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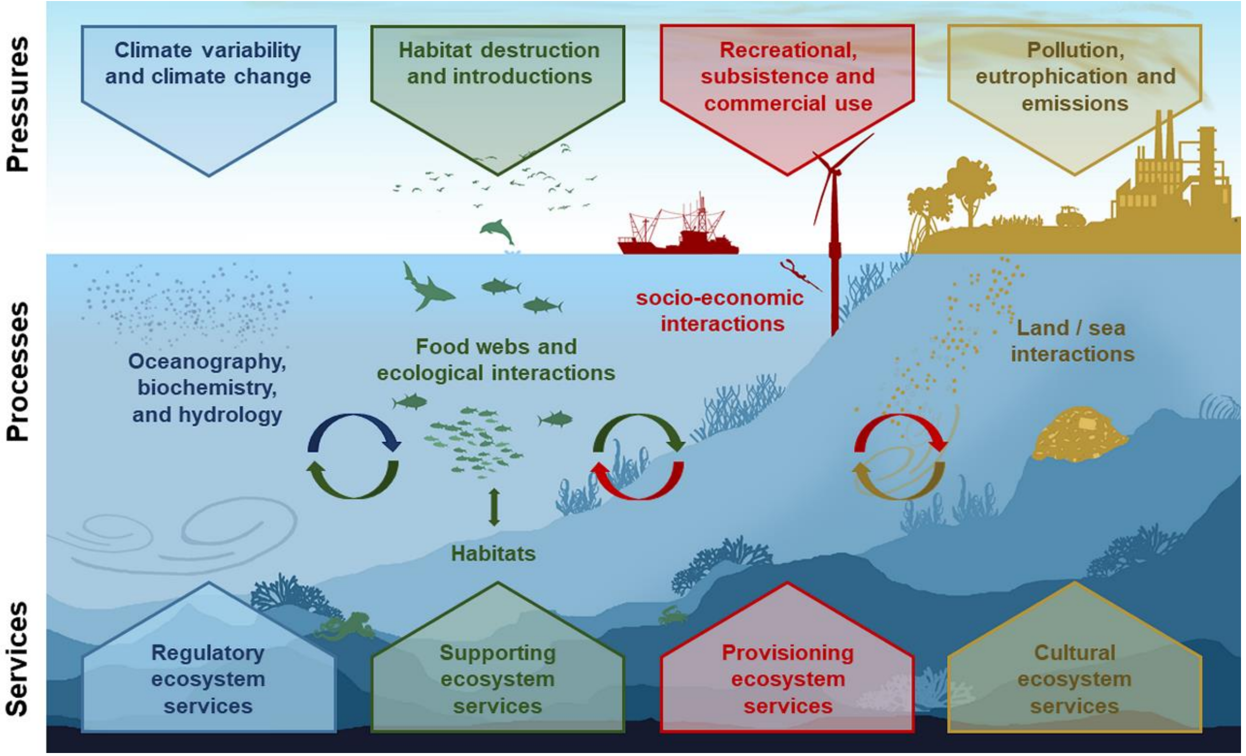
Ecosystem modelling for the Ocean Decade: facing the (technical) challenges

MEMs

- Mechanistic mathematical models ("process models")
- Address the dynamics of marine life over time and space
- Incorporate human activities and environmental change
- Hindcasting – why and how?
- Forecasting – what if?
- Built to address specific research questions

Complex:

- Non-linear processes, feedbacks
- Temporal and spatial scales differ by orders of magnitude



Declaration of UN Ocean Decade

Unique opportunity and incentive for ocean sciences:

i. Make models available to decision-making arenas
ii. Communicate meaningfully
iii. Co-create marine science
iv. Make modelling more robust

Borja et el. 2020; Fulton et al. 2015; Hyder et al. 2015; Lotze et al. 2019; Peck et al. 2018; Pethybridge et al. 2019; Heymans et al. 2020

Aim, research questions, objectives and manuscripts

Overarching aim

Obtain a better understanding of the limitations that prevent the uptake of MEMs in management and policy, and offer technical solutions to address these limitations to smooth the path for wider MEM uptake

Question 1 – Can ecosystem modelling be made better?

