JOINT ICES/EUROMARINE WORKSHOP ON COMMON CONCEPTUAL MAPPING METHODOLOGIES (WKCCMM; Outputs from 2021 meeting)

VOLUME 4 | ISSUE 19

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
CIEM CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 4 | Issue 19

JOINT ICES/EUROMARINE WORKSHOP ON COMMON CONCEPTUAL MAPPING METHODOLOGIES (WKCCMM; Outputs from 2021 meeting)

Recommended format for purpose of citation:

ICES. 2022. Joint ICES/EUROMARINE Workshop on Common Conceptual Mapping Methodologies (WKCCMM; Outputs from 2021 meeting).
ICES Scientific Reports. 4:19. 41 pp. http://doi.org/10.17895/ices.pub.10095

Editors

Marcos Llope • Debbi Pedreschi

Authors

Filipa Afonso • Andrea Belgrano • Patricia M. Clay • Geret DePiper • Alfredo García de Vinuesa
Julie Kellner • Andrew Kenny • Lis Lindal Jørgensen • Sean Lucey • Oceane Marcone
Renee Melkert • Nina Mikkelsen • Erik Olsen • Paulina Ramirez Monsalve • Heike Schwermer
Sonia Seixas • Angela Silva • Jamie Tam • Abby Tyrell • Matilda Valman

ICES CIEM International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Contents

i Executive summary

The Joint ICES/EUROMARINE Workshop on Common Conceptual Mapping Methodologies (WKCCMM) aimed to advance approaches to support inter- and transdisciplinary science via qualitative conceptual models to inform Integrated Ecosystem Assessment (IEA) throughout European seas and beyond.

The workshop focused on developing a common understanding of conceptual mapping methodologies, their key uses and limitations, and processes for effective conceptual modelling with stakeholders for a variety of applications (e.g. developing food-webs, socio-ecological modelling, scoping exercises, rapid/initial management action and/or impact evaluations). Discussion involved presentation and discussion of a range of conceptual modelling approaches and contexts through the examination of case studies. These case studies gave rise to a suite of recommendations, including the development of a workflow for IEA, and more generic guidelines and best practice advice for the use of conceptual modelling approaches with stakeholders. Although stakeholders were not able to be included in this workshop, they were very much at the heart of discussions, with the challenges and good practices of stakeholder inclusion addressed. WKCCMM also investigated how the methodologies can be best used to contribute to IEA, and may otherwise be applied throughout the ICES community, including identifying opportunities for cross-collaboration and knowledge transfer within the network.

ii Expert group information

Expert group name	Joint ICES/EUROMARINE Workshop on Common Conceptual Mapping Methodologies WKCCMM
Expert group cycle	Annual
Year cycle started	2021
Reporting year in cycle	1/1
Chair(s)	Debbi Pedreschi, Ireland
	Marcos Llope, Spain
Meeting venue(s) and dates	Online, 1-4 November, 2021 (20/25)

1 Introduction

The Joint ICES/EUROMARINE Workshop on Common Conceptual Mapping Methodologies (WKCCMM) aimed to advance approaches to support inter- and transdisciplinary science via qualitative conceptual models to inform Integrated Ecosystem Assessment (IEA) throughout European seas and beyond.

IEAs are a key tool enabling us to navigate ocean complexity and eventually support ecosystem-based management (EBM). Conceptual modelling facilitates and informs the scoping steps of IEA by identifying key drivers (economic, social, cultural, ecological) and priorities of stakeholders, including policy-makers. Understanding priorities and perceptions is critical to identifying risks and opportunities for action to instigate lasting change and provide the evidence required to efficiently manage and protect the ocean commons. Social science integration into marine ecosystem assessment has been flagged by EuroMarine, ICES, and at the UN Decade of Ocean Science preparatory meetings as a key research need. WKCCMM tackled this need by bringing together social and natural scientists for knowledge exchange and skills-sharing on conceptual mapping methodologies to inform IEA. WKCCMM built on current and ongoing IEA work in ICES and NOAA, with scalable methods capable of focusing on multiple human uses of marine systems. The cross-collaboration of ICES, NOAA and EuroMarine scientists and standardization of methodologies (adaptable to specific circumstances/needs) across IEA groups will benefit interested parties both within and beyond ICES

The workshop aimed to create good practice guidelines for coherent conceptual mapping for IEA through scoping participant needs, skill sharing, and knowledge transfer. The ultimate goal is to advance understanding of socio-ecological systems and facilitate practical implementation of ecosystem-based marine management.

2 Developing a common understanding of conceptual mapping methodologies.

ToR A: *Develop a **common understanding** across ICES working groups on conceptual mapping methodologies, their key uses and limitations, and processes for effective conceptual modelling with stakeholders. This will help to identify commonalities, differences and issues encountered, and standardize methodological approaches useful for a variety of applications (e.g. developing food-webs, socio-ecological modelling, rapid/initial management action and/or impact evaluations).*

Introduction

ToR A leads: Trish Clay, Sean Lucey, Jamie Tam.

A conceptual model is a graphical representation of a system, here an ecosystem or subsystem thereof such as an Ecosystem Production Unit (EPU). Because ecosystems are so complex, a conceptual model will always be a simplified version of an ecosystem. Choosing the level of specification will be one of the initial steps in its creation. Even given its simplification, conceptual mapping is a useful tool in a number of respects, and has been highlighted as an excellent communication tool for working with stakeholders, to identify common understanding, goals and objectives of complex systems, and in highlighting differences in perspective, values and priorities, e.g. from different stakeholder groups (Levin et al., 2016; DePiper et al., 2017; ICES, 2020a).

As simplified models of reality, conceptual models can be very simple or very complex, grounded in reality or theoretical - and either way can be useful. Ecosystem models are traditionally large mathematical models designed to measure changes in biomass, or measure nutrient flows between functional groups or trophic levels. Social and cultural, and even economic data often are at very different resolution than ecological data (e.g. human communities or species by market category), and/or have different (often much shorter) time-series. For some social and economic data, and frequently for cultural data, there may not be time-series at all, or it may exist as qualitative data that cannot easily be integrated into a mathematical model. These issues are often exacerbated by attempting to retro-fit these aspects to existing ecological models rather than starting anew, which would usually require new ways of modelling and integrating data. In contrast, conceptual models allow you to combine all components conceptually and to agree the essential components of the system, and how they are linked. In this way they are inclusive, and can be used to identify components that could be included in a next stage of more quantitative modelling, along with flagging important components that we may not have data series for, but that are relevant for management consideration.

Exercise

Participants were split into 4 breakout groups and asked to build a conceptual model using the software package Mental Modeler[1] (Gray et al. 2012, 2013a, 2013b). No prior instructions were given as to what to include or whether the ecosystem should be a specific system or a generic system, so as to allow the groups to tackle the issue/s of interest to them. Each group had one or two people to act as facilitator/modeller.

Breakout Group 1

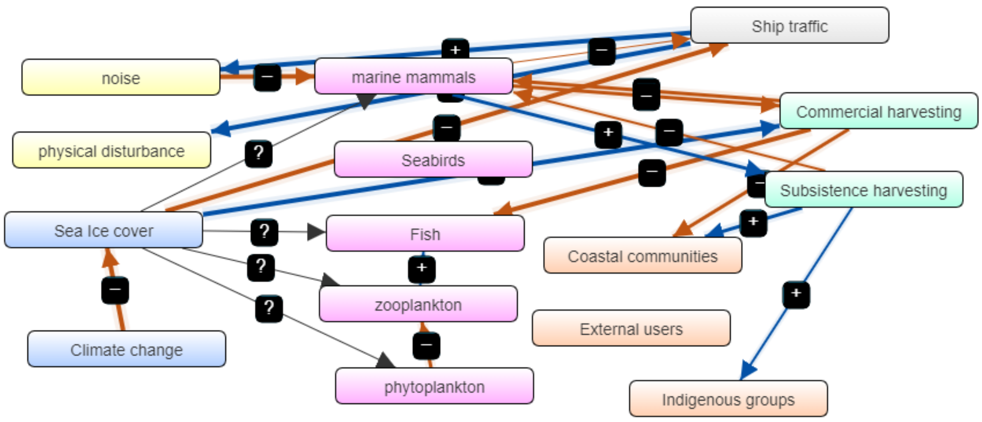


Figure 2.1. Mental model produced by break out group 1, focusing on climate change and shipping increases in the Central Arctic Ocean.

Breakout Group 1 chose the Central Arctic Ocean (CAO) (under WGICA) for their example. In this region, most of the potential activities are emerging rather than currently present, and so the assessment was carried out with a view to the future. It was noted that some human groups/activities are transitory or seasonal (e.g., hunting activity). The region also presented some complications as many of the activities have knock-on effects (e.g., employment) in regions outside of the studied ecoregion. Similarly, many of the pressures that currently affect the system are exogenous to the region. Furthermore, there are some indigenous groups outside the CAO that have rights to take some amount of marine mammals that transit the CAO. The political context of the region is complicated and hard to capture as there are many nations bordering the CAO, each of which may have different regulations regarding noise, pollution, plastics, and other pressures.

The primary question driving construction of the model was specifying and categorizing the focal components, figuring out what to group together and colour the same, before working to identify where to draw the arrows and positive/negative aspects. The second question focused on how climate change impacts will lead to decreasing ice cover, and how this may then impact shipping, fisheries and marine mammals and thus potentially coastal communities and indigenous groups in the region, as well as corporations and economies located outside the region.

[1] This is not the only modelling tool available; another, for example, is the Bow-Tie Method, but Mental Modeler is in common use and has been used by ICES working groups in the past so was considered the best for this workshop. More on this below.

Breakout Group 2

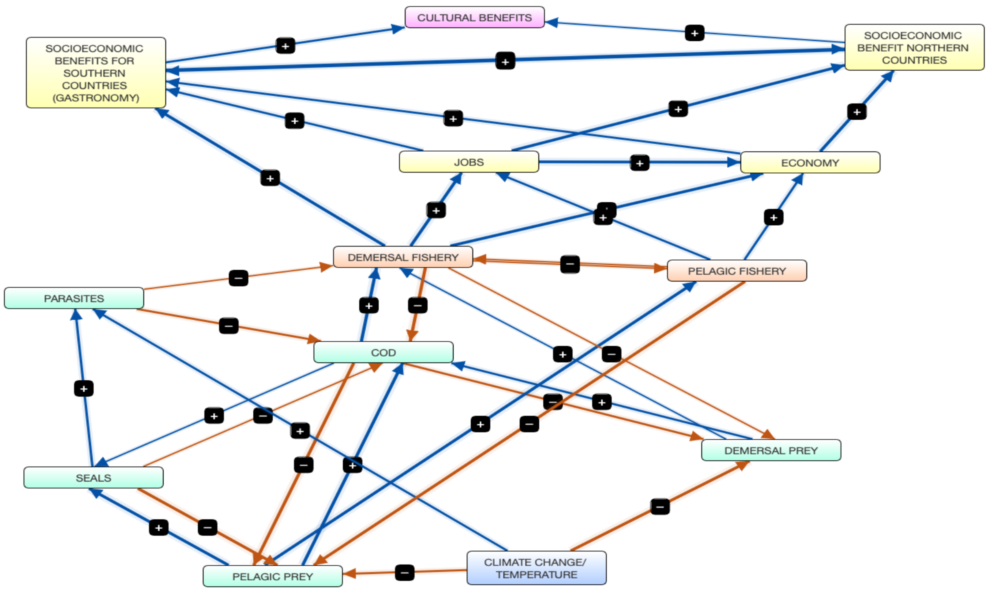


Figure 2.2. Mental model produced by break out group 2 focusing on cod.

Breakout Group 2 started by choosing cod as a central species and then including the socio-economic benefits of this fishery to northern (producers) and southern (traditional consumers) countries. This north-south relationship through cod commerce was considered positive and to have mutual cultural benefits, for instance the gastronomy in the south (e.g. bacalao is a central item in southern European countries gastronomy, particularly in Portugal) or the sense of place in the north (e.g. iconic cod drying racks in Lofoten, Norway).

