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Report of the ICES/PICES Workshop on Economic Modelling of the Effects of Climate Change on Fish and Fisheries (WKeconSICCME)

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Executive summary

The ICES/PICES Workshop on Economic Modelling of the Effects of Climate Change on Fish and Fisheries (WKeconSICCME) was convened on 3–4 June 2016 in Brest, France. The workshop arose out of the August 2015 of the Structural Initiative on the Effects of Climate Change on the Marine Environment (SICCME) workshop and an awareness of the need to develop economic and social pathways to include in different efforts to model the impacts of climate change on fish and fisheries. The workshop was chaired by Alan Haynie (USA), Sophie Gourguet (France), John Pinnegar (UK), Lisa Pfeiffer (USA), and Jörn Schmidt (Germany) and followed the 'Understanding marine socio-ecological systems' symposium (MSEAS) which was held the previous week in Brest. Associating this workshop with MSEAS significantly reduced its cost, as virtually all participants attended the MSEAS meeting earlier in the week. The workshop was funded by NOAA and hosted by IFREMER.

Approximately 35 people from a broad group of ICES, PICES, and other nations participated in the workshop. The workshop included a balanced group of biologists, economists, and other social scientists with members having a wide variety of experiences in interdisciplinary projects and in contributing to fisheries and marine resource management in North America, Europe, and elsewhere.

As articulated in the terms of reference for the workshop, the workshop was held primarily to address the following three goals: a) identify the socioeconomic data and features of a suite of representative future fishing and ecosystem scenarios that could be employed for use in evaluating climate change effects on fish and fisheries; b) identify how fisheries management policies will interact with climate change and identify how researchers can best evaluate what management tools are most likely to be resilient to climate change effects on fisheries; and c) identify suites of bio-economic and spatially explicit models of fishery behaviour that can be used to project the implications of different climate models on commercially important marine fish stocks in the northern hemisphere.

Workshop participants addressed these and a variety of related questions. The workshop was a success and identified the means for ongoing collaboration, common assumptions that can be made across projects, and the need for additional research on the further development of common scenarios. Individual integrated modelling projects have made great progress developing socioeconomic scenarios which will be compared, refined, and further coordinated in 2017. We expect that collaborations from this workshop will result in several peer-reviewed publications and addition international collaboration in coming years.

1 Introduction

As articulated in the terms of reference (ToRs), the primary intent of the workshop was to address the following three goals:

a) identify the socioeconomic data and features of the suite of representative future fishing and ecosystem scenarios identified in the August 2015 intersessional that could be employed for use in evaluating climate change effects on fish and fisheries;

b) identify how fisheries management policies will interact with climate change and identify how researchers can best evaluate what management tools are most likely to be resilient to climate change effects on fisheries;

c) identify suites of bio-economic and spatially explicit models of fishery behaviour that can be used to project the implications different climate models on commercially important marine fish stocks in the northern hemisphere.

The primary geographic focus of the meeting was the ICES/PICES countries, but considerable concern was raised during the workshop about the importance of research exploring linkages between climate change and fisheries health in developing and Southern Hemisphere countries.

Prior to the workshop, participants were surveyed to identify their participation in related projects, interest in collaboration, and vision of future integration and cooperation. This provided participants with a common understanding of the purpose of the meeting, gathered a body of relevant papers for participants to read, and made clear that the large number of different issues could potentially be addressed in this and subsequent related workshops.

The 1.5 days of the workshop were divided among quick background talks on projects (approximately ten 5-minute talks plus discussion), breakout sessions (participants were typically in 3 groups), and discussions of breakout session outcomes with the entire group. Please see Appendix 2 for the agenda.

2 Key findings

A core finding of the workshop is that there is a lot of work yet to be done and it will be challenging to reach a consensus on small number of socioeconomic scenarios. Because of the large number of variables that are part of a complete socioeconomic scenario, there are many choices to be made and there is a limited understanding or consensus on the long-term implications of some of the possible decisions. While the nature of scenarios is such that not all questions will be answered, the group found limiting the number of variables to be very challenging given the diverse focuses of different stakeholders.

After participant introductions when the workshop began on Friday, the group received short presentations on a set of projects that apply different approaches to scenario development and utilize scenarios in different ways. The remainder of the workshop was then spent primarily examining the three primary ToRs of the workshop.

