. fishing, ORE, biodiversity protection). Trade-offs occur across multiple spatial and temporal scales and also multiple dimensions e.g. economic, ecological, social.

Annex 4: Overview of data availability on ICES level

Table 4. Overview of data availability.

Data	Data type	Best data available	Data collection	To be considered
Fisheries activity data	Characteristics: Vessel characteristics from logbooks, gear types, landing weight and value Pressures: Effort hours, Swept areas, fuel use, kwhours	Logbook data for vessels >10m length Data from vessel monitoring systems (VMS) for vessels >12m length	Annual data collection with data processing standardized (ICES, 2022) Ad hoc request from countries	Selecting an appropriate spatial grid, e.g. fishing activity at a 0.05 (~5 x3 km) C-square, OWF at 0.001 (~1 x 0.6 km) C-square, generates high resolution data but leads to challenges in processing big data. Not included: fishing activity of vessels ≤12m length. Standardized methods need to be developed to integrate the (newly) available data on this fleet segment (ICES, 2023d). ICES experts develop and implement methods to generate indicators from the collected data once key required indicators are identified for ICES advice requirements. The developed indicators can then be provided by the experts per unit area of assessment aka C-square resolution chosen to be most optimal. ICES Data Center and the ICES Data Governance working groups are responsible for data quality and access, hence ensuring that data sensitivity is not compromised in advisory products. However, some indicators such as fisheries dependency need vessel individual data and therefore will be generated on a national level, which may compromise the comparability between indicators of different countries (see transboundary considerations).
Economic data	Fishing effort, catch and landing values is available through RDBES, cost data etc. can be obtained from STECF for EU member countries	Currently reported by vessel length categories and gear groups/metier levels.	Annual data collection with data processing standardized (ICES, 2022) as well as STECF Annual Economic Report (AER) data	Linking the economic data to the RDBES is an ongoing challenge (ICES, 2024c) as well the definition of the fishing fleet as this may impact the results (ICES, 2024b). For detailed assessment, individual vessel based data often more advisable to also include changes in fishers' behaviour. In addition, the challenge is to assess the wider economic impact on the supply chain or fishing community as well as the actual loss for the fishery as using only landing values tend to misrepresent the actual impact on the fishing industry. Other indicators and metrics need to be found. Some national work is ongoing.

Social data	Similar to economic data, several national data collections on its way to inform STECF for EU member countries, mainly focused on employment. Several case study but not a wider social data call.	Currently reported by vessel length categories and gear groups/metier levels. Case studies on social impacts of policy or at-sea changes, including ORE, on fishers and communities (for example on well-being) are available for some countries.	National data collection	A clear-cut definition of a fishing community is elusive. Instead, there are fluid boundaries between place-based, practice-based, and social and cultural-historic communities. In addition, such communities are characterised by heterogeneity (Kraan *et al.*, under review). Currently, within ICES the place-based approach based on the landing port is predominantly used (ICES, 2021). Connectivity between ports or communities is acknowledged but currently not further assessed in detail.
ORE activity data	Construction activity: position: drilling, installation, concrete etc. [e.g., swept area, habitat loss, footprint of the foundation etc.] Operational phase: pylon position and characteristics [hight of pylon, blade size material, perimeter of the pylon], and indicators of	OWF – C4Offshore discussion		Not regulators data – non-authoritative. If more detailed data are needed, the individual ORE operator would need to be contacted.

	activity. [e.g. Mw, operational time] ORE license areas Decommissioning phase			
Habitat type (including sediment, benthos, …)	Case study and general mapping at point in time	Benthos Primary productivity	Habitat mapping	Habitat often does not fit the c-square grid used for fisheries data. Difference in reference period, sampling method etc. Identifying the stressor leads to changes in the ecosystem, but local dynamics will determine the impact on the ecosystem. Assessment window to be considered carefully.
Ecosystem data	International joined survey as well as national focused surveys	Species composition, presence of protected, endangered or threatened species; ecosystem structure and functional aspects/indicators	Ecosystem and fisheries independent surveys following predominantly sampling design to assess specific fish stocks or environmental assessments	Surveys provide status of the ecosystem at a specific point of time, dynamics of ecosystem needs to be considered. Data on species and biological community structure and function should be incorporated, where available. Datasets on functional traits and ecosystem process indicators are increasingly being compiled however there are important assumptions and caveats that should be acknowledged too.