Trade-offs between demersal and pelagic fisheries were identified and illustrated as well as a simplified food-web that included the effect of seals (cod predators) and parasites. Climate change was also considered.

Breakout Group 3

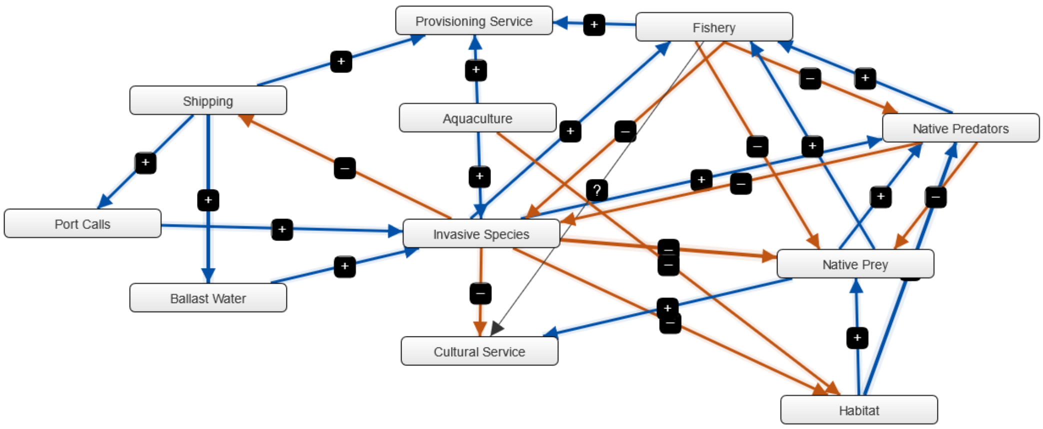


Figure 2.3. Mental model produced by break out group 3 focusing on invasive species

Breakout group 3 chose the issue of invasive species in marine ecosystems (including nearshore). Invasive species are a problem in multiple countries and typically have environmental, social and economic consequences.

The process of constructing the model began by identifying sources of these species and potential impacts. This initial process was mainly focused on assessing the impact of invasive species on the environmental mechanisms (e.g., predation) and human activities (e.g., fisheries, shipping), as well as possible ways to insert nodes where regulation could be applied (e.g., ballast waters). The next step was to include in the conceptual model the social impact, by including the ecosystem services of provisioning and cultural services. This last topic brought some discussion about the diverse impact of invasive species in a social perspective, and highlighted the importance of constructing conceptual models with some initial objective/stakeholder group. Working with stakeholders on a specific objective will also help bound your conceptual model and help identify nodes that need to be present.

Breakout Group 4

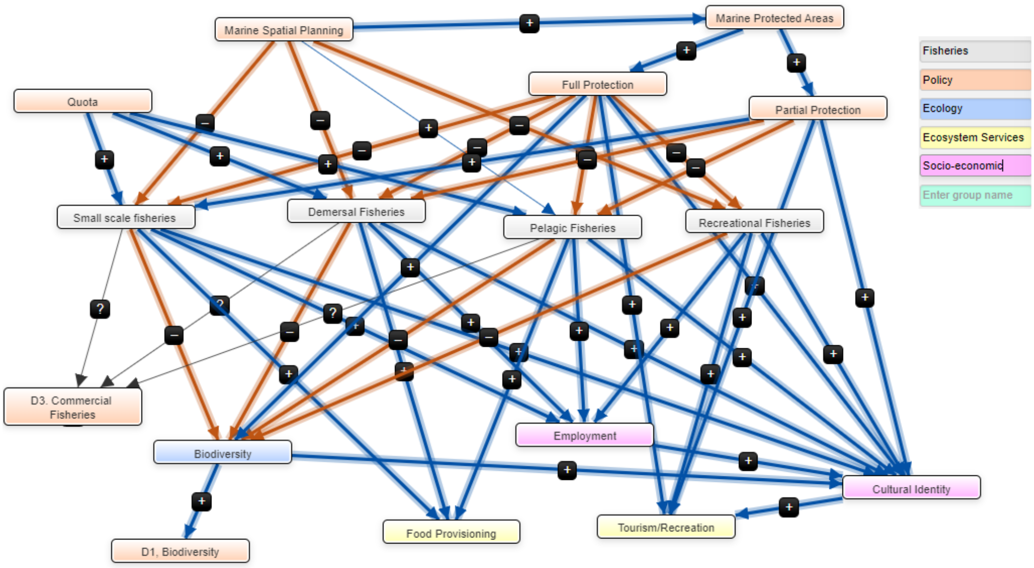


Figure 2.4. Mental model produced by break out group 4 focusing on the potential interactions of fisheries and Marine Protected Areas (MPAs), and their effects on biodiversity.

Breakout group 4 focused their model around investigating the interactions between Fisheries, Marine Protected Areas (MPAs) and Biodiversity, including major socio-economic concerns. The location was generic, and not explicitly specified, but was focused around the short term (3-5 year) trade-offs through spatial interaction and/or exclusion between different types of MPAs and fisheries, and the potential effects on biodiversity, employment, other sectors such as Tourism/Recreation and Ecosystem Services such as food provisioning. While the presented figure 2.4 does include some policy aspects, the initial effort included more (e.g., the Marine Strategy Framework Directive (MSFD), Marine Spatial Planning Directive (MSPD), Integrated Maritime Plan (IMP)) that were later omitted to avoid over-complicating the structure. The group discussed how further detail (e.g., breaking out 'biodiversity' into functional groups) would help to better identify differential effects on various categories – however, for this task that was considered to be too complicated, though perhaps it would be a good place for 'sub-model' development.

Summary

When left to open interpretation, a range of questions, approaches, levels of complexity and structures were observed. Some groups developed a left-to-right layout (in terms of ecosystem components-sectors-services; Group 1), others followed a more top-to-bottom type of scheme (Group 2), or more rounded (Groups 3 and 4). Both the different systems modelled and the different arrangements of the layouts helped to show the flexibility of conceptual modelling for a variety of ecosystems and issues. The exercise was extremely useful in getting participants on the same page and demonstrating some of the key aspects and challenges involved in conceptual modelling.

Mental Modeler

Mental Modeler (Gray et al. 2012, 2013a, 2013b: https://www.mentalmodeler.com/) was considered a very good tool for outlining and discussing components of the system under consideration and a good communication tool to initiate discussions. The ability to highlight and see linkages to or from individual components is useful for more complicated mental maps. However, the metrics and scenario tools have some limitations. For example, the metrics are useful for questions that are very focused and where most components can be included so that connectivity calculations are meaningful. The scenario tools are heavily reliant on the relative weighting of the linkages, so if this tool is to be used, it is important to thoroughly go through the matrix and assess the strength of the linkages relative to one another. Otherwise scenario testing can yield some surprising and even counter-intuitive results.

Overall, the group thought this was a good scoping and exploratory tool that would be useful to help identify further where analysis using more semi-quantitative and/or quantitative tools with more explicit identification of relationships and parameters would be useful, whether they are simple theoretical models or more complex Ecosim with Ecopath models (although these methods are more time-consuming to build and require considerably more data and knowledge to develop).

Lessons Learned

- When you talk to stakeholders it can be better to take them something that they can fiddle with rather than a blank slate.
- Setting the question you want to answer is very important as it frames the model.
- The context should also be set: the temporal and spatial scales involved in the model - some net benefits may change from positive to negative over time, most pressures and impacts vary spatially.
- Having focal components (e.g. ecological, economic, social) is important to focus the conceptual map. It is a representation of elements, not intended to cover everything.
- Ask questions: what are the focal components? Who are the people who are impacted?
- Documenting everything is important, especially if using mental modeler, since you can't save that the information on how choices were made when exporting the matrix. For this reason, a separate spreadsheet is critical to facilitate detailed note-taking, so that someone new coming in, or even initial modelers some years later, can clearly understand what was done and why. It also helps to document what was NOT included when specific elements are omitted, or a level of aggregation is chosen.
- Building a conceptual model can highlight areas that are important but lack data/indicators. Gap analysis can be also one of the outcomes when using of conceptual models.
- The scenarios module in Mental Modeler is useful as a validation tool - if the system doesn't respond as expected you can come back and adjust. It can also help to identify missing components.
- Be clear in defining your category boxes (allow boxes in the same category to be all the same colour) connections, not only which way the arrows and strength, go but the reason/s behind your choices.
- Mental Modeler is good for diagramming data-poor scenarios, but conversely, you have to be careful in how you interpret models that don't have much quantitative data behind them.
- An hour is long enough to make something complicated - but not long enough to do all the checks. Time should be dedicated to checking what is produced to examine for missing links and inconsistencies.

- It takes time to decide on the final model. You will need to go back to it multiple times to feel sure you've included the important features and excluded things that beyond the scope/question of interest.
- There is a potential dampening effect in the network when adding too many components. Components 3+ links away from the component which is increasing/decreasing in a scenario may demonstrate a lower than expected response.
- A hierarchical approach (using sub-models whose key components can be summarized in an over-arching model) is really useful to avoid over complicating any one model. However, they may not be able to directly interact.
- It is possible to explore uncertain linkages in the model using Qualitative Network Modeling (QNM) software (see Melbourne-Thomas et al. 2012). With QNM, the analysis uses a Bayesian framework to interpret the uncertainty that can then be applied to compare alternate model formulations.
- Multilayer ecological networks are a potential option, see Pilosof et al. (2017) and Jacob et al. (2020).

3 Developing common conceptual mapping guidelines

ToR B: *Develop semi-standardized conceptual mapping approaches and* ***guidelines*** *that can be used by those interested in using conceptual mapping as a tool in a variety of contexts, including in ICES Working Groups involved in Integrated Ecosystem Assessment (IEA)*

ToR B leads: Erik Olsen, Sean Lucey, Jamie C. Tam.

Introduction

A number of examples and experiences of working with conceptual models both within ICES and beyond were presented to the group to demonstrate a variety of contexts, applications and methods.

Participants Experiences with Conceptual Modelling

Working Group on the Northwest Atlantic Regional Sea (WGNARS) conceptual model example

Presentation by Patricia M. Clay, based on a manuscript in process: *Gamble, R., J. C. Tam, S. Gaichas, G. DePiper, S. Lucey, R. Wildermuth, P.M. Clay, P. Pinto da Silva, P. Fratantoni, V. Saba, L. Smith, C. Perretti, G. Fay. Conceptual models and qualitative network modeling: How can they advance EBFM?*

WGNARS, following on some work done by NOAA for the California Current ecosystem, used conceptual modelling to define transdisciplinary representations of the social-ecological system of the Northeast U.S. Shelf Ecosystem (Northeast Shelf), forming separate sub-models of the biological, physical and social components before merging them into a full model (DePiper et al., 2017; Muffley et al., 2020). Similarly, WGNARS created overview and detailed sub-models for each of 4 defined Ecosystem Production Units[2] (EPUs) in the Northwest Atlantic along the coasts, three in the U.S. and one in Canada.

This work is most advanced in the U.S. at the moment, due to WGNARS' ability to start there with using the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to define high-level management objectives. Conceptual modelling was then used to identify at the EPU level the focal components (focal species, focal human groups), human activities, objectives, environmental drivers to be included. Decision criteria and reasoning were meanwhile documented in a spreadsheet, along with available data for each component (EPU-specific or Northeast Shelf-specific) and/or scientific literature to support a linkage. For example, a common focal component across all EPUs might be pelagic fish, but the individual species of pelagic fish might differ by EPU. An example of the approach to documentation can be viewed here. A food-web model of the marine community already existed that could be used. Similarly, there was an existing physical model of environmental drivers. The human dimensions' model (including

[2] EPUs are defined by oceanographic, biological, and socio-economic properties (Lucey & Fogarty 2013).

human communities and social systems) for each EPU needed to be created from scratch. The human dimensions, especially the social and cultural aspects, are currently the least developed[3]. All three models (biological, physical, human dimensions) were then merged into one overall model with sub-parts for each model by EPU. Even a single EPU makes for a complex horrendogram. The diagrams were then cleaned up for clarity, and later further simplified conceptually for public consumption here, with a listing of models on the right. Clicking on a model takes you to an explanation of what that model is and more detailed information by EPU.