Here we sequentially present summary findings that correspond to those three ToRs.

a) identify the socioeconomic data and features of the suite of representative future fishing and ecosystem scenarios identified in the August 2015 intersessional that could be employed for use in evaluating climate change effects on fish and fisheries;

The August 2015 WKSICCME workshop held in Seattle concluded that given the many factors operating across ecosystems, agreeing on common biological models was less important (and more difficult) than agreeing on common emissions scenarios. That meeting concluded that it was important to consider different types of management measures, but left the question of specific measures for future investigation. This Brest Economics Workshop further addressed this topic and in a similar manner concluded that we were not at a point to identify a small number of corresponding common socioeconomic scenarios.

To address this ToR, participants divided into breakout groups and discussed the nature of socioeconomic scenarios for a fishery. We considered the following questions:

1) How do we define the scenarios?

2) What are the implications of selecting certain factors?

3) What are the feedback mechanisms that need to be considered in economic scenarios?

How do we define the scenarios?

Socioeconomic scenarios are developed to provide a finite number of options that give bounds for understanding what may occur under different climate change scenarios.

In defining scenarios, a range of relevant factors were considered, such as biophysical characteristics of the management system, the fishery cost structure, fishery vessel and processor characteristics, compliance, income, jobs, livelihoods, food security, sociocultural drivers, governance, fishery access and effort control, technology, value chains, supply chains, equity, and the economic distribution of marine resource benefits.

The group discussed the existing IPCC socioeconomic scenarios, beginning with SRES Scenarios and connecting to RCPs and the Shared Socioeconomic Pathways (SSPs) in the IPCC. John Pinnegar identified a paper, van Vuuren & Carter 2014, which nicely demonstrates the relationship between these two groups of scenarios. The narratives in the SSPs are described in O'Neill *et al.* (2015).

What are the implications of selecting certain factors?

A central challenge to this workshop is that there are many elements of human society and management institutions that will vary in coming decades, with or without climate change. These features are interacting with the dynamics in the changing environment.

Because of the many dimensions of the problem, a primary challenge is to decide what factors to include. Incorporating too many dimensions means too many options, making the modelling process intractable. Including too few dimensions means that many important or essential socioeconomic complexities are excluded from the problem.

What types of feedback should be considered in socioeconomic scenarios?

A large number of topics were discussed, including the following:

- Both economic supply and demand were recognized as essential elements to develop the link and feedback between biophysical and socioeconomic parts of the system.
- The health of different ecosystems/fisheries will have economic impacts on systems with fish species that are sold in common global or regional markets.
- Generally speaking, economic and management factors seem to dominate in the short/medium term unless a biophysical state change happens (e.g., under extreme rapid climate shifts or change which have occurred and are expected to happen in the future).
- Other connections within the human system are vital to include, such as aquaculture. Potential changes in agricultural productivity and demand and land availability will also impact the cost of terrestrial food production and therefore seafood demand and prices.
- Human demographic factors (e.g., population growth, migration to coastal areas, world fisher population, fish consumption, regional shifts if markets, market size).
- Fish price volatility is recognized as a key factor that impacts fisheries.
- Extreme events, pathogen outbreaks, marine heat waves, and similar shocks are more likely to occur more frequently at a global scale.
- The degree of connectedness to global markets can generate local effects of larger scale connections. For example, remote villages may experience dramatic changes in income with global economic oscillations. On the other hand, if a location is not connected to markets through infrastructure, information transfer, or markets, they may experience effects contrary to those predicted by a global models.
- Research is continuing on how different types of fisher adaption strategies (e.g., portfolio management, fishing timing and location) are impacting fisher resilience. This work needs to be incorporated into socioeconomic assessments of different management strategies.
- Fleet impacts need to be extended to, and coupled with, impacts on processors and communities.
- A major area of discussion in the workshop was that unlike in climate scenarios, management can change significantly in ways that change fishing behaviour and the creation and distribution of economic benefits. The large number of possibilities makes a realistic representation of these policies very challenging. Modellers must select some of the general features of a management system (e.g., TAC) and then may explore other options through management strategy evaluation or other simulations.

The workshop provided the following guidance on developing and using scenarios.

Begin by looking at what has already been done. For example:

- Existing databases and existing reports or papers
- Existing projection reports (e.g., in other countries, IPCC, by industry, World Bank, IMF, OECD, etc.)
- Existing large-scale scenarios (SSPs, etc.).

Develop a conceptual model of the local system and what it looked like in past and future (evolution of drivers and then drivers of the drivers) (e.g., Haynie and Huntington 2016).

