Theme session B

Marine aquaculture in a changing ocean

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Both the recent and the future growth in marine aquaculture expected around the world are expected to present a host of opportunities and challenges for ocean planning, and for the sustainable use of ocean resources. Anticipating and planning for the range of possible changes – including where growth will occur, which species will be farmed, efficiency of production, spatial interaction and conflicts, how local communities will respond to the changes, and uncertainty how changing climate will influence all of these other dimensions – presents a host of scientific and management questions and needs.

Some of the most pressing questions facing ocean aquaculture sustainability in the future revolve around climate change, the ability to model aquaculture impacts and opportunities at multiple scales, and in anticipating the complex interactions with wild fisheries that are likely to increase as marine aquaculture expands into the oceans and into wider markets. As a result, this theme session provided an opportunity to review the latest advances in ecological, socio-economic and coupled-ocean system research around current and future marine aquaculture.

Contributed talks covered, and were grouped into, four broad themes:

1. Aquaculture framing conditions and context
2. Aquaculture systems
3. Aquaculture interactions
4. Aquaculture management and governance

Within these themes, talks spanned scales from global to local cases; ecological, social science, and interdisciplinary; and basic to applied.

As conveners, we asked each speaker to address two general framing questions. These are listed below with convener's notes on the key issues emerging from presenters' responses.

1. How would you describe the connection between your presentation topic or results, and the sustainable future of aquaculture in changing oceans?

- Mapping of Aquaculture: the importance of knowing where systems are, in order to understand how they are affected by climate change
- The ways in which supply chains of feed ingredients are influenced by climate change
- Alternative feeds dimensions, i.e. the effects of introducing terrestrial feeds like soy beans into marine environments, are not fully understood

- Studying the ways in which ecosystem service impacts interact with physical coastal changes
- Eco-innovation, or spatial synergies
- Ecological footprint: the importance of visualization in planning processes and in understanding trade-offs, for example
- Whether aquaculture should be more connected to ocean sparing, or ocean sharing
- The link between global drivers of market-demands and changing mental mind models
- The need to consider both carrying capacity and climate change, although so far there is a strong leaning towards ecological dimensions
- Identifying spatial variability, i.e. in places public perceptions are "being fishy"
- Environmental change seeming to affect a species' capacity to adapt to climate change, even after decades of only very minor human activities/impact (the example of the pearl oyster)
- A measure of animal behaviour needing to be integrated into studies of the effects of climate change
- SWOT as a tool to link between different perspective scenarios (social SWOT/business SWOT, for example)
- Local production limiting the outsourcing of environmental footprint responsibility
- Feed is most energy resource intense source, and replacing fish meal with soy bean is not helpful as high energy impact is still needed.

2. What challenges or constraints do you see in relating your topic or results to the broader context of climate change as a central driver?

- A comparative analysis of GHG resulting from food production
- Public perceptions vs. market-drivers
- The warming effects of climate change mean that aquaculture strategies remain reactive, because public perception of the threat is not yet severe enough
- The transparency and adaptability of governance and the time scales needed for decisions, which are too slow for tackling climate change
- The need for fixed installations to be relocated as a result of climate change
- The growing importance of footprint accounting and carbon taxation
- The interactions of different food systems under sustainable ocean food systems, with a central target on local rural areas, and the link to global food systems
- Linking climate change to the effects of large-scale RAS
- The need for adaptive planning, as climate change effects are difficult to predict, but data availability and resolution (in terms of time and space) are limited

- The need for multi-level linkages between systems; ways to integrate while being inclusive and transdisciplinary
- The lack of climate change recognition in Blue Growth agendas, and friction towards climate change adaptability planning
- Downscaling models/predictions critical
- Finding the central drivers of climate change in a specific aquaculture. Context matters!
- The lack of a baseline on what is “normal” means that the effects of climate change are hard to predict
- Knowledge is needed on how climate change effects population change, and how the relationship alters when seen in the context of aquaculture
- Whether the buffering capacity of aquaculture will become more important
- The lack of willingness in terms of capital investment, due to uncertain policy backing
- The threat to all marine infrastructure from the effects of climate change
- The need for innovation when planning to reduce climate change impact on the production of fish feed.

Aquaculture will be challenged, at both a social and ecological level, in the future. At a social level, improved marine spatial planning is being used to either make space for or restrict marine aquaculture - particularly by the ICES member countries. There is heterogeneity in the ways people perceive, value, and prescribe aquaculture risk(s) across different ecosystems and between different types of aquaculture production. Importantly, the challenges posed by climate change to the larger seafood sector are by large not being considered, besides reactively at the individual farm level. At an ecological level, research presented at this theme session indicates that climate change will challenge aquaculture. This could be through feeds (crops and marine sources), suitability of conditions (e.g. temperature, acidification), and/or the capacity to scale given tradeoffs of culturing systems (e.g. closed vs. open). While there is variability in the social and ecological components relevant for aquaculture at a global and local scale, there was a consistent thread of optimism across the talks around existing planning frameworks (space and species), technology, and accounting of stakeholders. These can be, and are being, implemented in ways that will improve and help guide a more sustainable aquaculture sector. The ability of long term and adaptive management to achieve these outcomes however, particularly at a national level, remains to be seen.