Objective 1 – To identity why MEMs aren't systematically validated and calibrated; propose a possible solution

Manuscript 1 – Steenbeek et al. 2021, *Environmental Modelling & Software Q1*

Objective 2 – To build a prototype software for Objective 1 and apply it

Manuscript 2 – In prep, *Ecological Modelling, Q2*

Question 2 – Can ecosystem modelling be made more accessible to policy makers and ocean managers?

Objective 3 – To integrate a live MEM into a Decision Support Tool (DST)

Manuscript 3 – Steenbeek et al. 2020, *Ecology and Society, Q1*

Question 3 – Can MEMs bridge disciplines to communicate meaningfully to other audiences?

Objective 4 – To use new media to meaningfully communicate MEM output to non-scientific audiences

Manuscript 4 – Steenbeek et al. 2021, *Frontiers in Marine Science, Q1*

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Question 1 - Can ecosystem modelling be made better?

Objective 1 – To determine why MEMs aren't systematically validated and calibrated

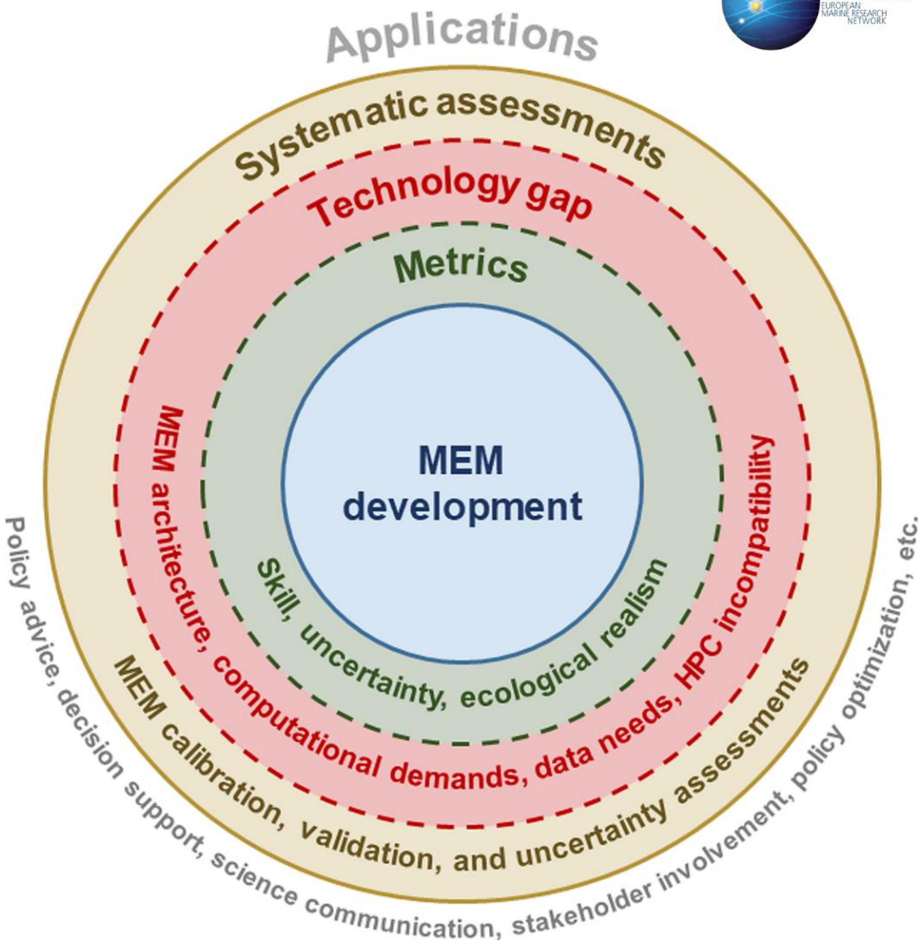
Barcelona 2019: EuroMarine foresight workshop

Review of:

- State-of-the-art in MEM and ESM validation and calibration
- Skill metrics, uncertainty assessments, ecological indicators
- Ecological realism assessments and emergent properties
- Ensemble modelling

MEM key findings:

- Science into metrics abounds, systematic assessments rarely done
- Lack of data is often cited, technical limitations are the real bottleneck
- MEM capacity is unevenly distributed around the globe
- ESM techniques do not translate to MEM non-linearity
- High-Performance Computing (HPC) is not necessarily a solution
- **The global MEM community needs a framework to systematically run and assess the heaviest of MEMs on the most minimal architectures, with minimal reliance on funding, IT expertise, and HPC access**



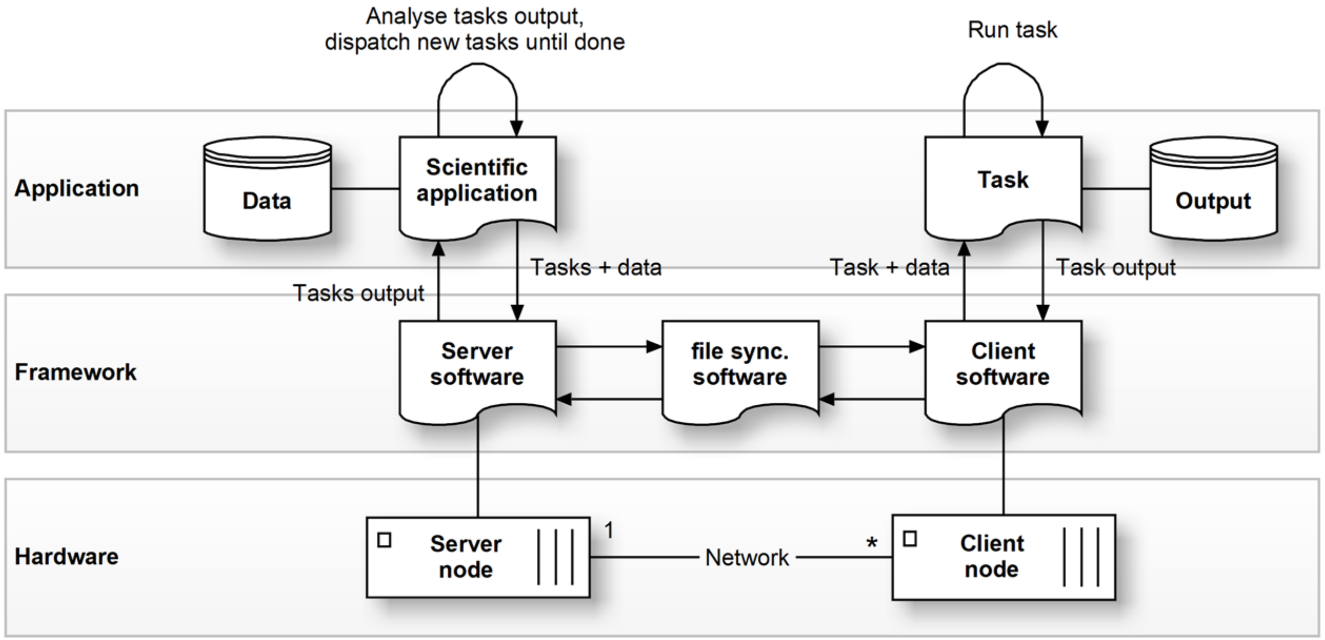
Coll & Steenbeek 2017; Hipsey et al. 2020; Link 2011; Olsen et al. 2016; Pantus 2009; Payne et al. 2016; Skogen et al. 2021; Stow et al. 2009; Spence et al. 2021

Question 1 - Can ecosystem modelling be made better?

Objective 2 – To build a prototype framework and apply it

Objective 2 – Build framework prototype

- Adhere to specifications from Objective 1
- Cross-OS programming languages (.NET Core, Python)
- Cross-OS statistical tools (R, etc.)
- File-based, low-tech communication (Dropbox, OneDrive, Sync, Box, etc.)



Objective 2 – Apply framework prototype

- Systematically assess a MEM to find the best fitting model structure, and understand why this works best
- Use two contrasting ESMs with two contrasting Shared Socioeconomic Pathway (SSP) scenarios

Coll et al. 2020; Steenbeek et al. 2016

Question 2 - Can ecosystem modelling be made more accessible?