- Talk to experts on different aspects to do gap analysis
- Have defined connections/relationships so have internal consistency
- Use qualitative modelling methods (e.g., Dambacher *et al.* 2009) and quantitative analysis when appropriate data are available.

Where possible, run scenarios both forward and backwards (start with where want to end up and step backwards from there). This type of analysis can help clarify how different policies are likely to interact with future climate change.

Participants agreed that it is very important that the assumptions behind scenarios are made transparent.

b) identify how fisheries management policies will interact with climate change and identify how researchers can best evaluate what management tools are most likely to be resilient to climate change effects on fisheries;

Breakout groups discussed the interaction between climate change and management strategies and institutions. It is clear that effective management leads to better ecosystem outcomes (e.g., Bundy *et al.* 2016) and that some management approaches may be better suited to climate change adaptation than others. Workshop participants recognized that we have to be aware of the responses over time; simple extrapolation of the current fishery-to-fish models is unlikely to be stable over time. More research is needed to evaluate the interaction of climate change and current management and how existing institutions (e.g., management agencies) are likely to be impacted by longer-term environmental change.

Some discussion occurred around the fact that diversification has been observed to lead to higher economic returns and lower variance (e.g., Kasperski and Holland 2013) but current management is often controlling effort by limiting entry and restricting the flexibility of fishing fleets. In systems without thorough management and monitoring, environmental change and unregulated effort may exacerbate management challenges. There is thus a trade-off between the flexibility needed in management measures to cope with climate change and the robustness of governance systems. Allowing flexible adaptation can be couple with an effective limitation of effort and catch. It's expensive to repeatedly analyse management changes.

Climate change will increase uncertainty in both biological and social aspects of ecosystems. In a carefully managed system, this can lead to more precautionary management measures. For instance, total allowable catches (TAC) might be more precautionary to avoid potential collapses. Without management changes, there will be greater risks to ecosystems, fishers, and communities.

The interaction of climate change with a wide range of management actions was discussed, including the following. Some of these topic address management measures that may make climate adaptation easier.

- Under current management, what are the implications at different temporal and spatial scales?
  - How address short-term changes (e.g., dynamic ocean management (e.g., Lewison *et al.* 2015))?
  - Identify when you need fine scale/more detail to represent key features (e.g., ice/upwelling/key social mechanisms);
  - We need to think about sociocultural complexity in the same way that we think about biophysical complexity).
- What are key policy instruments that can facilitate sustainability? Discussion included the following topics:
  - Fixed MPAs vs dynamic ocean management or shifting MPAs. Some participants noted that dynamic ocean management works for single sector but across industries is usually very challenging to implement.
  - Quota baskets vs fixed single-species TAC;
  - Cross jurisdictional arrangements;
  - Continuum of flexibility and responsiveness.
- Cost and complexity of management is very different across regions so there is not a common policy solution for all management systems' or problems.
- High-cost data collection and socioeconomic research are not possible for all systems.
- Which management strategies provide the most adaptive capacity?
- Are there transitional management strategies that may be effective?
- The group discussed the degree to which policy makers may have a tendency to develop static rules, which means that the rules will need to be adapted to address a changing environment.
- Effective flexibility must not be confused with ineffective or insufficient management. Management has been essential to successful and sustainable fisheries. By flexible management we mean the ability of the management system to effectively adapt to and evolve with a changing environment.
- More heterogeneity among fishers means a management action is less likely to be optimal for all fishery participants.
- How do we deal with implications of laws that require long-term rebuilding plans?
- There may be short- vs long-term trade-offs because a specific species may be more valuable at one point and receive the most effort, leading to short-run economic benefits but working against the long-term productivity (and potentially economic benefits) of the system.

- What kinds of monitoring should be linked to management options (economic, social, electronic, observer)? Technological development will continue to influence observer coverage and alternative systems.
- The changing geopolitical environment needs to be included (like alternate futures in Oceans Future and the SSPs):
  - What are the relevant trade-offs of fisheries versus other resource uses?
  - How will scenarios balance national vs. international goals that countries may follow?
- How should we consider intergenerational challenges/trade-offs?
- How do we address invading species/range shifts?
- Marketing systems such as green labelling may increasingly include a carbon footprint analysis.

c) identify suites of bio-economic and spatially explicit models of fishery behaviour that can be used to project the implications different climate models on commercially important marine fish stocks in the northern hemisphere.