Work with the two Fishery Management Councils in the Northeast U.S. led to the creation of a State of the Ecosystem Report for each Council. The New England Council has only one EPU while the Mid-Atlantic Council has two. Click here for a 2020 example from the New England Council and here for a 2021 example from the Mid-Atlantic Council to see how these reports are continuing to evolve. In the Mid-Atlantic, meanwhile, the interactive conceptual model, with concurrent presentation of linkage definitions, justification for inclusion, informational gap analysis, and available models as delineated in Gaichas et al. (2016), greatly facilitated the transition to initial risk assessments (Gaichas et al. 2018) and management strategy evaluations (MSEs) (Muffley et al., 2020).

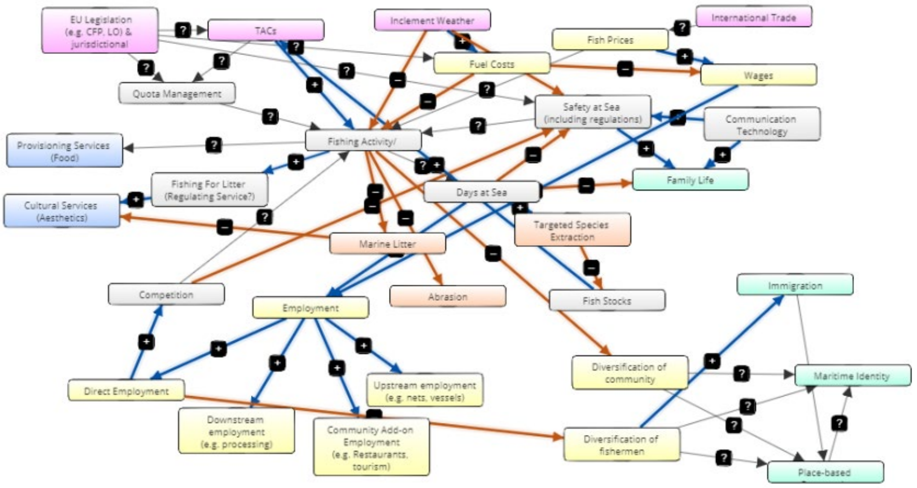
Workshop on an Ecosystem Based Approach to Fishery Management for the Irish Sea (WKIrish) (Ireland)

ICES. 2020. *Workshop on an Ecosystem Based Approach to Fishery Management for the Irish Sea* (WKIrish6; outputs from 2019 meeting). ICES Scientific Reports. 2:4. 32 pp. http://doi.org/10.17895/ices.pub.5551
Contributed by Debbi Pedreschi.

WkIrish6 participants, primarily fishing industry stakeholders, were asked to contribute to a conceptual mapping exercise based on the top risks and sectors identified in the ODEMM assessment (which identified top sectors and pressures of concern in the Irish Sea). The focus was to identify the relevant social and economic aspects and drivers from the perspective of the fishing industry stakeholders, with comments/questions from the scientific community to facilitate discussion and elaborate on detail. The discussion identified a range of aspects of relevance to the industry that were input into Mental Modeler with connections specified as positively or negatively correlated based on the conversations during the mapping exercise. Some additional 'missing links' were identified and included. The strength of the connections (degree of influence) was not addressed at this point due to time limitations. However, the exercise provides an excellent starting point for future discussions and for identifying aspects of key relevance to these stakeholders. These aspects can be taken into account in the context of IEA work and the work of groups like WGECON and WGSOCIAL. This work has been followed up on and advanced by WGEAWESS in collaboration with WGSOCIAL and WGECON for future reviews of the ICES Ecosystem Overview of the Celtic Seas.

[3] Currently, the only social indicators are the NOAA Community Social Vulnerability Indicators. These will be being refined in 2022-2023. There are currently no cultural indicators.

A.



B.

Figure 3.1. Outputs from WKIrish. A) the conceptual map produced in Mental Modeler during the workshop. B) key socio-economic aspects that were highlighted and discussed as relevant to the Irish Sea.

The process was a learning experience as no participants had led such an exercise before. The focus was rapidly narrowed in scope to focus on fisheries issues, which was not surprising given the stakeholders present and the scope of the workshop. Despite this, it was a successful and informative exercise that provided insight into some of the top concerns relevant to the stakeholders in the Irish Sea region of interest. Figure 3.1 highlights the key socio-ecological concerns identified by stakeholders through the Mental Modeling exercise and associated dialogue which should be included in our analyses moving forward. To date, we have made steps towards including *place-based identity* and *ecosystem services* into our IEA work and the ICES Ecosystem Overviews.

In the same workshop, similar approaches were used to build historical fleet effort trajectories and historical food-webs from fisher ecological knowledge (FEK) from periods for which we have no monitoring or survey data. This data was then used to inform an Ecopath model for the Irish Sea. The inclusion of FEK improved the fit of the model. This work has since been used to develop the F_{eco} approach, an approach which integrates strategic advice from ecosystem modeling with the tactical advice of single-species assessment models to provide practical ecosystem-based management advice within the constraints of the current system (Bentley et al. 2019a, b; Howell et al. 2021).

BARENTS-RISK project (Norway)

Contributed by Benjamin Planque and Nina Mikkelsen
We conducted an exercise with 6 small groups of stakeholders/managers representing different sectors (fishing, shipping, oil and gas, tourism, environment) to draw conceptual models of the Barents Sea.

We voluntarily left the **page blank**. The guidance for the groups was that they had to classify Barents Sea elements into sectors, activities, drivers, ecosystem components and services. The stakeholders were also provided guidelines and examples of components belonging to the different categories and asked to fill out support tables to provide further details on the relationships between elements (direction, sign, weight, uncertainty, knowledge base, comments, references). A project facilitator was appointed to each group to assist them if necessary. They were encouraged to focus on what they knew best, rather than trying to draw the whole system.
We found that:

- Each group provided an incomplete picture
- All groups revised the model, but after 2 rounds of drawing, 2 plenary sessions and discussion at the workshop, plus follow up communication by phone, individual group meetings and emails, there were still inconsistencies in some parts of the conceptual models.
- We used kumu for visualization of individual stakeholder group input and revision of models with stakeholders. The application of this tool (demonstrated by a scientist) was appreciated by stakeholders.
- 'Feedback' or two-way interactions in the models (not everything is linear going from sectors to activities, activities to drivers, drivers to components, etc.).
- Many links are uncertain (even the sign can be uncertain) and can be bidirectional.
- Similar elements could be considered at different levels of hierarchy (e.g. fish, demersals, cod).
- The only connection seen by all 6 groups was between oil pollution and birds.
- Every group mentioned climate change (CC), but CC was connected to different elements by the different groups.
- We were surprised to find that when we simplify these conceptual models to build "mental modeler" objects (fuzzy cognitive maps, FCM), we tend to get quite robust conclusions, i.e. the models are robust to many uncertainties and are robust to adding/removing many links that were specific to individual stakeholder groups.
- When running 'scenarios', we also found that cumulative effects are usually additive. We don't know yet if this is a property of the models drawn by the stakeholders or an artefact of the FCM method.

Western Baltic cod fisheries project (Germany)

Contributed by Heike Schwermer.
Schwermer, H., Aminpour, P., Reza, C., Funk, S., Möllmann, C. and Gray, S., 2021. *Modeling and understanding social–ecological knowledge diversity.* Conservation Science and Practice, 3(5), p.e396. doi: 10.1111/csp2.396

Using participatory modelling (e.g., table, portable white board, cards, pens), we conducted an analysis explicitly focusing on the perception of the western Baltic (WB) cod fisheries system across six stakeholder groups: commercial fisheries, environmental NGOs (ENGOs), recreational fisheries, tourism, administration and science. We placed particular emphasis on i) how the WB cod fisheries system is generally perceived and described, ii) which ecological and economic-social components are identified as relevant, iii) how these components are interconnected (direction, weight). The Mental Modeler tool has also been used for a first visualization (and communication with the stakeholders interviewed).

Results

- 33 systems with none being the same; various understandings of the system among all six stakeholder types
- number of components and interactions per model differed strongly in some cases (simple vs. complex system understanding)
- variation was observed in the qualitative semantics of system components represented in the cognitive maps (e.g. definition, measures)
- in parts, strong variation in the definitions and measures used to map the system; especially the social system components show a high variability concerning their definitions and measures, e.g., fisheries sector
- Compared to the ecological components, it was a major challenge for all 6 stakeholder groups to set measures for social components (e.g., how to integrate the role of eNGOs in the western Baltic cod SES).

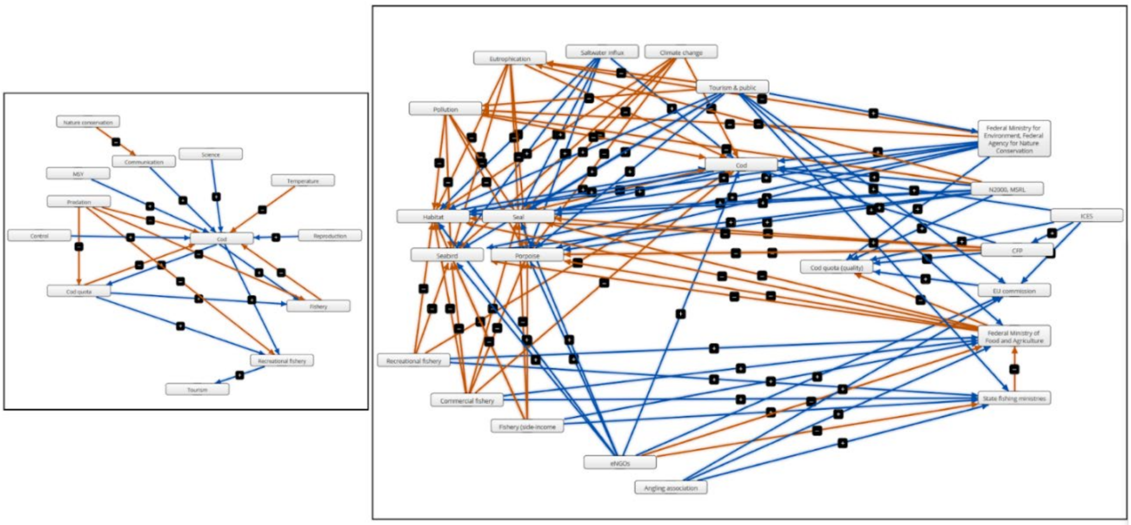


Figure 3.2. Stakeholders' mental models of SES Western Baltic fisheries. Two examples of mental models showing the diversity of the perception on the Western Baltic fisheries system (simple vs. complex system understanding).

Working Group on Integrated Assessments of the North Sea (WGINOSE)

Contributed by Erik Olsen

WGINOSE developed strata-specific decision support tools through mental models, bow-ties, and Ecopath with EcoSim models (ICES 2020a). WGINOSE has been working with Mental Modeler since 2017, with a primary focus on the most relevant ecosystem components to assess and compare within ecological models (ICES, 2020a). The group has built 4 sub-ecoregional models to date, with wide variation observed in the components included and the level of complexity observed. Some models/groups focused primarily on the ecological system, whereas others focused primarily on the sectors, pressures, and high-level objectives. WGINOSE is actively investigating how to integrate multiple sub-ecoregional mental models into a common framework.

Through its terms of reference, WGINOSE will "continue to develop and test/validate strata specific decision support tools to support ecosystem management and advice" within the time frame 2021-2023 (ToR C).
Further information see: https://doi.org/10.17895/ices.pub.7430

Summer flounder management strategy evaluation (United States Northeast Shelf)

Contributed by Geret DePiper

Geret presented conceptual modelling work undertaken on behalf of the U.S. Mid-Atlantic Fishery Management Council in support of their Ecosystem Approach to Fishery Management process. The work was centred on the summer flounder fishery, which had previously been identified through an ecosystem-level risk assessment as the fishery under management by the Council that was facing the largest number of high-risk factors. The conceptual model was used as a scoping tool, aimed at identifying key ecosystem linkages, inventorying data, identifying knowledge gaps, cataloguing existing models that could inform a quantitative Management Strategy Analysis (MSE), and developing example questions which could be addressed through the MSE. The resulting model was developed in R using R Markdown to create an interactive html representation which could be readily customizable and allowed managers, stakeholders, and scientist to more easily trace linkages. The html format also allowed the presentation of supporting documentation alongside the conceptual model to aid in transparency and reproducibility. More details can be found in DePiper et al. (2021) and code to reproduce the conceptual model is available at https://github.com/NEFSC/READ-SSB-DePiper_Summer_Flounder_Conceptual_Models.

