Title

Climate, fisheries and food web dynamics in the Barents Sea, modelling plausible futures

Background

How will the Barents Sea food web dynamics respond to anticipated changes in regional ocean climate? Can changes in fisheries management impact the productivity, stability or resilience of the Barents Sea food web? Can changes in food web structure and dynamics impact fisheries potential in the Barents Sea? These are central questions to be addressed by the national project *The legacy of Nansen* over the period 2017-2023. Past and current observations of the Barents Sea ecosystem provide the empirical background to understand interactions between species and their environment and numerical models of ecosystems provide a platform to explore the likely responses of ecosystems to expected changes in climate and fisheries dynamics. Numerical models are highly simplified representations of complex real-world systems and their performance at mimicking real-world dynamics must be evaluated before they can be used to illustrate possible future scenarios and serve as a basis for management advice. To date, models of marine food web dynamics are often complex and deterministic and can hardly account for uncertainties in knowledge, processes and parameters. A modelling approach based on non-deterministic principles proposed by Mullon et al. (2009) provides an interesting non-deterministic alternative framework to explore the possible response of the Barents Sea food web to climate and fisheries scenarios. But, like other modelling tools, the performance of this model needs evaluating before it can be used to inform about possible future food web dynamics.

Objective

The objectives of this PhD are to conduct an objective evaluation of the performance of the non-deterministic food web model and to use this model to explore plausible responses of the Barents Sea food web to climate/harvesting scenarios.

Approach

The non-deterministic network dynamics (NDND) model will be used to simulate and analyse patterns of food web dynamics under fisheries/climate scenarios. The NDND model is a non-deterministic food web model (Planque et al., 2014), constrained by mass-balance (changes in mass are the result of feeding and losses through predation and metabolism), inertia (population growth and mortality rates are bounded) and satiation (feeding rates are bounded). The current version of the NDND model for the Barents Sea is based on a network of eight trophospecies (Lindstrøm et al., 2017). The PhD will contribute to the development and application of robust tools to explore plausible responses of the Barents Sea food web to climate/harvesting scenarios by: further developing the NDND model for the Barents Sea; developing model evaluation methods; simulating food web dynamics under specific climate and fisheries scenarios.

Project work

The PhD work will be organised around three main axes: NDND model developments, NDND model evaluation methods and simulation of food web dynamics under specific climate and fisheries scenarios.

NDND model developments: Three lines of development are planned: 1. the development of a module that incorporates the effects of changing temperature on trophospecies vital rates, 2. the development of a module that simulates fisheries catches, their effects on food web structure and how they respond to changes in resource availability and 3. the development of a more complex food web topology, which includes a greater number of trophospecies in order to resolve the dynamics of species – or species groups – of particular interest.

NDND model evaluation: An important task will be to develop and apply model performance evaluation based on food web 'patterns' rather than individual species trajectories, following Pattern Oriented Modelling (POM) approach and statistical evaluation techniques for stochastic models (Wood, 2010; Hartig et al., 2011; Fasiolo et al., 2016).

Simulation of Barents Sea food web dynamics under climate/fisheries scenarios: NDND simulations will be performed based on a limited number of contrasted climate/fisheries scenarios for the future (Planque et al., submitted). These simulation ensembles will serve as a basis to illustrate the consequence of possible future changes in climate and fisheries on the ecosystem dynamics. They will be used to explore the range of possible future ecosystem trajectories and to perform risk analysis, i.e. investigate the probability of 'undesired' ecosystem states to occur under various climate and fisheries scenarios.

The PhD work will be conducted in connection with the research focus 'Future Barents Sea' of the *Legacy of Nansen* project.

Candidate

The PhD candidate must document a solid background in quantitative ecology and statistical inference, background in time series analysis and experience in programming in Matlab or R. In addition, the candidate should be familiar with several of the following topics: trophic ecology, community ecology, macroecology and linear algebra. Interests in epistemology and creative thinking and previous knowledge on the Barents Sea ecosystem and coupled physical-biological models will be advantageous.

Location

The PhD student will be based at the Institute of Marine Research in Tromsø and the work will be conducted in collaboration with the Department of Arctic Marine Biology at University of Tromsø. A grant to support 6 months in a laboratory abroad will be sought at the beginning of the PhD project.

Contact

Additional information about the PhD project and application procedure is available from Ulf Lindstrøm (ulf.lindstroem@imr.no, +47 55 90 65 66), Benjamin Planque (benjamin.planque@imr.no, +47 48 89 30 43) and *Nigel Yoccoz (nigel.yoccoz@uit.no, +47 91 61 61 94)*

References

Fasiolo, M., Pya, N., and Wood, S. N. 2016. A Comparison of Inferential Methods for Highly Nonlinear State Space Models in Ecology and Epidemiology. Statist. Sci., 31: 96-118.

Hartig, F., Calabrese, J. M., Reineking, B., Wiegand, T., and Huth, A. 2011. Statistical inference for stochastic simulation models – theory and application. Ecology Letters, 14: 816-827.

Lindstrøm, U., Planque, B., and Subbey, S. 2017. Multiple patterns of food web dynamics revealed by a minimal non deterministic model. Ecosystems, 20: 163-182.

Mullon, C., Fréon, P., Cury, P., Shannon, L., and Roy, C. 2009. A minimal model of the variability of marine ecosystems. Fish and Fisheries, 10: 115-131.

Planque, B., Lindstrøm, U., and Subbey, S. 2014. Non-Deterministic Modelling of Food-Web Dynamics. PLoS ONE, 9: e108243.

Planque, B., Mullon, C., Arneberg, P., Eide, A., Fromentin, J.-M., Heymans, J. J., Hoel, A. H., et al. submitted. A multiple-perspective scenario method to explore the future of marine social-ecological systems - an application to the Barents Sea. Ecology and Society.

Wood, S. N. 2010. Statistical inference for noisy nonlinear ecological dynamic systems. Nature, 466: 1102-1104.