Before the workshop, breakout session #3 was intended to address three different topics, namely (i) which data are needed in data-rich and data-poor fisheries to implement different scenarios, (ii) specific economic scenarios for small-scale fisheries, and (iii) matching climate-fish models to specific economic and social science models and indicators. However during the workshop, the group agreed that all three breakout groups would focus on the question of matching climate-fish models to specific economic and social science models. Consequently the three breakout groups all focused on the question of which socio-economic indicators and models could be used in climate-fish models.

There were discussions about how to ensure that we have available data/indicators that help reveal which scenario is actually occurring. Thus when scientists are considering which socio-economic indicators they should integrate in their climate change models, they should first check if their indicators reflect observed changes and how the environmental change impacts the stakeholders/communities involved.

The discussion considered the following topics:

- Which data are needed (in both data-rich and data-poor environments)? Small-scale fisheries may require different data. Which indicators tell us which scenario is occurring?
- When is it desirable to add an additional feature/indicator and what is it capturing?
  - ICES WG on Integrated Models have done it for some economic models, but less has been done for social issues.
- Social indicators are perceived to be hard to develop because we do not have the correct information and methods at hand to capture all that is important.
  - If we want to look at well-being, what needs to be in models to be informative on that topic?

   - Many models have too gross a resolution to be useful for cultural factors which occur at a finer scale; models need to downscaled or nested from a regional scale down to the community, watershed, etc.
   - The required scale varies depending on which societal aspect is being considered (broad society vs fisher, community, etc.)
- Quantitative anthropology models may be useful to apply more broadly.
- Transparency of modelling and data is a key need.
- If we can characterise the "viability space" of a community, what indicators can models output that can estimate risk of leaving viability space? What information do we need to put into models to do that estimation well?
- How to allocate resources after determining a sustainable use level is not for a model to say; this is a social / policy decision dictated by the equity objectives of managers.
- The maritime poor are a population vulnerable to climate change and other economic and demographic changes; we discussed research efforts underway in a several countries (e.g., Philippines, Indonesia, and Bangladesh). Climate change will continue to put pressure on the rural, urban and maritime poor.
- How many dimensions are essential on the socio-cultural dimension? Some needs that we discussed included: coordination, responsiveness, well-being assessment, cost/feasibility axes, equity of distribution of outcomes, profitability, and biodiversity.

3 General workshop findings

The workshop provided valuable discussion on the nature of socioeconomic scenarios in climate-fish-fisheries modelling efforts, resulting in the following general findings:

- There is not one perfect way to do develop scenarios to do prediction in the context of many changing management and socioeconomic variables.
- It is important to separate the economic and social methodological discussions so that they do not become conflated. They can and should be appropriately integrated, but blending the two will often miss important factors.
- No model results should be driven by narrow, specific assumptions about price changes or economic growth. Scenarios need to consider a range of feasible changes as seemingly realistic point estimates may be wrong. For example, with energy prices, there was the assumption that energy prices would never fall but they fell dramatically during the last decade.
- All aspects of a system do not have to be integrated in one model. Analyses can be chained together. This is challenging if the goal is to provide a very limited number of scenarios to run across models; more work is needed to address how to most effectively integrate different models and scenarios.
- Small-scale fisheries have different needs than large-scale fisheries. It is essential not to ignore small-scale fisheries because of better data availability for larger fisheries.

- There are different types of data-poor situations that require different approaches.
  - No knowledge
    - Where to begin?
    - What's the goal?
  - No fisheries management but some knowledge from similar systems
  - Fishery data but little environmental knowledge
  - Some fishery data but inadequate detail to separately identify many changing factors.
- Socioeconomic variables that are put into model need to be a useful proxy – not just an available number that may not be a good measure of socioeconomic benefits.
- How do allocation after you have what sustainable use level is isn't for model to say, that is a social decision dictated by own equity objectives.
- There is a clear trade-off between modelling what we are able to model and what we would like to model. What is feasible will evolve dramatically over coming decades with better data (e.g., vessel monitoring systems) and better socioeconomic models.
- There is a significant need to facilitate better communication about different projects and their assumptions. The continued development and support of the MSEAS Network, SICCME, and other efforts to improve communication about the impacts of climate on fish and fisheries will lead to better research and management in the systems throughout the ICES/PICES countries.

4 Conclusions

The workshop was successful in that it will contribute to the advancement of several project-specific efforts and improve future international efforts. We expect that collaboration underway will result in several collective papers to be submitted to the peer-reviewed literature.