Annex 5: SES in graphical form

To represent the above table in another form, we sketched how “Fishing Behaviour” is an interaction between Fishers (Actor, A) and Fish (Resource Unit, RU); (Figure 9). Hence, different ways of representing the SES are possible, depending also on the context and scale it should be represented.

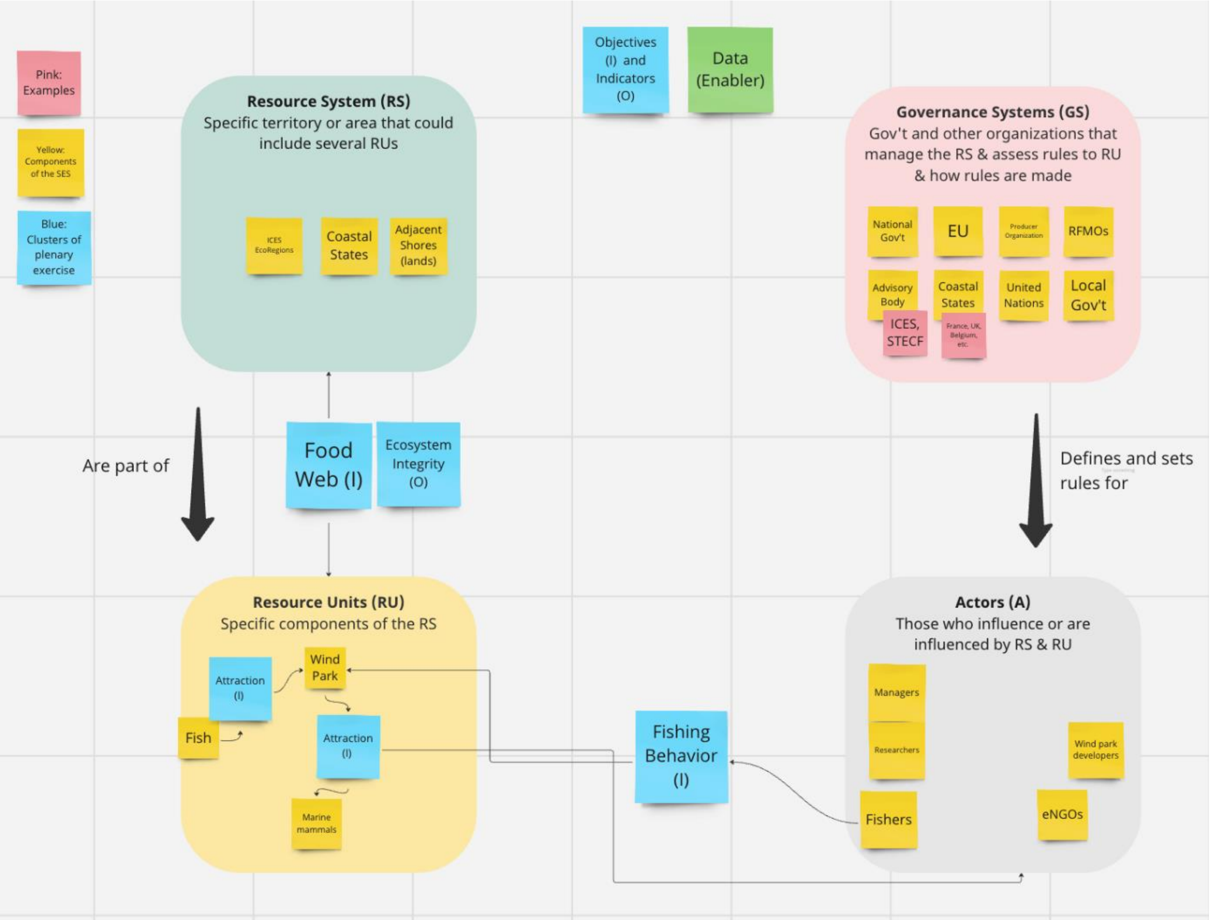


Figure 8. A schematic interpretation of a non-exhaustive worked example of a social-ecological system in a North Sea ICES Ecoregion.

