Workshop Report

Ecosystem modelling for data-limited high-latitude ecosystems

Date & Location: 1-2 May 2023 – Newport, Oregon, USA

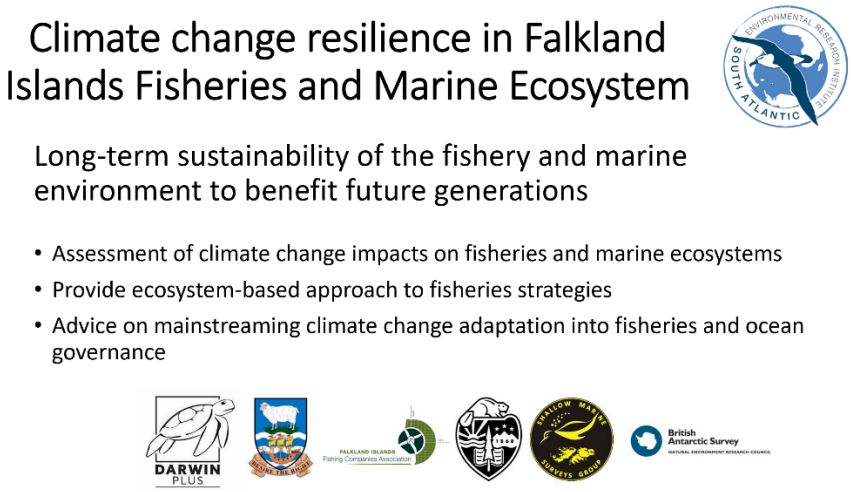
Attendees: Alberto Rovellini, Kim de Mutsert, Szymon Surma, Will White (organiser), Jesse van der Grient (organiser)

Workshop

This workshop focused on using ecosystem modelling approaches, and in particular Ecopath with Ecosim, in a fisheries/climate context for high-latitude ecosystems, where data necessary to inform modelling efforts may be limited. The aim of the workshop was to understand how to use ecosystem-based approaches to ocean management, and specifically fisheries management, to aid the development of management recommendations taking into account climate-driven changes.

The effects of climate change can result in functional changes in marine food webs, with potential consequences for the ecosystem services they deliver, including fisheries support. Ecosystem models are increasingly used to inform ecosystem-based approaches to fisheries management and to investigate climate-change effects on fisheries. The Ecopath with Ecosim (EwE) software is commonly used around the world in these efforts. EwE, like other ecosystem models, requires different types of data to inform the modelled ecosystem. However, available data may be limited in high-latitude ecosystems, yet the development of ecosystem-based approaches to ocean management are beneficial in these areas, too. The workshop focused on the use of EwE in a fisheries/climate context for high-latitude ecosystems, using the Falkland Islands as a case study. The aim was to understand how best to develop management recommendations in such ecosystems given the data limitations.

The workshop started off with presentations from each participant on their work and what they thought was the biggest issue in modelling data-limited high-latitude environments. This was followed by discussions focused on four topics, including three discussion topics and one case study. The three discussion topics focused on (1) Characteristics of high-latitude ecosystems, (2) Model structure, quality, and validation, and (3) Model application, and each were guided by several questions pertaining to the topic.



Participants presented their work during the workshop

Workshop Report

Key points per topic

Topic 1: Characteristics of high-latitude ecosystems

- *What are key differences between high latitude and other ecosystems?*
- *What are key processes that have to be captured to model high-latitude ecosystems?*
- *Can such processes be properly captured in 1-year time steps?*
- *Where are gaps in understanding and priority areas for studying?*

Some key differences between high latitudes and other ecosystems include (i) the slow turnover rates and life history in high-latitude ecosystems, especially for larger-bodied species, (ii) strong seasonal environmental changes in light, ice and primary productivity, (iii) proportion of wasp-waist species and their dynamics (although more in subpolar regions), (iv) differences in bentho-pelagic coupling (often influenced by ice), and (v) localised differences in coastal upwelling and offshore dynamics.