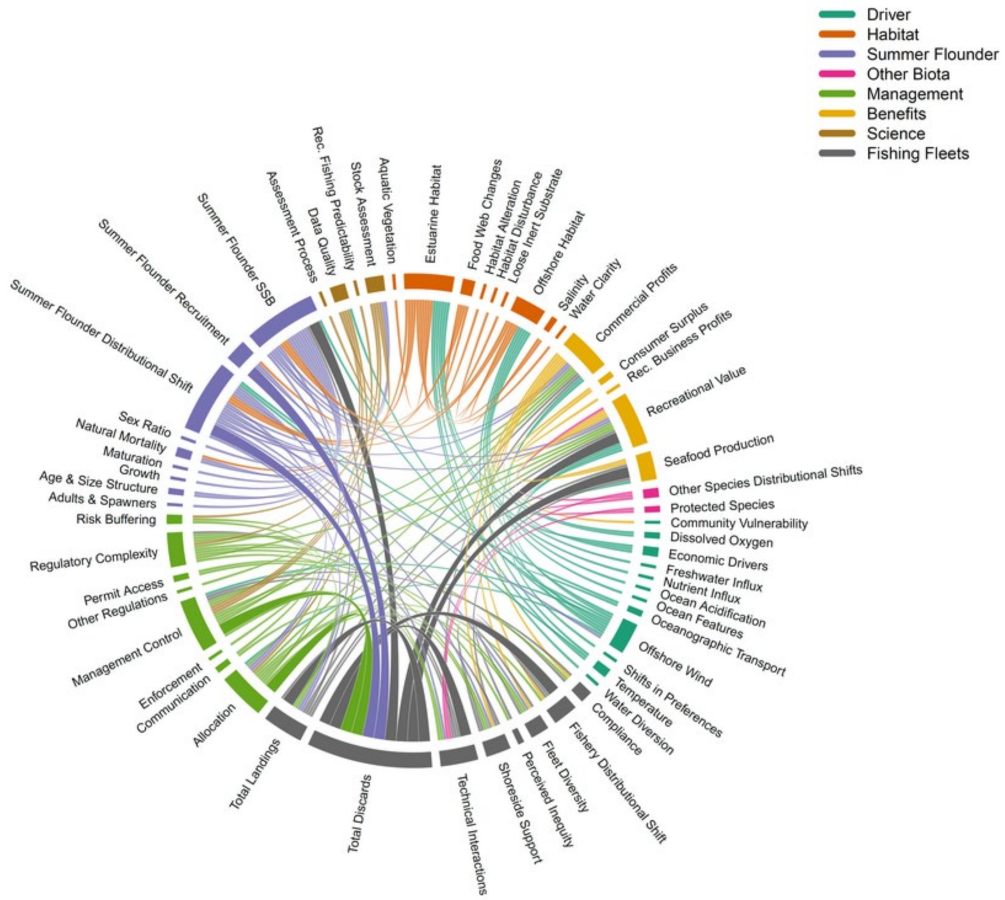


Figure 3.3. Cord diagram representation of the summer flounder conceptual model. For a fully interactive version visit: https://nefsc.github.io/READ-SSB-DePiper_Summer_Flounder_Conceptual_Models/sfconsmod_final_2col.html

Network Analyses (United States)

Contributed by Sean Lucey

The nationwide NOAA IEA program held a workshop on qualitative network approaches in order to better integrate conceptual models within ecosystem-based approaches to management. During the workshop several common network approaches were discussed: Qualitative Network Models (QNMs), Fuzzy Cognitive Maps (FCMs), and Bayesian Belief Networks (BBNs). After the workshop, these three approaches were applied to three different conceptual models representing three different coastal systems that had been developed for different reasons. The NOAA IEA team then applied different scenarios representing an increase in fishing effort and/or environmental warming to see how varied the conclusions would be for the different methods. Results varied between methods based on the sign of the projected change as well as the certainty of the change. General patterns were similar across systems and scenarios. Unfortunately, the different outcomes between models could led to different inferences regarding trade-offs under the scenarios. Therefore, it is recommended that these methods not be used in isolation. When used as part of an ensemble, these network approaches can help to better characterize structural uncertainty and leverage insights gained under one framework to inform the others. For more detailed information, see Reum *et al.* (2021).

Workshop on Socio-economic Implications of Offshore Wind on Fishing Communities (WKSEIOWFC)

Contributed by Angela Silva

The Working Group on Offshore Wind Development and Fisheries (WGOWDF) hosted the virtual workshop on Socio-Economic Implications of Offshore Wind on Fishing Communities (WKSEIOWFC) in March of 2021. The workshop consisted of 3 half days with 50 participants, including experts from the fields of natural and social science (e.g., oceanography, biology, economics, anthropology) and governance (e.g., policy, nature conservation, administration), as well as wind industry and fishing industry members. The cause-effect mental modelling exercise using Mental Modeler software was helpful in understanding participants' perceptions of how changes in the environment could lead to changes in fishing behaviour and the implications for the economy and wider society.

The workshop was organized around three topic areas: environmental, economic, and cultural. Participants completed a pre-workshop survey with open-ended questions which allowed organizers to begin three conceptual models, one for each topic area, based on the survey's coded responses. For example; fishing ground access, fuel costs, and displacement were major themes coded from the economic questions that were used as starting nodes within the economic model. The workflow for the workshop consisted of 3 rotating breakout group sessions for 90 minutes each which allowed all participants the opportunity to work on each of the three models in smaller groups. Those moderating and running the Mental Modeler software stayed with the same topic area throughout the workshop. Google Jamboard was also used as a virtual tool for sticky notes for further organizing themes and sub-themes of nodes. Participants began discussions around the starting nodes, added nodes they believed were missing from the initial model, and developed the linkages between nodes. The modelling exercises allowed the group to describe, summarize and illustrate effects that offshore wind development has on fisheries. It was quickly discovered in all three models that making a distinction for a positive or negative effect is difficult based on fishery type, regional characteristics (between and within the U.S. and Europe), as well as spatial and temporal characteristics (e.g., scale and timeline of offshore wind development). In order to illustrate how the generic cause-effect maps might be used to evaluate a specific situation, the second cultural breakout group began to work through two specific examples, including one for crab/lobster fishermen in the UK and their experience in a partnership with Orsted (a Danish multinational power company), and a second that mapped the potential displacement effects of the surfclam fishery in the U.S., a fishery that has limited ability to diversify. Future work will include bringing the three models together into one conceptual model of the fisheries and offshore wind system.

The model outputs were recognized as a useful tool in showing the complexity of these issues. Further analysis of the narrative within each node, captured in detailed notes during the discussions between stakeholders, will allow us to continue work to: 1) determine the extent, and sources, of current evidence between each linkage; 2) identify methods for filling gaps; and 3) develop recommendations for generating evidence to support management decisions related to offshore wind and fishery interactions.

Full report available at: https://doi.org/10.17895/ices.pub.8115

Workshop on pathways to climate-aware advice (WKCLIMAD)

Participants in WKCLIMAD used conceptual models to scope next steps towards developing an operational advisory framework that addresses key climate hazards to aquaculture, fisheries, and ecosystems.

The workshop's 50+ online participants utilized a number of templates designed by the chairs for brainstorming and evaluation using the Miro online collaboration platform. Of particular value was the use of: (1) mind maps for idea generation and review of existing information, (2) interactive figures to help participants discuss and assess various impacts with respect to their relative magnitude and likelihood, (3) sticky notes for commenting, that helped other participants expand on ideas, and (4) voting to gather impressions on highest priorities. Notably, the platform facilitated active participation by all participants, whether working in a large discussion forum or small breakout groups, and was therefore especially valuable for synthesizing and gathering feedback on a very large field of topics and expert knowledge.

For example, participants used an exercise to evaluate a list of impacts generated in a pre-meeting survey. Here they placed each risk on a grid during discussions of their relative magnitude of impact; leaving comments to expand ideas on the risk itself and identifying when disparities were identified in relation to where each risk should be placed.

Next the participants used a mind map exercise to evaluate various climate-related impacts on fisheries and aquaculture (Figure 3.4), and expand on their thoughts on risks and both current and potential management measures.

Figure 3.4. An example mind map filled in by participants at WKCLIMAD.

Participants then used a similar mind map exercise to note what supporting information, data for the management measures, as well as data needs and tools, would be needed to operationalize the measure and to identify which adaptation measures would be addressed by each of the management measures.

Fish Aggregating Devices in the Eastern Caribbean (Canada, Eastern Caribbean)

Contributed by Jamie C. Tam.

The conceptual model was designed to answer governance questions surrounding the implementation of Fish Aggregating Devices (FADs) in the Eastern Caribbean. Here we developed a socio-ecological conceptual model linking fisheries related to Fish Aggregating Devices (FADs) in the Eastern Caribbean to policy and management through: 1) the provisioning of FADs, 2) fisheries resource appropriation, 3) human well-being and 4) food-web impacts. This model combined a multi-level governance network model, semi-structured interviews and analysis from local fishers to a mass-balanced ecosystem model for the region. Using Qualitative Network Modelling to overcome data limitations, this work examined the relative performance of three governance scenarios: private-individual, community-based, and top-down governance (Pittman et al. 2020). This is a novel case study using methods that can be used as a basis for exploring the outcomes of management decisions of a fishery.

Tools and Approaches

Conceptual Modelling Tools

A high-level comparison of the strengths, weaknesses and features of tools used by presenters is detailed in Table 1.

Table 1. Overview of the strengths, weaknesses and features of tools used by WKCCMM participants.

TYPE	TOOL	STRENGTHS	WEAKNESSES	Allows for simulations?	Exportable matrix?
Fuzzy Cognitive Mapping (FCM)	Mental Modeler (MM)	Easy to use / learn	Does not allow self-looping	Yes, inbuilt and through QPRESS	Yes, but misses nodes
		Free software	Visualization: only direct lines possible, lines overlap quickly and model becomes difficult to read	Potential dampening effect when multiple connection	
		Commonly used, including in ICES	No undo button		
		Possibility to categorize system components			
		Outcome: table of network metrics for further analysis			
		No need for coding			
	KUMU	Allows the use of loops (meaning: two arrows in the same direction with opposite signals)	Some knowledge of coding necessary	No, but one could use Qpress	Yes (even the comments)
		Easier to add notes and document the process (than MM)	Can be expensive if high quality image needed		
	Dia	Diagram Editor for developing and visualizing the model, links to Qpress	Visualization only	Links to Qpress	Yes, via Qpress
	Miro	Interactive web-based tool good for brainstorming and initial diagramming, a simple template for mind map template is available.	Visualization only. Can be difficult to control/track what is going on with multiple contributors at once. Export options limited.	No	No
Qualitative Network Modelling (QNM)	Qpress	Analytical tool to operate stochastic loop analyses.	Analytical tool with some basic graphical outputs.	Yes, primarily a simulation tool for qualitative models	Yes
Bayesian Belief Networks (BBN)	GeNIe	Interactive model building and analysis using BBN.	private software	Yes, a simulation tool using BBN	No, but compatible with other software

Additional tools that have been used by the group and may be useful were also discussed. SeaSketch supports collaborative planning in shared ocean space. It is primarily a Marine Spatial Planning tool, but is useful for incorporating social issues. The software is currently commercially available but is expected to become fully open source in 2022 (GitHub).

Visualization Tools

A high-level comparison of the strengths, weaknesses and features of visualization tools used by presenters is detailed in Table 2.

Table 2. Overview of the strengths, limitations and features of visualization tools used by WKCCMM participants.