Objective 3 – To integrate a live MEM into a Decision Support Tool (DST)

- Most DSTs optimize policy to status quo, but are unable to forecast future
- MEMs have the needed capabilities, but have never been integrated in a DST

Objective 3 – Maritime Spatial Planning (MSP) Challenge Simulation platform

- A serious game where player groups design, negotiate, and approve spatial plans for a shared marine space
- Stakeholder engagement, planning through co-design, learning, education
- Information discovery, conflict resolution
- Plans cover a wide range of human activities in space and time
- Part computerized, part social
- Has simulation models for energy and shipping; ecological impacts desired

Abspoel et al. 2020; Christensen et al. 2014; Duke 1974; Katsanevakis et al. 2011; Mayer et al 2013; Keijser et al 2018; Steenbeek et al. 2020; www.mspchallenge.info

Question 2 - Can ecosystem modelling be made more accessible?

Objective 3 – Implementation

Planning phases alternate with simulation phases

During simulation phase, spatial plans gradually come into effect

Spatial plans have effects:

Surface, bottom disturbance	*niche model*
Noise	*niche model*
Artificial substrate	*habitat affinities*
Fishing closures	*protected areas*

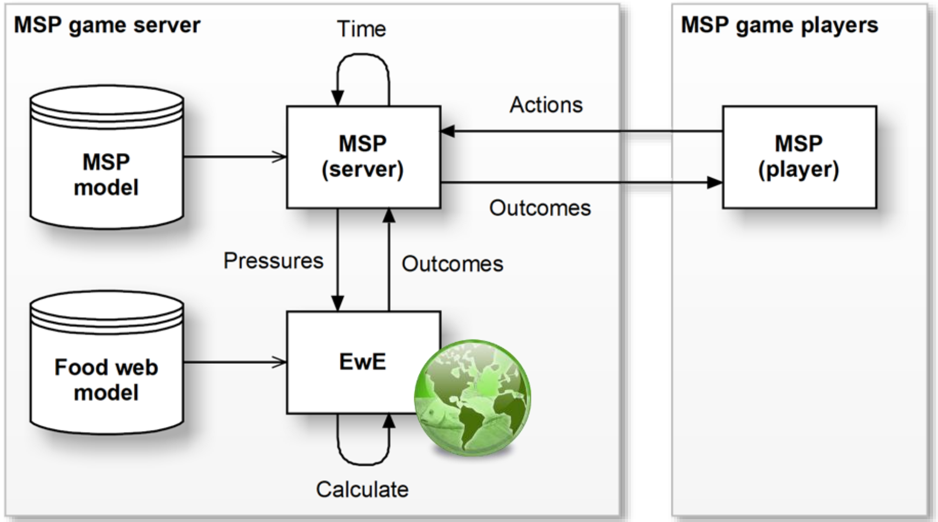
Objective 3 – Important lessons

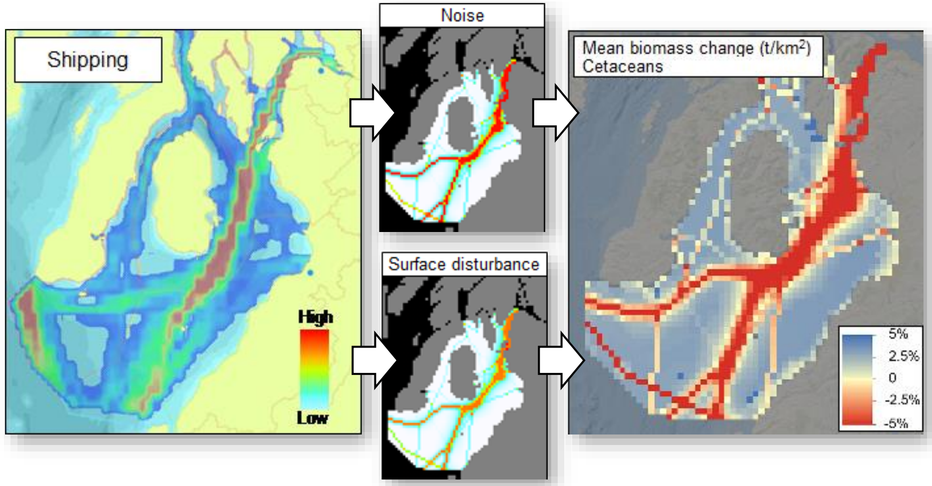
- Response has been overwhelmingly positive across audiences
- Ecological feedback is received as an "eye opener"
- Trade-offs: realism vs. performance; process vs. details
- Blueprint for other DSTs

Objective 3 – Future work

Add climate change, currents; increase realism; improve fisheries; etc.