Annex 6: Relevance of the United Nations Sustainable Development Goals (SDGs) to WKWIND

The following is a summary of how specific Sustainable Development Goals (SDGs) targets relates to the co-existence of sustainable offshore wind and sustainable fisheries in ICES Ecoregions. An overview of the UN SDGs can be found in figure 10.

Figure 9. The 17 Sustainable Development Goals as prescribed by the United Nations in the Agenda 2030 Report (UN 2015).

SDG 4 Quality Education

Target 4.7: This target focuses on ensuring that all learners acquire the knowledge and skills needed to promote sustainable development, including awareness of the importance of sustainable practices in sectors such as offshore wind and fisheries.

SDG 5 Gender Equality

SDG Target 5.5 is relevant for the co-existence of sustainable offshore wind and sustainable fisheries by promoting gender equality, enhancing community engagement, improving governance, fostering socio-economic empowerment, supporting environmental stewardship, and building resilience in coastal communities.

SDG 6 Clean Water and Sanitation

Target 6.3: This target emphasizes the importance of improving water quality by reducing pollution, which indirectly supports both offshore wind and fisheries by maintaining healthy marine ecosystems.

SDG 7 Affordable and Clean Energy

Target 7.1: This target aims to ensure universal access to affordable, reliable, and modern energy services, including renewable energy sources like offshore wind, which can reduce reliance on unsustainable energy sources that harm marine ecosystems.

Target 7.2: This target focuses on increasing the share of renewable energy in the global energy mix, including offshore wind, which contributes to reducing greenhouse gas emissions and mitigating climate change impacts on marine environments.

Target 7.A: This target encourages enhancing international cooperation to facilitate access to clean energy research and technology, which could lead to advancements in offshore wind technology and sustainable fishing practices.

SDG 8 Decent Work and Economic Growth

Targets 8.1, 8.2, and 8.9: These targets emphasize promoting inclusive and sustainable economic growth, decent work for all, and fostering innovation, all of which are relevant to supporting the development of sustainable offshore wind and fisheries industries.

SDG 9 Industries, Innovation and Infrastructure

Targets 9.1 and 9.5: These targets aim to build resilient infrastructure and promote inclusive and sustainable industrialization, which includes the development of infrastructure and technology to support offshore wind farms and sustainable fishing practices.

SDG 10 Reduced Inequalities

Targets 10.1 and 10.2: These targets focus on reducing inequality within and among countries, which is relevant as both offshore wind and fisheries industries should benefit communities equitably and ensure fair access to resources and opportunities.

SDG 11 Sustainable Cities and Communities

Targets11.4 and 11.A: These targets highlight the importance of sustainable urbanization and promoting resilience to disasters, which indirectly support offshore wind and fisheries by protecting coastal communities and ecosystems.

SDG 12 Responsible Consumption and Production

Targets 12.2, 12.4, and 12.B: These targets emphasize sustainable consumption and production patterns, reducing waste generation, and promoting sustainable management of natural resources, all of which are crucial for ensuring the long-term viability of offshore wind and fisheries industries.

Target 12.6: This target focuses on encouraging companies to adopt sustainable practices and integrate sustainability information into their reporting cycles, which is relevant for both offshore wind developers and fisheries management.

SDG 13 Climate Action

Targets 13.1, 13.2, and 13.3: These targets address the urgent need to take action to combat climate change and its impacts, including promoting renewable energy sources like offshore wind and reducing carbon emissions from industries such as fisheries.