TOOL/METHOD	R PACKAGE?	INTERACTIVE OUTPUT?	STRENGTHS	LIMITATIONS
GGally	yes	no	free	Not interactive
visNetwork	yes	yes	shiny compatible	Requires some coding skills
chorddiag	yes (github)	yes	free	Requires some coding skills
diagrammeR	yes	no	free	Not interactive
igraph	yes	no	free	Not interactive
circlize	yes	no	free	Not interactive
KUMU	no			low image quality in free version
nomnoml.com	no	no	free	Not interactive
Ben Best Infographiq	yes (github)	yes	free	Requires some coding skills
Dia	no	no	Interacts with Qpress	Not as flexible as some of the other methods
yEd	no, but importable with read.yEd package	no	free, web-based and downloadable	Not interactive

Summary

Each presentation was followed by a specific discussion, before a wider general approach discussion which elaborated on some of the features identified under ToR A. These discussions informed the comparative tables 1 and 2 and formed the basis for the Guidelines (see Annex 4).

4 How to apply conceptual modelling in Integrated Ecosystem Assessment and for use in ICES

ToR C: *Investigate how the methodologies can be best used to contribute to* ***Ecosystem Overviews*** *(e.g., via food-web and/or socio-ecological system modelling),* ***Integrated Ecosystem Assessment****, and to inform/underpin wider trade-off analyses relevant to* ***ICES*** *and the wider scientific community.*

ToR Lead: Debbi Pedreschi

Integrated Ecosystem Assessment (IEA)

IEA is a tool that can be used to develop ecosystem advice, and implement/operationalize EBM. IEAs function to organize science in a way that can enhance the ability of managers to evaluate cumulative impacts and carry out trade-off analyses (Levin et al., 2009). IEA operates as an incremental iterative process where socio-ecological objectives, the associated data and knowledge needs, and the available data/knowledge to meet those needs are identified (along with data/knowledge gaps), prior to synthesis and analyses to produce assessments that can inform EBM (Levin et al. 2009). IEAs are intended to be all encompassing, taking a multi-sectoral, multi-pressure ecosystem view of the entire social-ecological system. Furthermore, the early steps involve working with stakeholders to identify the management objectives/issues to be addressed, which ensures the relevance and applicability of the work for the region under assessment. The framework is flexible, adapting to regional requirements and various data situations (Levin et al., 2014; Holsman et al., 2017).

Conceptual Mapping/ Participatory Modelling in ICES

Mental models can provide a key transition point between more linear DPSIR (Drive-Pressure-Sector-Impact-Response) approaches (Knights et al., 2014; Borgwardt et al., 2019), and IEA or ecosystem modelling approaches (Levin et al., 2016). A number of ICES groups (e.g., WGINOSE (ICES, 2020a), WGNARS (DePiper et al., 2017), WGMARS (ICES, 2017), and WKIrish (ICES, 2020b) have used Mental Modeler (Gray et al., 2013) for a variety of applications (see ToR B summaries).

As outlined in ToRs A and B, Mental Modeler has been identified as a useful tool for conceptual modelling. It is free, very simple to learn, and easy to use, meaning even complex models can be rapidly produced, with immediate scenario testing allowing for dynamic interaction and facilitating shared understanding. There are also some drawbacks, as outputs from conceptual models are highly dependent on timing, context and the perspectives of the individuals present during the exercise. They also rarely capture the full range of sectors, pressures and components of interest/concern within a given ecoregion, due to the limits of the expertise in the room. There is also a risk of the ease of production leading to highly complex and unwieldly models that are effectively uninformative. Due to these issues, it is unlikely that conceptual models can be directly incorporated into ICES advice outputs such as the Ecosystem Overviews, which should be transparent and adhere to the FAIR principles: findable, accessible, interoperable and reusable. Despite this, conceptual models are highly useful in IEA, particularly in the scoping stages.

ICES workflow

In 2020 a common risk assessment approach for ICES IEA groups was developed at the workshop on methods and guidelines to link human activities, pressures and state of the ecosystem in Ecosystem Overviews (WKTRANSPARENT). This approach, adapted from the ODEMM project (Robinson and Knights, 2011; Knights et al., 2013, 2014; Robinson et al., 2013, 2014; White et al., 2013; Piet et al., 2015) outlines standardized guidelines for carrying out a risk assessment and prioritization exercise to identify the top 5 pressures and human activities within each ecoregion.

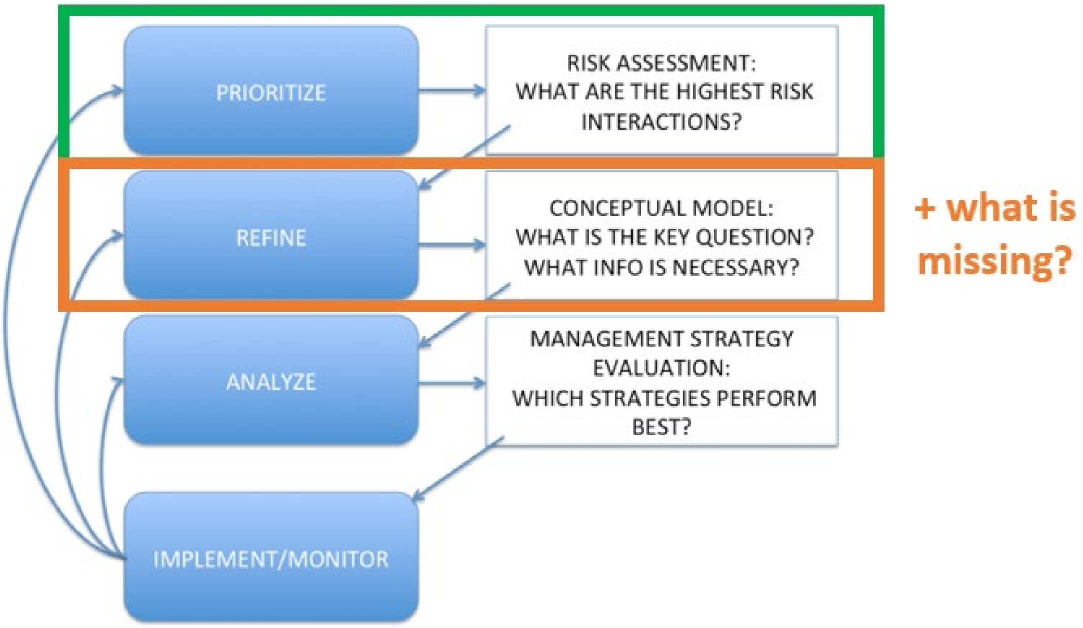


Figure 4.1. A potential framework for integrating interactions into management. Adapted from Gaichas et al. 2016. The green box indicates the aspects covered by the WKTRANSPARENT workshop where a standardized approach to risk assessment and prioritization has been adopted by ICES IEA groups. The orange box indicates the contribution that can be made through conceptual modelling exercises, to continue scoping with stakeholders to identify key questions, available information, and missing elements from our framework, including social and economic aspects (the 'human dimensions').

WKCCMM proposes that the best practice guidelines (Annex 4) developed herein can provide a valuable resource for helping with this second stage of analyses; refining the scope of the research question and the assessment itself. Furthermore, the process of conceptual modelling helps to engage stakeholders, access other forms of knowledge (e.g. traditional (indigenous) ecological knowledge (TEK), local (fishers') ecological knowledge or (LEK/FEK)) and includes social and economic dimensions that are often omitted through other processes. It provides a pathway through which we can access and assess the locally and regionally relevant priorities of stakeholders, as well as highlight some of the less 'tangible' aspects, such as cultural heritage and aesthetics (e.g., via ecosystem services). Furthermore, where resources are limited, conceptual modelling can be used to identify what elements are critical and what next steps/tools/skills are needed to continue the IEA process, or in exceptionally resource-limited circumstances, conceptual modelling could be used as the main tool to carry out IEA (e.g. using an ensemble approach to better investigate uncertainty). In all cases, we hope that both this report and the guidelines will help to facilitate efforts of groups and individuals within ICES and beyond in their efforts to carry out conceptual modelling with stakeholders.

A remaining challenge is how to manage and deal with the outputs that may arise from such exercises. Although ICES has actively worked to progress the integration of human dimensions throughout ICES work (e.g. SIHD), many IEA groups have few, if any, members with social or economic backgrounds. Working interdisciplinarily is essential to maximizing the success of conceptual modelling exercises, and analysing and interpreting their outputs. Furthermore, facilitation and engagement is a skill, and best done with those who have experience and training in such social science methods. WKCCMM identified shared membership (where individuals involved in (e.g.) SIHD groups also join their regional IEA group) to facilitate knowledge exchange and enable best practice as a key route to ensuring the success of such approaches.

5 Dissemination and output

ToR D: ***Dissemination*** *of workshop outputs to wider ICES and scientific community via online webinar and/or talk at the ICES Annual Science Conference.*

ToR Lead: Marcos Llope

Introduction

Several avenues to communicate WKCCM outputs were considered, discussed and agreed upon:

- A short **video** that could be uploaded to the various IEA EG SharePoint sites and played at the beginning of their meetings was discussed and identified as a good idea to convey the main outputs of WKCCMM and encourage IEA groups to try out this methodology while not being too prescriptive. The idea of another video to recruit members to IEA EGs was also put forward.
- Peer-reviewed articles are the main communication means within the scientific community. The generation of a **paper** able to reach a wider audience was agreed to and leads were identified. The paper could pull from lessons learned from experience and/or suggest/discuss ways and examples in which conceptual modelling can be used to support IEA and eventually EBM. The article should include a comprehensive literature review. A sub-team will work on a general outline to structure the paper.
- Finally, we considered a **conference presentation**. ICES ASC 2022 (Dublin) felt like the natural place to do so. However, theme sessions have not yet been published and it was not possible to be very specific about it. The new Early Career scientist keynote speaker initiative proposed by the Strategic Initiative on Integration of Early Career Scientists (SIIECS) was discussed. There were three eligible WKCCMM participants who considered volunteering for this option.

6 Summary

This workshop addressed a rapidly developing area within ICES IEA groups. Multiple IEA groups are currently advancing conceptual mapping methodologies in support of IEA/EO work, and as a method to engage with stakeholders (see WKCONSERVE, ICES 2020c). A common approach (see Annexe 4 Guidelines) across groups not only helps to eliminate redundancy in effort, but ensures improved transparency and consistency between groups and between EOs in line with the FAIR data principles (that data are findable, accessible, interoperable and reusable). Finally, as a potential vehicle for advancing identification of regionally relevant social and economic aspects/indicators, and as a format for advancing food-web understanding, conceptual modelling is relevant to the priorities specified by WKEO3 (ICES 2019d) and WKTRANSPARENT (ICES 2021), to groups such as WGSOCIAL, WGCOMEDA and WGECON, and to progressing the SIHD.

7 References

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Diduck, A. P., *et al.* 2009. Adaptive co-management for social-ecological complexity. Frontiers in Ecology and the Environment, 7: 95–102.

Bentley, J. W., Serpetti, N., Fox, C., Heymans, J. J., & Reid, D. G. 2019b. Fishers' knowledge improves the accuracy of food-web model predictions. ICES Journal of Marine Science, 76(4), 897-912.

Bentley, J.W., Hines, D.E., Borrett, S.R., Serpetti, N., Hernandez-Milian, G., Fox, C., Heymans, J.J. and Reid, D.G., 2019a. Combining scientific and fishers' knowledge to co-create indicators of food-web structure and function. ICES Journal of Marine Science, 76(7), pp.2218-2234.

Dambacher, J. M., Gaughan, D. J., Rochet, M. J., Rossignol, P. A., and Trenkel, V. M. 2009. Qualitative modelling and indicators of exploited ecosystems. Fish and Fisheries, 10: 305–322.

DePiper, G. S., Gaichas, S. K., Lucey, S. M., Pinto da Silva, P., Anderson, M. R., Breeze, H., Bundy, A., et al. 2017. Operationalizing integrated ecosystem assessments within a multidisciplinary team: lessons learned from a worked example. ICES Journal of Marine Science, 74: 2076–2086.