The CERES (Climate change and European aquatic RESources) and the Alaska Climate Change Integrated Modeling (ACLIM) projects are both developing socioeconomic scenarios that can be mapped to the SSPs in the development of as reference points. Other projects/papers are also building out of the SSPs and RCPs.

From the workshop, it is clear that there are many choices and approaches to the elements to be included in scenarios, so it is not a straightforward process to provide a small and finite suite of socio-economic scenarios to be included in climate change models. Therefore this issue requires further work and examination of scenarios over the next few years.

Researchers are still wrestling with scenario standardization across regions. There is a clear value of the effort to integrate, but also many complexities. Scenarios cannot do everything, but abstracting too much from the specific management challenges and economic paths likely to occur in different areas has the potential to be very misleading.

The group recommended that an additional socio-economic workshop be proposed and convened in 2017 or 2018 to further address the range of possible management responses and to report on project-level progress.

The group established the following timeline for completion of the scenarios by the 2019/2020 target.

- Short-term reporting: 1) September 2016 Presentation on this Workshop at the Principal Investigators Meeting at the ICES Annual Science Conference; 2) November 2016 Report on Workshop at the Principal Investigators Meeting at the PICES SICCME Workshop; and 3) March 2017 report on the ongoing status of related projects at the SICCME workshop at the PICES Symposium on Drivers of dynamics of small pelagic fish resources in Victoria, Canada.
- Participation in the ICES Annual Science Meeting sessions in 2017.
- 2018 Inter-sessional workshop (possibly part of 4th Effects of Climate Change Effects on the World's Ocean meeting) to discuss results / paper writing.
- 2019/2020 Publish results in a special issue of a peer-reviewed journal.

At the conclusion of the workshop, we discussed the creation of a working group to look at integrated tools and what they can evaluate. Doing a review of all existing marine scenarios could become quite large depending on how far back in past it goes and what time horizons/timelines are considered. Members of this group are continuing to discuss how this might most effectively be accomplished.

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Annex 2: Agenda

Friday, June 3

- 14:00- 15:00 : Introduction
    - Overview of goals of the workshop and subsequent papers
    - Quick sub-group introductions
    - Introductions of participants
        - Quick comments on goals
- 15:00-16:00: Presentations by participants (speed introductions of interdisciplinary projects and specific topics)
    - Luc Doyen: SEAVIEW
    - Ingrid Van Putten: GULLS
    - Jeffrey Dambacher: Ocean Future
    - Lisa Colburn: Community vulnerability
    - Anne Hollowed: COCA
    - Phil Levin
- 16:00 - 16:20: Break - coffee/tea
- 16:20 - 18:00: "Breakout group session 1": discuss workshop objective #1 and the search for common pathways. Discuss economic and social data and indicators used in different projects as well as data gaps. Introduce the connection of data to modelling approaches.
- 18:00- 18:30: Discussion and summary of the outputs from "Breakout group session 1"
- 18:30 - 19:00: Lay out goals and questions for Saturday
- 19:00 - 22:30: Drinks and dinner

Saturday, June 4

- 9:00 - 9:30: Summary of day 1 and revisiting of discussion day 2 goals
- 9:30- 10:45: "Breakout group session 2": discussion of objective #2 - management and climate change.
- 10:45- 11:00: Break - coffee/tea
- 11:00 - 12:15: Summary of the outcomes of the "Breakout group session 2"
- 12:15-12:45: Presentations by participants (speed introductions of other interdisciplinary projects)
    - Kirstin Holsman: ACLIM
    - Beth Fulton: FISH-MIP
    - John Pinnegar: CERES
    - José Fernandez: DECCMA and others
- 12:45-14:00: Lunch
- 14:00 - 14:15: Introduction to the "Breakout group session 3" goals. This time will be used to adjust the goals according to the discussions of the morning
- 14:15-16:00: "Breakout group session 3". Three different topics are planned:
    - Which data are needed: from data-rich to data-poor fisheries
    - Specific economic scenarios for small-scale fisheries
    - Matching climate-fish models to specific economic and social science models and indicators

- 16:00-16:15: Break - coffee/tea
- 16:15-18:00: Quick summary of the outcomes from “Breakout group session 3” / planning for new projects / paper outline

18:00 - 18:30: Final words by the co-chairs and discussion about what are the next steps - assigning homework