Ecoscope EU H2020 project (2021-2025): offline runs that include comprehensive uncertainty assessments via framework (!)





Steenbeek et al. 2020

Question 3 - Can MEMs be used to communicate across disciplines?

Objective 4 – To use new media to meaningfully communicate MEM output

Challenges for scientists

Integrate MEMs in decision making processes (not the other way around)

Rephrase MEM output to decision making contexts (not the other way around)

Provide only needed information, not too little, and certainly not too much

OceanViz concept

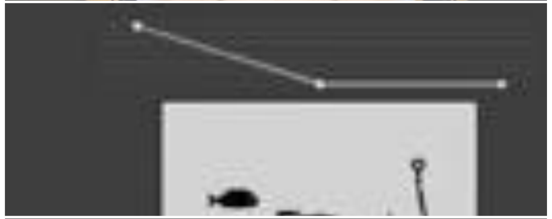
Multi-media platform for group-based exploration of plausible fisheries management options

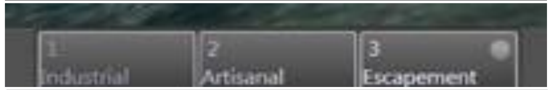
OceanViz features

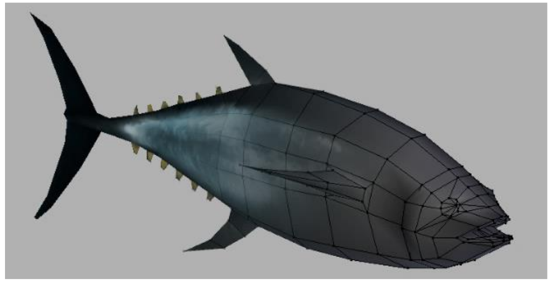
Transparently operate a marine ecosystem model

Data visualization techniques:

- Data hierarchical organization (first glance > system-wide > details)
- Performance indicators
- Ecological indicators
- Management thresholds + traffic lights
- 3D immersions (virtual field trips)







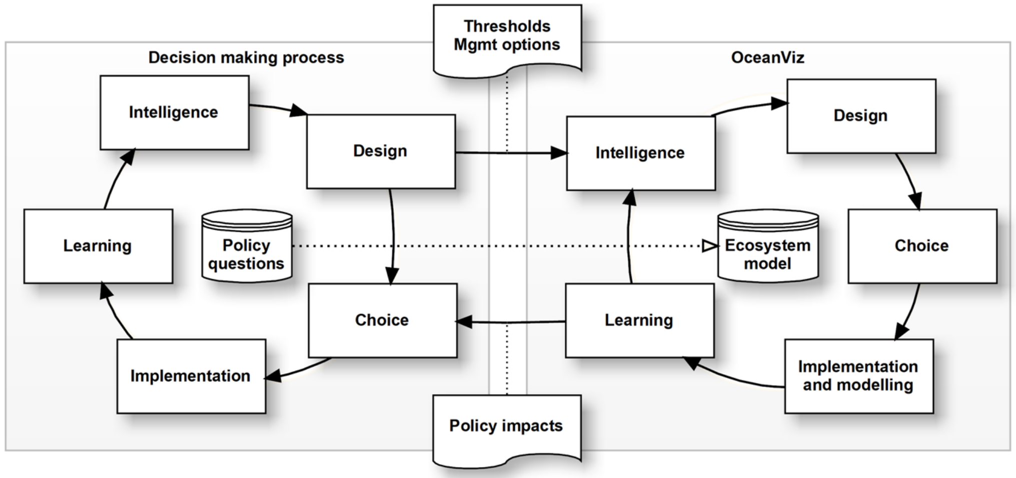
Alexander et al. 2019; Christensen & Lay 2011; Heymans et al. 2020; Kelleher & Wagener, 2011; Steenbeek et al. 2021; Walling & Vaneeckhaute, 2020; Walters 1986; Wang et al. 2019

Question 3 - Can MEMs be used to communicate across disciplines?