DePiper, G.S., Gaichas, S.K., Muffley, B., Ardini, G., Brust, J., Coakley, J., Dancy, K., Elliott, G.W., Leaning, D.C., Lipton, D., McNamee, J., Perretti, C., Rootes-Murdy, K., and Wilberg, M.J. 2021. Learning by doing: collaborative conceptual modelling as a path forward in ecosystem-based management. ICES Journal of Marine Science, 78 (4): 1217–1228. https://doi.org/10.1093/icesjms/fsab054

Gaichas, S. K., DePiper, G. S., Seagraves, R. J., Muffley, B. W., Sabo, M. G., Colburn, L. L., & Loftus, A. J. 2018. Implementing ecosystem approaches to fishery management: risk assessment in the US MidAtlantic. Frontiers in Marine Science, 5, 442.

Gaichas, S., R. Seagraves, J. Coakley, G. DePiper, V. Guida, J. Hare, P. Rago, and M. Wilberg. 2016. A framework for incorporating species, fleet, habitat, and climate interactions into fishery management. Frontiers in Marine Science 3 (105):1–17. 10.3389/fmars.2016.00105.

Gray, S., Chan, A., Clark, D. and R.C. Jordan. 2012. Modeling the integration of stakeholder knowledge in social-ecological system decision-making: Benefits and limitations to knowledge diversity. *Ecological Modeling* 229, 88-96.

Gray, S. Gray, S., Cox, L., and Henly-Shepard, S. 2013. Mental modeler: A fuzzy-logic cognitive mapping modeling tool for adaptive environmental management. *Proceedings of the 46th International Conference on Complex Systems*. 963-973

Gray, S., Zanre, E., and Gray S. 2013. Fuzzy Cognitive Maps as representations of mentalmodels and group beliefs: theoretical and technical issues. *In Fuzzy Cognitive maps for Applied Sciences and Engineering - From fundamentals to extensions and learning algorithms* Ed: Elpiniki I. Papageorgiou. Springer Publishing

Harvey, C. J., Reum, J. C. P., Poe, M. R., Williams, G. D., and Kim, S. J. 2016. Using conceptual models and qualitative network models to advance integrative assessments of marine ecosystems. Coastal Management, 44: 1–18.

Holsman, K., Samhouri, J., Cook, G., Hazen, E., Olsen, E., Dillard, M., Kasperski, S., et al. 2017. An ecosystem-based approach to marine risk assessment. Ecosystem Health and Sustainability, 3: e01256.

Howell, D., Schueller, A.M., Bentley, J.W., Buchheister, A., Chagaris, D., Cieri, M., Drew, K., Lundy, M.G., Pedreschi, D., Reid, D.G. and Townsend, H., 2021. Combining ecosystem and single-species modeling to provide ecosystem-based fisheries management advice within current management systems. Frontiers in Marine Science, 7, p.1163.

ICES. 2019d. Workshop on the design and scope of the 3rd generation of ICES Ecosystem Overviews (WKEO3). ICES. http://www.ices.dk/sites/pub/Publication Reports/Forms/DispForm.aspx?ID=35937 (Accessed 16 November 2020).

ICES. 2019e. Working Group on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS). ICES. http://www.ices.dk/sites/pub/Publication Reports/Forms/DispForm.aspx?ID=36234 (Accessed 17 June 2020).

ICES. 2020a. Working Group on Integrated Assessments of the North Sea (WGINOSE). ICES. http://www.ices.dk/sites/pub/Publication Reports/Forms/DispForm.aspx?ID=36887 (Accessed 16 November 2020).

ICES. 2020b. Workshop on an Ecosystem Based Approach to Fishery Management for the Irish Sea (WKIRISH6). http://doi.org/10.17895/ices.pub.5551.

ICES. 2020c. Workshop on Challenges, Opportunities, Needs and Successes for Including Human Dimensions in Integrated Ecosystem Assessments (WKCONSERVE) ICES Scientific Reports. 2:10. 30 pp. http://doi.org/10.17895/ices.pub.5950

ICES. 2021. Workshop on methods and guidelines to link human activities, pressures and state of the ecosystem in Ecosystem Overviews (WKTRANSPARENT). ICES Scientific Reports. 3:17. 59 pp. https://doi.org/10.17895/ices.pub.7930

Jacob, U., Beckerman, A.P., Antonijevic, M., Dee, L.E., Eklöf, A., Possingham, H.P., Thompson, R., Webb, T.J. and Halpern, B.S., 2020. Marine conservation: towards a multi-layered network approach. *Philosophical Transactions of the Royal Society B*, *375*(1814), p.20190459.

Knights, A. M., Culhane, F., Hussain, S. S., Papadopoulou, K. N., Piet, G. J., Raakær, J., Rogers, S. I., et al. 2014. A step-wise process of decision-making under uncertainty when implementing environmental policy. Environmental Science & Policy, 39: 56–64.

Knights, A. M., Piet, G. J., Jongbloed, R. H., and Robinson, L. A. 2013. An exposure-effect risk assessment methodology to evaluate the performance of management scenarios: Case study examples from Europe's regional seas. Deliverable 9, EC FP7 project (244273) 'Options for Delivering Ecosystem based Marine Management'. University of Liverpool, UK. 43 pp.

Levin, P. S., Breslow, S. J., Harvey, C. J., Norman, K. C., Poe, M. R., Williams, G. D., and Plummer, M. L. 2016. Conceptualization of Social-Ecological Systems of the California Current: An Examination of Interdisciplinary Science Supporting Ecosystem-Based Management. Coastal Management, 44: 397–408. Taylor & Francis.

Levin, P. S., Fogarty, M. J., Murawski, S. A., and Fluharty, D. 2009. Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. PLoS Biology, 7: e1000014.

Levin, P. S., Kelble, C. R., Shuford, R. L., Ainsworth, C., deReynier, Y., Dunsmore, R., Fogarty, M. J., et al. 2014. Guidance for implementation of integrated ecosystem assessments: a US perspective. ICES Journal of Marine Science, 71: 1198–1204.

Lucey, S. M., & Fogarty, M. J. 2013. Operational fisheries in New England: linking current fishing patterns to proposed ecological production units. Fisheries research, 141: 3-12.

Melbourne-Thomas, J., Witherspoon, S., Raymond, B., and Constable, A. J. 2012. Comprehensive evaluation of model uncertainty in qualitative network analyses. Ecological Monographs, 82: 505–519.

Muffley, B., Gaichas, S., DePiper, G., Seagraves, R., and Lucey, S. 2020. There Is no I in EAFM Adapting Integrated Ecosystem Assessment for Mid-Atlantic Fisheries Management. Coastal Management: 1–17.

Pedreschi, D., Bouch, P., Moriarty, M., Nixon, E., Knights, A. M., and Reid, D. G. 2019. Integrated ecosystem analysis in Irish waters; Providing the context for ecosystem-based fisheries management. Fisheries Research, 209: 218–229.

Piet, G. J., Jongbloed, R. H., Knights, A. M., Tamis, J. E., Paijmans, A. J., van der Sluis, M. T., de Vries, P., et al. 2015. Evaluation of ecosystem-based marine management strategies based on risk assessment. Biological Conservation, 186: 158–166.

Piet, G. J., Knights, A. M., Jongbloed, R. H., Tamis, J. E., de Vries, P., and Robinson, L. A. 2017. Ecological risk assessments to guide decision-making: Methodology matters. Environmental Science & Policy, 68: 1–9.

Pilosof, S., Porter, M.A., Pascual, M. and Kéfi, S., 2017. The multilayer nature of ecological networks. *Nature Ecology & Evolution*, *1*(4), pp.1-9.

Pittman, J., Tam, J.C., Epstein, G., Chan, C., and Armitage, D. 2020. Governing offshore fish aggregating devices in the Eastern Caribbean : Exploring trade-offs using a qualitative network model. Ambio, 42: 254–265. Springer Netherlands. doi:10.1007/s13280-020-01327-7.

Reum, J.C., Kelble, C.R., Harvey, C.J., Wildermuth, R.P., Trifonova, N., Lucey, S.M., McDonald, P.S., and Townsend, H. 2021. Network approaches for formalizing conceptual models in ecosystem-based management. ICES Journal of Marine Science https://doi.org/10.1093/icesjms/fsab211

Robinson, L. A., and Knights, A. M. 2011. ODEMM Pressure Assessment Userguide. ODEMM Guidance Document Series No.2. EC FP7 project (244273) 'Options for Delivering Ecosystem-based Marine Management'.

Robinson, L. A., Culhane, F. E., Baulcomb, C., Bloomfield, H., Boehnke-Henrichs, H., Breen, P., Goodsir, F., et al. 2014. Towards delivering ecosystem-based marine management: The ODEMM Approach. Deliverable 17, EC FP7 Project (244273) 'Options for Delivering Ecosystem-based Marine Management. 96 pp

Robinson, L. A., White, L. J., Culhane, F. E., and Knights, A. M. 2013. ODEMM Pressure Assessment Userguide V.2.. ODEMM Guidance Document Series No.2. EC FP7 project (244273) 'Options for Delivering Ecosystem-based Marine Management'. 14 pp.

Samhouri, J. F., Haupt, A. J., Levin, P. S., Link, J. S., and Shuford, R. 2014. Lessons learned from developing integrated ecosystem assessments to inform marine ecosystem-based management in the USA. ICES Journal of Marine Science, 71: 1205–1215.

White, L. J., Koss, R. S., Knights, A. M., Eriksson, A., and Robinson, L. A. 2013. ODEMM Linkage Framework Userguide (Version 2). ODEMM Guidance Document Series No.3. EC FP7 project (244273) 'Options for Delivering Ecosystem-based Marine Management. University of Liverpool. 14 pp.

Wildermuth, R. P., Fay, G., and Gaichas, S. 2018. Structural uncertainty in qualitative models for ecosystem-based, 1643: 1635–1643.

Zador, S. G., Holsman, K. K., Aydin, K. Y., and Gaichas, S. K. 2016. Ecosystem considerations in Alaska: the value of qualitative assessments. ICES Journal of Marine Science: Journal du Conseil: 1–10.

Annex 1: List of participants

Participants in grey were unable to attend the meeting but followed by correspondence. Chairs are in bold.

Name	Institute	Country (of institute)	Email
Abby Tyrell	NOAA	USA	abigail.tyrell@noaa.gov
Alfredo García de Vinuesa	Instituto Español de Oceanografía (IEO-CSIC)	Spain	alfredo.gvinuesa@ieo.es
Andrea Belgrano	SLU	Sweden	andrea.belgrano@slu.se
Andrew Kenny	Cefas	UK	andrew.kenny@cefas.co.uk
Debbi Pedreschi	**Marine Institute**	**Ireland**	**debbi.pedreschi@marine.ie**
Erik Olsen	Institute of Marine Research	Norway	eriko@hi.no
Filipa Afonso	MARE-ULisbon (Marine and Environmental Sciences Center)	Portugal	filipafonso7@gmai.com
Heike Schwermer	University of Hamburg	Germany	heike.schwermer@uni-hamburg.de
Jamie Tam	DFO	Canada	Jamie.Tam@dfo-mpo.gc.ca
Julie Kellner	ICES	Denmark	julie.kellner@ices.dk
Lis Lindal Jørgensen	Institute of Marine Research	Norway	lislin@hi.no
Marcos Llope	**Instituto Español de Oceanografía (IEO-CSIC)**	**Spain**	**marcos.llope@ieo.es**
Matilda Valman	Länsstyrelsen	Sweden	matilda.valman@lansstyrelsen.se
Nina Mikkelsen	Institute of Marine Research	Norway	nina.mikkelsen@hi.no
Oceane Marcone	Plymouth Marine Lab	UK	ocm@pml.ac.uk
Patricia M. Clay	NOAA	USA	patricia.m.clay@noaa.gov