Generally, there is a lower species richness compared to temperate or tropical environments, although marine mammal and seabird diversity (and biomass) is often higher in high-latitude environments. The lower species redundancy per functional group and slow life history influences polar and subpolar ecosystem potential for response to disturbance. They likely will take a long time to recover. For example, cetacean and pinniped populations in these areas are still recovering from (over)exploitation. This needs to be considered in a modelling environment, too.

Strong seasonal migration in high-latitude environments means large changes in biomass pools. Seasonal migration is a response to the strong primary productivity increase in spring and can include extreme seasonality. These strong changes have important implications for phenology.

Several effects of climate change that need to be considered are shifting distributions, habitat compression, new species and interactions, the extended stays of migrant species and prolonged competition as a result.

Topic 2: Model structure, quality, and validation

- *What are key assumptions and concerns for data-limited ecosystem models?*
- *Should other modelling techniques be used (instead), or in combination of, and how?*
- *To what extent can other high latitude areas be substituted for each other (general high latitude vs. area specific characteristics)?*
- *Certain areas have disproportionate effects in ecosystems compared to their size (e.g., nursery habitats). How to incorporate such spatial coupling and pathways in non-spatial models?*
- *What strategies can be taken to validate data-limited ecosystem models?*

Ecological representation is important in modelling the ecosystem, but lower-trophic levels are often not well understood in their functions. It is important to capture the change in biomass pools in the season depending on the time-step of the model, and its effects on the food web as a result. Primary productivity data (modelled or observed) can aid in ensuring the model is fitted to realistic seasonal inputs and drivers. Note that the role of cephalopods in the food web, and their high cannibalism can be difficult to capture properly. However, often data for validation are lacking. Ecosystem responses can be checked to see if there are reasonable. For example, ecological first principles should still hold, trophic interaction responses should be reasonable (predators should not eat a lot of uncommon prey), biomass pools of functional groups should be of reasonable sizes. If catch data is available locally or from other sources, these can be used to calibrate the model. In addition, it is important to evaluate the uncertainty around data sources, which can be done with data pedigrees. This can then be used to influence weighing and reliability (the latter can influence Monte Carlo sampling analyses). The influence of ontogenetic changes (diet, use of space) can be quite important to capture and should be

included as much as possible (data allowing). While data on certain parameters may be lacking for (most) specific areas, parameters such as P/B and Q/B are likely transferable between areas as they are properties of species. These values are influenced by size (and thus also life stage). However, ecosystem models often use functional groups, and capturing accurate parameters for these from species can be difficult and may limit analyses to environmental responses. When there are gaps other (modelling) techniques can potentially be used to fill them, including habitat suitability indices, physiological experiments, MICE models or qualitative models. The use of ensemble models can be an approach to reduce uncertainty in ecosystem responses.

There can be nuances in space, which are a nonissue in non-spatial ecosystem models. Spatial restrictions can be included, however, by making them implicit in the food web. This can be done via mediation in prey-predator relationships, diet, or via forcing functions by applying different foraging or mortality effects to different groups in the food web (which can represent specific areas or depth). One issue is that there is no escape (it is an all-or-nothing effect), although via response curves this can be addressed somewhat.

Topic 3: Model application

- *How can ecosystem model approaches be used in data-limited high-latitude ecosystems for ecosystem-based approaches to management (or fisheries at least)?*
- *What are the strategies/check points for applying ecosystem models to data-limited high-latitude ecosystems?*
- *What considerations need to be taken into account given that high-latitude environments are one of the fastest changing environments in the world, and data collected currently may not represent baseline data?*
- *Climate change not only results in changes in mean conditions, but also increases the frequency of extreme events. How can data-limited high-latitude models capture these differences? What can we interfere from such models based on the limited input data?*

Model design should be influenced by the focus/topic addressed, which is also partly influenced by data availability. This can include pressures, sectors, or goals of interest in an ecosystem setting with regards to resource management and industry impacts (as well as environmental change). In turn, this can help identify potential indicators to watch. In short, models can aid in developing strategies for the management of the ocean. Questions of ocean management can relate to sector-on-sector effects (how does fishing of one commercial species result in changes for other commercial species or tourism), or effects of new industry sectors (e.g., oil, salmon farming), or new interactions (e.g., invasive species, or entanglements from fishing gear), or other ocean management strategies (creation of MPAs, changes in fishing seasons, shipping lanes). The latter requires spatial models for the investigation.