Objective 4 – To use new media to meaningfully communicate MEM output

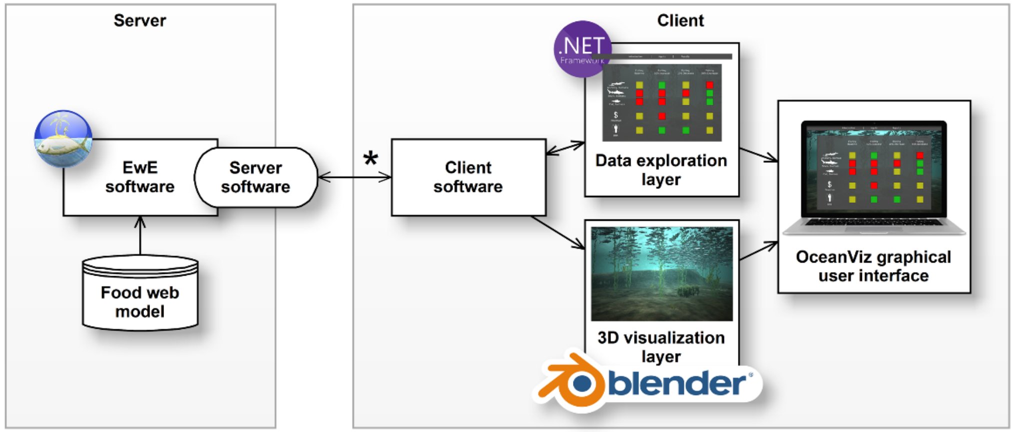
Implementation

- OceanViz: MEM, client/server, and visualizations
- Complement decision-making processes, fast-track learning
- Central operation of a MEM in function of policy exploration
- Central discussion of policy objectives
- Science co-creation: model, historical period, and management thresholds are defined pre-summit
- Focus on forecasting / "what if" style exploration



Important lessons

- Non-scientific MEM operation and interpretation is possible
- Overwhelming positive responses to 3D visualizations
- 3D visualizations have a great general utility
- Traffic light system preferred over detailed data
- Every research question is unique
- Science co-creation can be costly and time consuming
- Management discussions are political discussions