Name	Institute	Country (of institute)	Email
Paulina Ramirez Monsalve	World Maritime University	Denmark	pauli.ramirez.monsalve@gmail.com
Renee Melkert	EU DGMARE		Renee.MELKERT@ext.ec.europa.eu
Sean Lucey	NOAA	USA	sean.lucey@noaa.gov
Sonia Seixas	UAB	Portugal	Sonia.Seixas@uab.pt
Angela Silva	NOAA	USA	Angela.Silva@noaa.gov
Geret DePiper	NOAA	USA	Geret.DePiper@noaa.gov
Alan Haynie	NOAA	USA	alan.haynie@noaa.gov
Sophie Gourguet	Ifremer	France	Sophie.Gourguet@ifremer.fr
Benjamin Planque	Institute of Marine Research	Norway	benjamin.planque@hi.no
Sigrid Lehuta	Ifremer	France	Sigrid.Lehuta@ifremer.fr

Annex 2: Resolutions

The **ICES/EUROMARINE Workshop on Common Conceptual Mapping Methodologies** (WKCCMM), chaired by Debbi Pedreschi, Ireland, Maria Cristina Mangano (Italy) and Marcos Ilope (Spain) will be established and will meet in Galway, Ireland, 1 – 5 November, 2021 to:

a) Develop a common understanding across ICES working groups on conceptual mapping methodologies, their key uses and limitations, and processes for effective conceptual modelling with stakeholders. This will help to identify commonalities, differences and issues encountered, and standardize methodological approaches useful for a variety of applications (e.g. developing food-webs, socio-ecological modelling, rapid/initial management action and/ or impact evaluations). (Science Plan codes: 3.6, 6.1, 7.5)
b) Develop semi-standardized conceptual mapping approaches and guidelines that can be used by those interested in using conceptual mapping as a tool in a variety of contexts, including in ICES working groups involved in Integrated Ecosystem Assessment (IEA) (Science Plan codes: 6.3, 6.4).
c) Investigate how the methodologies can be best used to contribute to Ecosystem Overviews (e.g., via food-web and/or socio-ecological system modelling), Integrated Ecosystem Assessment, and to inform/underpin wider trade-off analyses relevant to ICES and the wider scientific community. (Science Plan codes: 2.2, 6.5, 6.6, 7.3, 7.4, 7.6)
d) Dissemination of workshop outputs to wider ICES and scientific community via online webinar and/or talk at the ICES annual Science Conference.

WKCCMM will report by December 17th, 2021 for the attention of SCICOM.

Supporting information

Priority	This workshop specifically addresses a rapidly developing area within ICES IEA groups, and as such has been proposed (and awarded EuroMarine funding) via a collaborative effort of six different ICES groups, including the outgoing and incoming IEASG Chairs, and a Chair of the SIHD. Multiple IEA groups are currently advancing conceptual mapping methodologies in support of IEA/EO work, and as a method to engage with stakeholders (see WKCONSERVE). A common understanding across groups would not only help to eliminate redundancy in effort, but ensure improved transparency and consistency between groups and between EOs in line with TAF. Finally, as a potential vehicle for advancing identification of regionally relevant social and economic aspects/indicators, and as a format for advancing food-web understanding, it is relevant to the priorities specified by WKEO3 and WKTRANSPARENT, to groups such as WGSOCIAL, WGCOMEDA and WGECON, and to progressing the SIHD.
Scientific justification	IEAs are a key tool enabling us to manage ocean complexity. Conceptual modelling facilitates and informs the scoping steps of IEA by identifying key drivers (economic, social, cultural, ecological) andpriorities of stakeholders, including policy-makers. Understanding priorities and perceptions is critical to identifying risks and opportunities for action to instigate lasting change and provide the evidencerequired to protect the ocean commons. Social science integration into marine ecosystem assessment has been flagged by EuroMarine, ICES, and at the UN Decade of Ocean Science preparatory meetings as a key research need. WKCCMM tackles this need by bringing together social and natural scientists for knowledge exchange and skills-sharing on conceptual mapping methodologies to inform IEA. WKCCMM builds on current and ongoing IEA work in ICES and NOAA, with scaleable methods capable of focusing on multiple human uses of marine systems. The cross-collaboration of ICES, NOAA and EuroMarine scientists and standardization of methodologies (adaptable to specific circumstances/needs) across IEA groups will benefit interested parties both within and beyond ICES.
Resource requirements	Funding has been secured via EuroMarine subject to acknowledgement of the funding in the Workshop report. This funding will cover the hosting of the workshop and attendance of key participants.
Participants	Expected participants include Chairs or nominated attendees from IEASG groups, EuroMarine Network attendees, others interested in conceptual mapping methodologies, to a maximum of 20 individuals
Secretariat facilities	Online meeting coordination (if online or hybrid required)
Financial	No financial implications.
Linkages to advisory committees	There are no obvious direct linkages with the advisory committees, although later outputs may be of interest.
Linkages to other committees or groups	Highly relevant to all IEASG groups and the SIHD.
Linkages to other organizations	Joint ICES/EuroMarine workshop.

Annex 3: Meeting Agenda

WKCCMM: Joint ICES/EUROMARINE Workshop on Common Conceptual Mapping Methodologies *to inform integrated socio-ecological system assessment*

1-5th November
14.00-18.00 CET
Chairs: Debbi Pedreschi & Marcos Llope

Agenda outline:

Monday	Tuesday	Wednesday	Thursday	Friday
14.00 CET	14.00 CET	14.00 CET	14.00 CET	14.00 CET
ToR A	ToR A/B	ToR B	ToR C/D	AOB
18.00CET	18.00CET	18.00CET	18.00CET	18.00CET

We plan to meet in plenary from 14.00 – 18.00 CET each day and would request that US/Canadian participants reserve (c. 2 hrs) afternoons and Europeans reserve (c. 2 hrs) mornings for intersessional work.

Monday 1st November:

14.00 CET Introductions

- Introductions, code of conduct, conflict of interest
- Participant introductions

ToR A: *Develop a common understanding on conceptual mapping methodologies, their key uses and limitations, and processes for effective conceptual modelling with stakeholders.*

14:20 CET Brief Overview of Conceptual Modeling

ToR A leads: Trish Clay, Jamie Tam, Sean Lucey

- Introduction to conceptual mapping and methodologies
- Usefulness – engage stakeholders / access other types of knowledge, etc.
- Overview of exercise

14:45 CET Breakout Groups

- 3 Breakout groups: Choose a system. Try to create a model.

- Group 1: Trish discussion lead, Jamie handles mental modeler
- Group 2: Debbi discussion lead, Sean handles mental modeler
- Group 3: Marcos discussion lead, Erik handles mental modeler

15:40 CET BREAK

16:00 CET Report out from Breakout Group Leads

- How did you begin? What was easy? What was hard? What surprised you? How did it go? (Present your mental model output and discuss)
  - Group 1
  - Group 2
  - Group 3

16:45 CET Additional Comments from Participants/Q&A/Group Discussion

- Where will you find your objectives?
- What expertises are you missing?
- Who are your stakeholders and how will you connect to them?
- How do the 3 models differ?
- Other comments/questions?

17:45 CET Prepping for Tomorrow

CLOSE 18.00 CET

(intersessional analysis of different models?)

Tuesday 2nd November:

14.00 Opening Remarks?

14: 10 CET Finalize ToR A, if needed OR Begin ToR B

ToR A: *Develop a common understanding on conceptual mapping methodologies, their key uses and limitations, and processes for effective conceptual modelling with stakeholders.*

ToR A leads: Trish Clay, Jamie Tam, Sean Lucey

- Continue from Day 1 if needed

ToR B: *Develop semi-standardized conceptual mapping approaches and guidelines that can be used by those interested in using conceptual mapping as a tool in a variety of contexts*

ToR B leads: Erik Olsen, Jamie Tam, Sean Lucey

1. Example applications within ICES and beyond (presentations may be split between Day 2 & 3 TBC). 15 min presentations + 5 min discussions
   - Fishing communities and offshore wind mental model – Angela Silva 15.00
   - WGINOSE food-webs and linking quantitative and qualitative models – Erik Olsen
   - WKIrish socio-ecological aspects - Debbi Pedreschi
   - Barents Sea (BarentsRisk) – Nina Mikkelsen
   - U.S. Mid-Atlantic summer flounder - Geret DePiper 16.30

- General discussion based on presentations (~1 hour)

CLOSE 18.00 CET

Wednesday 3rd November:

14.00 CET

ToR B: *Develop semi-standardized conceptual mapping approaches and guidelines that can be used by those interested in using conceptual mapping as a tool in a variety of contexts*

ToR B leads: Erik Olsen, Jamie Tam, Sean Lucey

- Where are guidelines (to do/not to do) more appropriate? Learn from experience / 'how to' get started guide….
    - Defining Objectives (iteratively)
    - e.g., use of strawman models….usefulness vs. influence…
- What aspects need (and are appropriate for) standardization?
    - Base discussion on models developed on day 1 and presentations on day 2
    - Aim for describing different options, benefits and drawbacks, different strategies to reach your goals (differing by ecosystem/region)
        - Developing clear objectives
        - Common model components
        - Documentation of nodes and connections

16:00 - 16:15 CET: Break

- Is there a standard method/tool that we recommend for adoption?
    - Discussion of tools available (presentations and then discussions)
        - Analytical approaches (e.g. QPRESS, Fuzzy Cognitive Mapping, Bayesian Belief Network) - Sean Lucey presents
        - Visualizations (e.g. CIRCLIZE, package, visNetwork package, GGally package) - Erik and Jamie presents

How do we deal with variations in representative stakeholders across IEA groups?

CLOSE 18.00 CET

Thursday 4th November:

14.00 CET

ToR C: *Investigate how the methodologies can be best used to contribute to Ecosystem Overviews (e.g., via food-web and/or socio-ecological system modelling), Integrated Ecosystem Assessment, and to inform/underpin wider trade-off analyses relevant to ICES and the wider scientific community*

ToR C lead: Debbi Pedreschi

- What are the Ecosystem Overviews?
- Details based on presentations on approaches and discussion from ToR A/B
- Is there a standard output that can be included in the EOs?
- Recap tools discussion
- If not, is there a workflow that can be established to pass information from (e.g.) IEA groups to other groups? WGSOCIAL, WGECON, WGBESEO, others?
- Can/should we use conceptual mapping/modelling where data do not allow a more quantitative assessment?

16.00 CET BREAK

16.15 CET

ToR D: *Dissemination of workshop outputs to wider ICES and scientific community via online webinar and/or talk at the ICES Annual Science Conference*

ToR D lead: Marcos Llope

- Propose outputs as appropriate depending on workshop outcomes and relevance to ASC 2022 sessions
- Paper discussion – topics? Team?

15.15 CET – Summary of progress on ToRs, report writing tasks, and wrap up.

CLOSE 18.00 CET

Friday 5th November:

14.00 CET

- Report writing
- Any other unfinished business

CLOSE 18.00 CET

Annex 4: Conceptual Modelling Guidelines

Key Messages

- Conceptual Modelling is not a one-stop solution: but a very useful and adaptable tool for the toolbox
- Question specification (the reason for doing the modelling exercise) is critical
- Documentation is essential
- Outcomes will vary depending on context, timing, stakeholders involved -- including their prior experiences.
- Conceptual models will never be fully standardized - their strength is in their adaptability to a particular case, context, or group. However, there are key lessons that we can share, and guidelines on best practices and workflows.
- There are elements that may be standardized across IEA groups to make models comparable (e.g., core focal components) - however this will require further discussion and elaboration (particularly the why).