SDG 14 Life under Water

Several targets SDG 14, which focuses on conserving and sustainably using the oceans, seas, and marine resources, are directly relevant to offshore wind and fisheries.

Target 14.2 emphasizes the sustainable management and protection of marine ecosystems, which is essential for both offshore wind and fisheries industries. Offshore wind farms must consider the impact on marine habitats, while sustainable fisheries rely on healthy ecosystems to maintain fish stocks.

Target 14.4: This target directly addresses sustainable fisheries management, which is crucial for maintaining fish stocks and ensuring the long-term viability of the fishing industry. Sustainable management practices benefit both fisheries and the marine environment, promoting co-existence with offshore wind projects.

Target 14.6 focuses on eliminating harmful fisheries subsidies that contribute to overfishing and unsustainable practices. By aligning fisheries subsidies with sustainability goals, it helps ensure the co-existence of fisheries with other marine activities such as offshore wind development.

The targets in SDG 14 emphasize the importance of sustainable management, conservation, and regulation of marine resources, which are essential for both offshore wind development and fisheries to thrive in a mutually supportive manner while ensuring the health and productivity of oceans and coastal ecosystems.

SDG 15 Life on Land

Targets 15.5 and 15.9: These targets aim to protect and restore ecosystems and promote sustainable use of terrestrial and marine resources, which are essential for supporting both offshore wind farms and sustainable fisheries.

SDG 16 Peace, Justice and Strong Institutions

Target 16.7: This target emphasizes ensuring responsive, inclusive, participatory, and representative decision-making at all levels, which is important for involving stakeholders in the planning and management of offshore wind projects and fisheries.

SDG 17 Partnership for the Goals

Targets 17.14, 17.16, 17.17, and 17.18: These targets focus on enhancing global partnerships for sustainable development, promoting multi-stakeholder partnerships, and strengthening the means of implementation and revitalizing the global partnership for sustainable development, all of which are relevant for fostering collaboration and cooperation in advancing sustainable offshore wind and fisheries initiatives.

The Sustainable Development Goals (SDGs) serve as a common language among policymakers, scientists, stakeholders, and citizens concerned with sustainable ocean use, particularly in the context of the emerging revolution of marine-based offshore renewable energy, for several reasons. First of all, the SDGs represent a globally agreed-upon set of targets and indicators endorsed by all United Nations member states. This consensus facilitates international cooperation and collaboration among countries, regions, and stakeholders with diverse interests and priorities, fostering a shared understanding of the importance of sustainable ocean use and the need for collective action.

In addition, the SDGs promote an interdisciplinary approach to sustainable development, recognizing the interconnectedness of social, economic, and environmental dimensions. This approach is particularly relevant for addressing complex challenges related to marine-based offshore renewable energy, which require integration of knowledge and expertise from multiple disciplines, including marine science, engineering, economics, policy, and social sciences. The SDGs also provide a common reference point for policymakers at the national, regional, and international levels, helping to align policies, strategies, and initiatives related to sustainable ocean use with broader sustainable development objectives. Policymakers can use the SDGs to prioritize actions, set targets, monitor progress, and evaluate the effectiveness of policies and interventions in promoting sustainable ocean management.

Relevant to the success of the ICES Stakeholder Engagement Strategy, the SDGs promote inclusive and participatory approaches to sustainable development, emphasizing the importance of engaging diverse stakeholders, including governments, civil society organizations, businesses, academia, and local communities. By providing a common language and framework, the SDGs facilitate dialogue, collaboration, and partnership-building among stakeholders with different perspectives, interests, and expertise, fostering collective ownership and commitment to achieving sustainable ocean use goals.

In summary, the SDGs serve as a powerful tool for promoting sustainable ocean use by providing a common language, framework, and platform for collaboration among policymakers, scientists, stakeholders, and citizens concerned with advancing the goal of marine conservation, sustainable resource management, and inclusive and equitable development, including the integration of marine-based offshore renewable energy into the broader sustainability agenda.

Reference: United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. https://wedocs.unep.org/20.500.11822/9814