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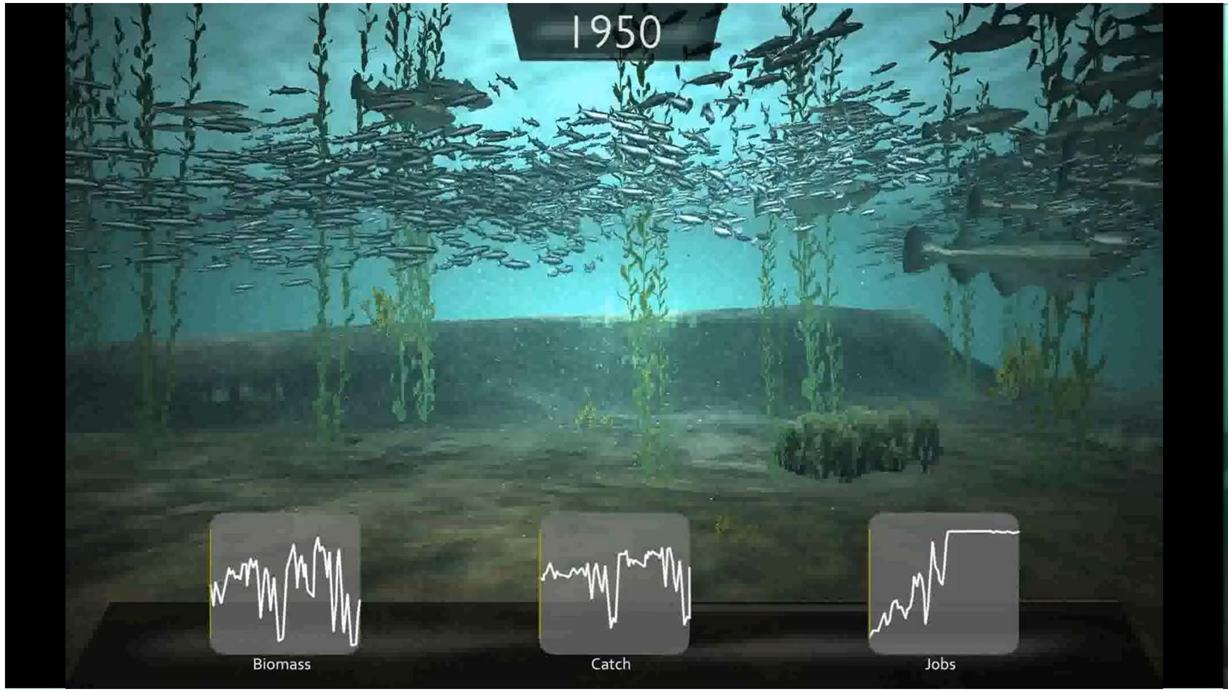
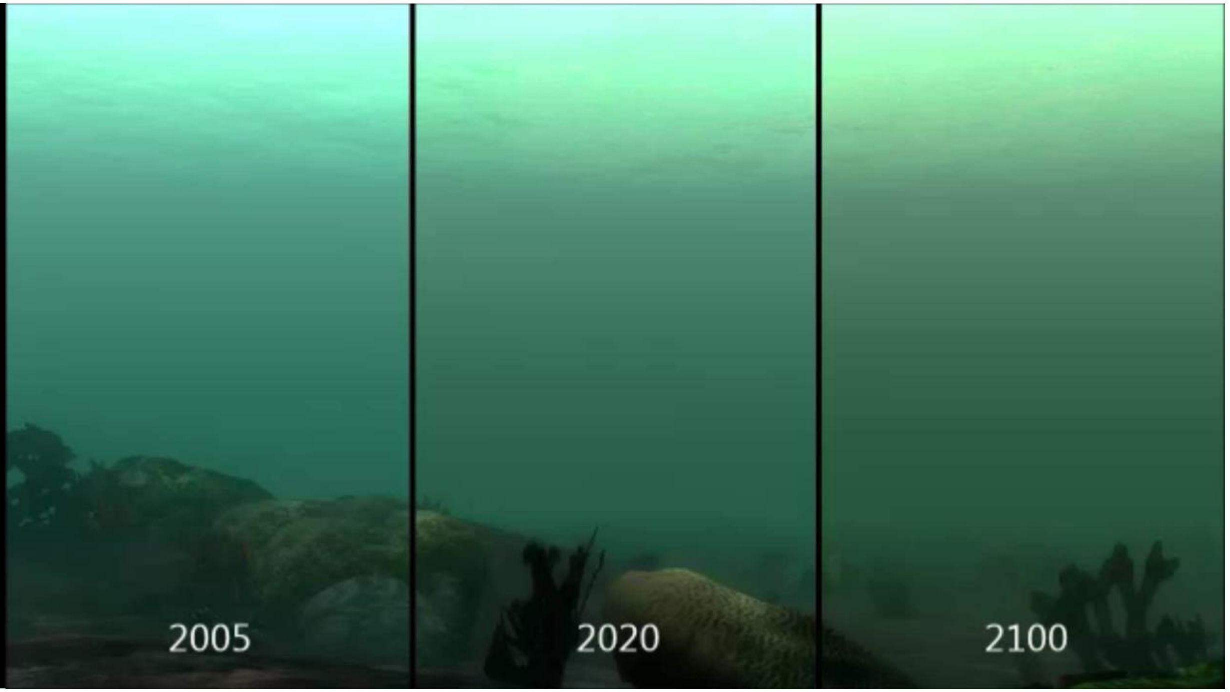
Q3 - Can MEMs be used to communicate across disciplines?

O3.1 – To use new media to meaningfully communicate MEM output

Experiences in visualizing change: OceanViz evolution



First versions: progressive animations



Later versions: time slice panels

Steenbeek et al. 2021