Uses/Benefits

- Conceptual models are simplified models of reality - can be very simple or very complex, grounded in reality or theoretical - and either way can be useful.
- Can help to build relationships and understanding across disciplines and different knowledge levels and types
- Useful to get stakeholders involved, and contribute to building a common understanding
- Allow inclusion of aspects that are otherwise hard to capture/quantify (e.g., some social and economic dimensions)
- Facilitates inclusion of other types of knowledge, e.g. traditional (indigenous) ecological knowledge, local/fishers' ecological knowledge
- Very useful for scoping (especially in relation to IEA) to identify important focal components (species, human groups, activities, human wellbeing, socio-economic drivers, benefits, ecosystem services, etc.) that should be included in analyses
- Useful for gap analysis and delineating areas for future priority research
- Useful as a communication and interaction tool
- Relatively rapid and inexpensive
- Rapid stakeholder data collection (on focal elements) prevents stakeholder fatigue
- Do not rely on quantitative information
- Both quantitative as well as qualitative data can be included

Cons/Caveats

- Subjective: will change based on the expertise in the room, timing and current socio-economic circumstances
- Analyses can be time consuming depending on experience level and the complexity of the model
- Results hard to verify
- Hard (impossible?) to get confidence intervals because it is not quantitative

- Difficulties in the incorporation of time and space dimensions
- Potential for stakeholder fatigue

Best Practices

Stakeholders / engagement:

- Plan ahead!
- Working interdisciplinarily is essential to maximising the success of conceptual modelling exercises, and to analysing and interpreting their outputs.
- It is best to bring stakeholders in early where possible - surveys/questionnaires prior to the meeting can help engagement. Network analysis and power dynamics analyses of the surveys/questionnaires can be useful to inform next steps and approaches.
- Engagement should be iterative, while cognisant of the need to avoid stakeholder fatigue.
- When you think you have enough time, **ADD MORE**. It is better to overestimate and let people leave early than to underestimate and not finish. However, meetings should still remain a manageable length (which will vary depending on the stakeholders involved) to avoid stakeholder fatigue, restrict the complexity, and maximise participation. For example, fishers' representatives may prefer a single day or half day meeting, but for individual fishers, it may be better to have two separate, shorter meetings so they don't have to give up a full day of fishing.
- Facilitation and engagement is a skill, and best done with those who have experience and training in such social science methods. In general, remember to facilitate, don't participate. Ask questions, seek elaboration. Allow the stakeholders to drive the process, but support where needed through questioning, and re-focusing if discussion gets too off track (away from the meetings goals).
- Ensure key terms are understood, provide definitions if needed.
- It is useful to have a team of at least four for stakeholder meetings:
    - one to chair the session,
    - one to build the model, but
    - others to help to capture side conversations (live meetings), and monitor chat (online meetings), and
    - someone to carry out the documentation of decisions. Additional support may be needed if carrying out breakout groups.
- Consider the use of 'participant observers', e.g., to note group dynamics. This can be particularly valuable when conflicting stakeholders are participating together.
- Strawdogs and objective setting (see below) can help to identify the expertise/stakeholders that are needed. Mental Modeling can be highly biased by those present in the room, so if you need to cover multiple disciplines / sectors / issues, it is important that there are representatives of each element.
- In some cases there is known conflict between stakeholder groups. In such cases it is recommended that separate meetings are held: 1) to ensure a productive meeting, and 2) because this can provide very useful insight into the different understandings and perceptions between user groups/stakeholders. These models can then be compared and contrasted, or combined (perhaps hierarchically) to identify commonalities and differences.

- Separate user/stakeholder groups may also be chosen as the preferred approach in order to provide these insights, and or, maintain meetings at manageable size. However, consideration should be given to whether consensus is required. And if this will require separate groups initially, but an all-stakeholder group later, or combined groups from the beginning.
- Separate user group/stakeholder groups have proven to help build trust and enhance freedom to speak, for instance, if participants belong to the same sector (a private company or NGO).
- In cases of conflict, it is particularly important to consider power dynamic issues which may arise.
- Another option is to split the participants into break out groups and rotate them through the various models (e.g., if working with different model types: social, economic, ecological, environmental, etc.). This gives all participants a chance to contribute to each element - but may be time consuming to try to explain the work that has been done before to each new group that arrives.
- A complex network can be reached pretty rapidly. Assigning directionality and strength to the linkages takes more time and thought (and documentation), so may need a separate meeting.
- Using a 'Parking Lot' of some sort for issues that arise that are tangential to the main focus of the exercise can be extremely useful and help to note points that may be useful to revisit in future, while keeping focus and attention on the task at hand.
- When carrying out meetings online (or hybrid), consideration of which tools to use is critical. Tools such as Google Jamboard or Miro have been successfully used to help capture contributions. Online meeting platforms offer different features, with some allowing side discussions or polls. Consideration should be given to which tool best suits your needs. Provide as many avenues for contributions as possible (discussion time, chat comments, collaborative note taking documents, file sharing, etc.). Consider stakeholder experience, keeping tools simple, and if planning a series of workshops, keep to the same tools and platforms.
- For online and hybrid meetings, ensure you try to accommodate as many time zones as possible (if relevant). This may require more but shorter meetings.
- Whether carrying out meetings online or in person, be sure to plan for breaks and downtime.
- Be sure to report back to the stakeholders with final outputs, an explanation of the process and any revisions or updates that have occurred since the meeting(s).
- Anonymity in reporting can be useful as it makes participants more comfortable. This can clash with transparency, but a good balance may be to report on the stakeholder types and roles rather than identifying participants, business companies, or agencies by name in follow-up documents.

Using Strawdogs:

- Pro's and con's and dependent on needs. Need to be aware that strawdogs bias outputs and may limit creativity. This may be an acceptable trade-off when a specific question/issue is in mind. In this case strawdogs can be used to direct and focus efforts.
- For the work considered here (e.g. in IEA) it was considered generally best not to go to stakeholders with a blank slate. Having a starting point helps to build understanding of what they are being asked to do, and how the tool works. Giving stakeholders something to react to can help to get the conversation started, and speed up the process.

- The use of registration forms when inviting/registering stakeholders can provide an opportunity to ask a few key questions which can be useful to gather further details in order to gain a better understanding of the stakeholder perspectives and knowledge of your participants, and to inform the production of a first strawdog model.
- If a strawdog is used, it is important to specify what objectives/questions have led to this initial model. Similarly, important contextual elements such as the spatial and temporal scales under consideration should be specified.
- In the ICES context, the top sectors and pressures identified for the ecosystem overviews may provide a starting point for discussion.
- In other contexts, simplified initial food-web models have been used, that are based on existing models (e.g., Ecopath) and can provide a starting point and/or cross-validation.
- Another option is to provide the broad categories that you want the group to discuss, and allow them to propose the details (e.g. Sectors, Activities, Drivers (pressures), Ecosystem Components, Ecosystem Services).

Objectives:

- Can be specified from policy or by stakeholders. We recommend using both (a nested approach, if possible, is desirable).
    - Stakeholders can identify regionally/locally relevant priority issues
    - A knowledge of the policy elements relevant to the region and issues identified by stakeholders is necessary to understand context and any potentially conflicting objectives that will need to be taken into account when conducting a Management Strategy Evaluation (MSE)
- Objectives can be to optimize or maximise certain elements, or maintain them at or between certain levels. Objectives may also be descriptive/investigative, aiming to gain a better understanding of the system or the linkages within the system. However, no matter the goals, it is important to specify these at the outset to ensure common understanding.
- Objectives may be pre-defined (based on need, e.g., of the project/reason for carrying out the exercise).
- Consideration should be given to the time period and area under consideration (phenological questions, regime shifts, historical events, policy changes, conservation areas (MPAs, temporal closures, permanent reserves, etc.), and the ecological scale (single species vs. multi species vs. ecosystem-level questions).

Documentation:

- It is essential to document as much as possible. Include data, references, where they are available. However, documentation may also consist of simply documenting the decision at the time: e.g. why a line was drawn, or given a certain weight. This is essential for understanding why the model looks as it does when you revisit at a later time/date. This can all be as simple as creating a spreadsheet and keeping it updated.
- Also important to document is when explicit choices are made NOT to include something, or to go to finer detail (and why).
- It is important that key contextual elements such as the spatial and temporal scales and objectives/questions under consideration are also explicitly documented.

- Documentation should not be used to weight or score the linkages in any way. Doing this biases the network towards only the elements for which we have data available. This is not the goal of the modelling exercise, and will be accounted for in later stages of the IEA process that use more quantitative approaches. However, uncertainty about information should be recorded in the documentation.

Proposed Workflow (imagine as a loop)

- ➢ Choose modelling objective: What is the reason for the modelling?
- ➢ Build strawdog: develop initial model boundaries/objectives/goals/questions
- ➢ Identify and engage stakeholders based on the strawdog (see engagement guidelines)
- ➢ Further elaborate model boundaries or objectives (policy/jurisdictional needs/specific questions from stakeholders)
- ➢ Conduct iterative model building (creating submodels/ joining models) -> analytics (Mental Modelling (MM)vs.Qualitative Network Models (QNM)vs.Bayesian Belief Networks (BBN), etc).
- ➢ Verification: Do model outcomes make sense? Can they be compared to quantitative models or a model ensemble? If the outcomes don't make sense, can the model be improved?
- ➢ Visualization options (see Table 2)
- ➢ Potential management advice (risk assessment, refining uncertainty, communication, transition to MSE)
- ➢ Evaluate success: Were objectives met? How can new iterations of the model be improved?
    - **REPEAT!**

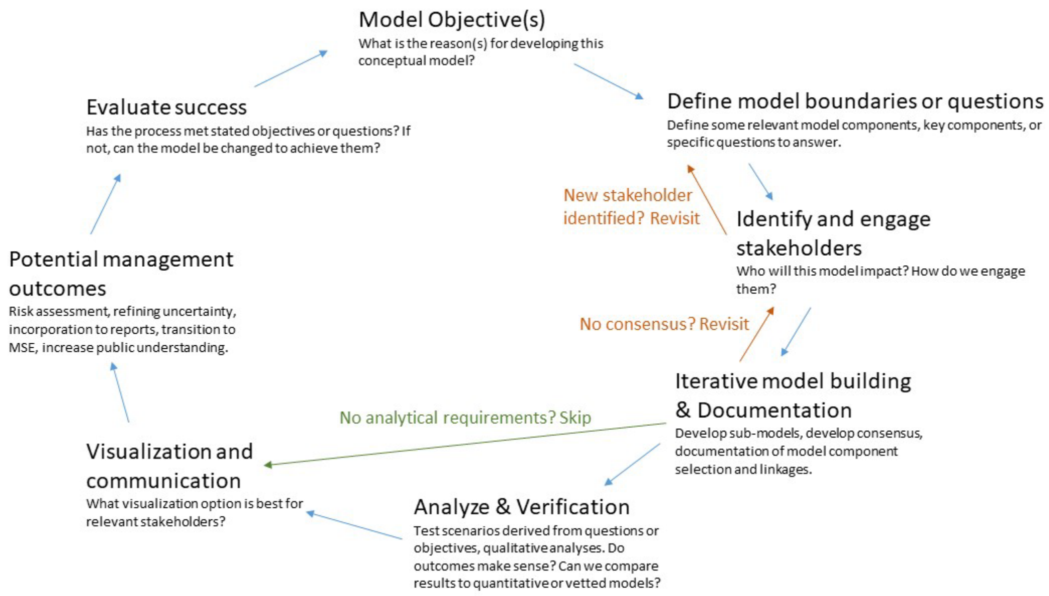


Figure A. Illustration of the proposed Conceptual Modelling workflow

Process

- Consider if there is information you can gain prior to the meeting through a questionnaire. This may inform your production of your strawdog model.
- First drafts are often whiteboards, flipcharts, sticky notes, etc.
- Models may evolve linearly (horizontal or vertical directional graphs), or as a web/complex network.
- It is easy to get complex very quickly. Facilitators must attempt to keep things manageable. Throughout the process the model may expand and contract as certain elements are identified as less important, collapsed into simpler categorizations, broken out into subgroups, etc.
- After identifying the key focal components, discussions should focus on the strength (where possible) and directionality of the linkages. This step often takes substantially longer than the initial component identification step.
- Time should be dedicated after the meeting for cross-checking and sensibility-checking the outcomes. Are there any links that were discussed but missed? Are there linkages that don't make sense? Does the model react to major changes as you would expect? If not, why not?
- Multiple approaches for hierarchical structuring exist: regional, sub-model types (ecological, economic, social, etc.). This can be a very useful way to capture the depth of knowledge and complexity, but manage key outputs and high-level messaging. Kumu (Table 1) provides options for indicating how many participants found specific linkages to be important.
- Network Analyses can be informative providing metrics on the importance/influence of individual components of the model.
- Consider perturbation analyses to study/test/understand the strength and behaviour of linkages