Food web and ecosystem models.
Can we mechanistically link the forecasts to be JUST ahead of the game i.e. how food webs may change location in the future and how that might affect fisheries resources and stocks?

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Some examples in the literature

CHEUNG, W. et al. (2010), Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology, 16: 24–35. doi: 10.1111/j.1365-2486.2009.01995.x


Nucella lapillus, Gastropod

Can we mechanistically link the forecasts to be JUST ahead of the game i.e. how food webs may change location in the future and how that might affect fisheries resources and stocks?

A big challenge:
- Fisheries are the ultimate integration of ecosystem function.
- Drivers + multiple interactions and feedbacks between system components that determine productivity etc.
- As we move up the foodweb, the implications of change become less clear, errors are magnified.
- Decade of emerging complexity in response to OA/Climate.

But:
- Synthesis of response across groups/classes is emerging (e.g. Kroeker papers).
- Models are developing some of the required complexity.

So:
- Currently we have partial mechanistic approaches and can play “what ifs” with models, identify envelope of possibilities and explore feedback mechanisms.
- There is a real possibility of making a step change in the next 5-10 years.
Natural analogues and release experiments show that ecological, life-cycle and to some extent behavioural responses are as important as physiology.

Altered competition for limiting resources, change in predation pressure, ability to shift location.

Further suggests the need for some model representation of ecosystem structure / biodiversity, as well as detailed life cycle models for HTL’s.

Requires spatial resolution and realistic environmental representation.

“Ocean acidification effects on the foodweb are mediated by predator/prey response”
Experiments focusing on physiological responses have revealed significant variability between species, within and between classes and dependency on resource.

Can a functional group approach effectively capture the response to OA/CC? How to parameterise that functional group
Or do we need more biodiversity in models

Can resource be adequately represented by biomass, or do we need variable stoichiometry to represent food quality?
Should we make optimal allocation models or DEB approaches standard?
Adaptation of a globally important coccolithophore to ocean warming and acidification

“Contrary to expectations, there were no apparent antagonistic effects when selecting for ocean acidification and high temperature simultaneously in the world’s most abundant calcifying organism, *Emiliania huxleyi*.”

Schluter et al., Nature Climate Change, 2014 doi:10.1038/nclimate2379
Organisms respond to local conditions, which are determined by a complex interaction of climate, acidification, weather, hydrodynamics, terrestrial factors. Large spatial heterogeneity.

Regional heterogeneity in impacts: Projected Aragonite saturation, (A1B)

2097-2099, daily

2080-2100, monthly

Requires well characterised drivers. Future riverine inputs???
Model skill is limited, spatial and temporally, and is partially a function of resolution, complexity and forcing detail.

Biggest determinant of difference between present and next few years is “weather” + meso-scale oscillations (NAO) - unless tipping points. These are very hard to predict, although projections are possible. Implications for management planning.
• Each of the challenges is a potential game changer.
• Combination of pressures results in emergent, non linear properties which are not statistically predictable.
• A end-to-end mechanistic link requires a consideration of a huge amount of complexity – not currently possible.

Just an example:

Primary production
Considering only climate and OA: ERSEM Modelling suggests a number of secondary effects and emergent properties
Unfortunately little data exists with which to evaluate many of these
Very difficult to judge these in the context of natural variability

Computational resource

Feedbacks and interactions are key to forecasting, hence models need to include sufficient complexity. Reasonably complex models take some months to run a forecast scenario.

Multiple scenarios coupled with requirements for sensitivity analysis of response parameterisations determines that resources remains limiting.

In the UK national HPC facilities are developing, but the number of users is growing faster.
Language, programme construction, short-termism

There are language and conceptual barriers between modellers and experimentalists, even within the same discipline (Queiros et al, 2014).

Programmes, whilst attempting better model – expt. integration haven't yet achieved it.

• What can be done now
• What we can already do on current resources?

  • Global mean field carbonate/biochemistry forecasts are fit for purpose
  • Small number of regions with relatively advanced modelling capability, reasonable model toolkit.
  • Currently one-way coupling of biogeochemical / LTL models to HTL / Socio models, provides projection capability.
  • Need to build in complexity and feedbacks, testing consistency of projections.

  • At least in the UK OA specific funding has essentially dried up

  e.g. ERSEM  divERSEM  GCOMS  Atlantis
Forward look

• What is feasible over the next 5 -10 years?
• What do we ideally need to do?

• Reasonably good match between what is feasible and what is needed
• Everywhere with a socio-economic or ecological value is vulnerable
• Use regions with advanced capability as trail-blazers (step 2-3)
• Use this experience to develop capacity in other regions (step 1)
• Develop as a minimum a global-coastal modelling capacity with LTL to make first order assessments of vulnerability within regions and provide a baseline modelling capability.
• Challenge to nail response synthesis in a modelling accessible framework, in the short term.
• Better links with climate/terrestrial community to give comprehensive scenario development. Constrain the sensitivity question.
• Improve model linkage (off and online) and intercomparison. Extend mechanistically towards HTL, embed aquaculture models etc.
Forward look

• Observational challenges

Data plus synthesis and understanding of that data

What Observations:
- DIC / Alkalinity / pH / pCO2.
- P-R, productivity, community structure, phenology
- Organic matter transfer, stoichiometry, lability
- Carbonate content, dissolution and calcification rates.
- Anaerobic diagenesis and redox chemistry
- Bioturbation rates.
- Nutrient exchange

Potential interaction with Carbon Capture and Storage monitoring

Observational Strategy
- Constrain natural spatial / temporal variability in the system. Transects and high resolution.
- Need to record co-drivers of carbonate chemistry
• What additional resources are needed to fund the ideal plan? and
• What new capacity is needed in the community to be able to do it?

• Expertise is relatively sufficient, although recruiting good modellers is sometimes difficult. Training issue.

• Long-term funding (inc. computational resource) and restructuring of programmes is key.

• International collaboration and coordination.
Thank you
Consideration of the micro climate at the cell/organism membrane level may be important.

“pH and carbonate chemistry at the exterior surface of marine organisms deviates increasingly from those of the bulk sea water as organism metabolic activity and size increases. These deviations will increase in the future as the buffering capacity of sea water decreases and as metabolic activity increases with raised temperatures: the carbonate chemistry experienced by most planktonic organisms will probably be considerably different from that measured in bulk-seawater samples”

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Modelling Strategy
- Archived data/projections for atmospheric, terrestrial and other forcings.
- Also for LTL projections
- Models with coherent interfaces

Impact synthesis
- Physiological & ecological response, fundamental rates and emergent properties e.g. stoichiometry
- What are the minimum number of functional groups?
- For each FG, what is the parameterisation range – e.g. sensitivity analysis
- Can we manage sensitivity analysis by developing coherent scenarios?