Falkland EwE model

The Falkland Ecopath model was evaluated, and several recommendations were made to improve the current model. Some groups will benefit from a higher resolution, including the incorporation of life stages (for which there is data) and the split of the group ‘other cephalopods’ in small and large cephalopods. These changes can also be used to include more implicit consideration of space. Given the seasonal migration, there needs to be more consideration for mortality outside the modelled domain. In addition, other data sources were proposed for calibration, including CPUE data and modelled biomass data. In addition, primary productivity data from satellites can also be explored as

a way to calibrate the model by providing time series data. Last, all potential environmental variables or indicators of interest need to be part of the model calibration even if their effects are low so that they can be used during the analyses of potential future scenarios.

Group photo of on-site and online participants of the workshop

Steps forward

During the workshop, several overarching key messages were highlighted regarding the challenges regarding modelling high-latitude ecosystems, including the high uncertainty to ecological functioning and how to address this uncertainty, wasp-waist dynamics, low species redundancy and population growth but at the same time recovering populations from (over)exploitation, importance of space (upwelling, nursery grounds, foraging grounds) and shifting distributions and how to capture this is in non-spatial models, amongst others. Overall, there is a need for ecosystem-based management even when (high) uncertainty exists, and calibration and validation of models may be challenging. These issues were recognised by the attendees as an opportunity for a review paper, which is being further explored by looking at different (published) case studies to facilitate discussion of the main messages. In addition, the attendees saw the potential of the Falkland Islands EwE model and are keen to aid in its further development, including helping source calibration data, model calibration and scenario analyses.

Note on engagement

Fourteen people were invited to participate in the workshop. While six people accepted the invitation, in the end three people attended (two in person, one online). One person who could not make the workshop indicated they would like to follow up in a private discussion. This is currently being scheduled, but a date and time have not agreed upon yet.

Workshop Report

Appendix 1 - Agenda

Monday 1st May

9:00 – 9:15	Welcome and outlining aim of the workshop
9:15 – 10:30	Presentations
10:30 - 11:00	Coffee break
11:00 – 12:30	Discussion Topic 1
12:30 – 13:30	Lunch
13:30 – 14:00	Discussion Topic 1
14:00 – 15:00	Discussion Topic 2
15:00 – 15:30	Coffee break
15:30 – 17:00	Discussion Topic 2

Tuesday 2nd May

9:00 – 10: 30	Discussion Topic 3
10:30 – 11:00	Coffee break
11:00 – 12:30	Discussion Topic 3
12:30 – 13:30	Lunch
13:30 – 15:00	Case study - applying lessons learned
15:00 – 15:30	Coffee break
15:30 –16:30	Case study - Ecosim scenario options
16:30 - 17:00	Summarise workshop results

Topic 1 – Characteristics of high-latitude ecosystems

- What are key differences between high latitude and other ecosystems?
- What are key processes that have to be captured to model high-latitude ecosystems?
- Can such processes be properly captured in 1-year time steps?
- Where are gaps in understanding and priority areas for studying?

Topic 2 – Model structure, quality, and validation

- What are key assumptions and concerns for data-limited ecosystem models?
- Should other modelling techniques be used (instead), or in combination of, and how?
- To what extent can other high latitude areas be substituted for each other (general high latitude vs. area specific characteristics)?
- Certain areas have disproportionate effects in ecosystems compared to their size (e.g., nursery habitats). How to incorporate such spatial coupling and pathways in non-spatial models?
- What strategies can be taken to validate data-limited ecosystem models?

Workshop Report

Topic 3 – Model application

- How can ecosystem model approaches be used in data-limited high-latitude ecosystems for ecosystem-based approaches to management (or fisheries at least)?
- What are the strategies/check points for applying ecosystem models to data-limited high-latitude ecosystems?
- What considerations need to be taken into account given that high-latitude environments are one of the fastest changing environments in the world, and data collected currently may not represent baseline data?
- Climate change not only results in changes in mean conditions, but also increases the frequency of extreme events. How can data-limited high-latitude models capture these differences? What can we interfere from such models based on the limited input data?