The Journal of Open Source Software

Viable North Sea (ViNoS): A NetLogo Agent-based Model of German Small-scale Fisheries

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DOI: 10.xxxxxx/draft

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Editor: Marcos Vital

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Submitted: 17 April 2023
Published: unpublished

Summary

Viable North Sea (ViNoS) is an Agent-based Model (ABM) of the German Small-scale Fisheries. As a Social-Ecological Systems model it focusses on the adaptive behaviour of fishers facing regulatory, economic, and resource changes. Small-scale fisheries are an important part both of the cultural perception of the German North Sea coast and of its fishing industry. These fisheries are typically family-run operations that use smaller boats and bottom trawling gear to catch a variety of demersal species, foremost plaice, sole, and brown shrimp.

Fishers in the North Sea face area competition with other uses of the sea—long practiced ones like shipping, gas exploration and sand extraction, and currently increasing ones like marine protection and offshore wind farming: German authorities released a maritime spatial plan implementing (1) the need for 30% of protection areas demanded by the United Nations High Seas Treaty and (2) aiming at up to 70 GW of domestic offshore wind power generation by 2045; the European Union is aiming to reduce fisheries in all Marine Protected Areas. Fisheries in the North Sea also have to adjust to the northward migration of their established resources following the climate heating of the water. And they have to re-evaluate their economic balance by figuring in the foreseeable rise in oil price and the need for re-investing into their aged fleet.

Statement of need

Socio-economic fishery models are among the earliest application of coupled human and natural systems modeling (Allen & McGlade, 1987). They have often concentrated on Maximum Sustainable Yield, and have been neglecting adaptive behaviour and diversity of fishers (Wijermans et al., 2020). The description of the patial, temporal and structural adaptations of a fishery fleet is the purpose of the ViNoS ABM. It is intended to be used for scenario development for future sustainable fisheries. The ABM describes foremost

- where to fish and how far to go out to sea,
- how often to go out,
- what gear to use and what species to target.

Its scope is the German North Sea small-scale fisheries. These encompass some 300 vessels based and landing in German ports along the North Sea coast and fishing in the German Bight, including but not restricted to Germany's exclusive economic zone. The target species described by the model are currently limited to the commercially most important ones in this sector: plaice, sole and brown shrimp; the model is extensible to further target species like

Norwegian lobster, whiting, or sprat.

The intended audience of the ABM are marine researchers, educators and government agencies concerned with spatial planning, environmental status assessment, and climate change mitigation. The ABM can assist in a stakeholder dialogue with tourism and fishers to contextualize the complexity of the interactions between fisheries economics, changing resources and regulatory restrictions.

Key features of the ABM

As a NetLogo implementation, the model comprises a (frontend) user `interface`, its basic `info` documentation, and the (backend) `code` in a single integrated development environment (IDE) provided by NetLogo (Wilensky, 1999, version 6 required), a Java-based portable ABM and system dynamics simulation platform.

The backend (`code`) features geospatial data access and integration of multiple georeferenced and tabular data sources, as well as integrating Web Mapping Services to describe the grid-based environmental context. This environmental context is dynamic in time, providing seasonal resource changes and dynamic area closures.

Agents are boats, the gear they use, the strategies they employ, and their prey. All agents are encapsulated in object-oriented design as NetLogo `breeds`. The agents' methods implement the decision rules of agents and the resulting interactions between them and with their gridded environment (`patches`). Key interactions are the movement rules of boats across the seascape, the harvesting of resources, and the cost-benefit analysis of a catch. Adaptation occurs at the level of changing priorities for fishing trips (i.e. gear selection and target species, time and distance preferences) towards increasing expected values of agents, according to the VIABLE model framework (BenDor & Scheffran, 2019).

The user `interface` provides an interactive environment, perusing all NetLogo's graphical features. Informational elements include a (georeferenced) map `view`, and several histograms and temporal scatter panels. Interactive elements include `switches` for toggling information on and off, `choosers` to toggle which information to show, `buttons` to control the simulation and `sliders` to adjust boundary conditions, such as the oil price.

Notable programming and software development features

This NetLogo model is a showcase of the integrated use of several extensions to the base language, featuring, amongst other

- reading and writing of tabular data (`csv` extension),
- import and export of Geographical Information System layers, both ESRII raster `.asc` and vector shapefiles `.shp`, both as local data and interacting with Web Mapping Services and Web Feature Services, from different projections and converted from other file formats like NetCDF and geoTiff (using the `gis` extension and `python` preprocessing),
- a real-time calendar using the `time` extension and both tick-based (daily model timestep) as well as discrete event scheduling for substepping.

A notable programming feature is the integration of the legend with the `view`, a feature that is lacking from the default capabilities of NetLogo. There have been discussions on how to implement a legend using the `plot` element and using the `bitmap` extension (arn et al., 2018), but so far this is the only NetLogo model known to the authors implementing a legend with the `view` using NetLogo's intrinsic capabilities.

To date, most NetLogo models have not exploited continuous integration (CI) and continous deployment (CD). With our implementation, we demonstrate how CI can be used for NetLogo by making use of NetLogo's `BehaviorSpace` tool that runs a suite of unit tests. We also use

BehaviorSpace for the CD of generating the resulting maps of fishing effort under different scenarios.

Model documentation and license

The model is documented in short form in the NetLogo IDE's `info` section. A full documentation follows the Overview, Design concepts, and Details (ODD, Grimm et al., 2020) standard protocol for ABMs. This standard intends to facilitate model replication and declares, amongst others, a model's purpose, entitities, scales, processes and scheduling, and initial and boundary data. The ViNoS ODD is available in the repository as `doc/odd/paper.md`. Data from third parties are licensed under a multitude of open source licenses. The model, its results and own proprietary data are released under open source licenses, mostly Apache 2.0 and CC-by-SA 4.0. A comprehensive documentation of all licenses is provided via *REUSE Software* (2023).

Acknowledgements

We acknowledge contributions from W. Nikolaus Probst, Marie Ryan, Jieun Seo, Verena Mühlberger and Kai W. Wirtz for providing feedback, data, fruitful discussions and for contributing to the ODD document. We thank all members of the MuSSeL consortium making this software relevant in a research context. The development of the model was made possible by the grants 03F0862A, 03F0862C, 03F0862D, 03F0862E "Multiple Stressors on North Sea Life" (MuSSeL) within the 3rd Küstenforschung Nord-Ostsee (KüNO) call of the Forschung für Nachhaltigkeit program of the Germany Bundesministerium für Bildung und Forschung (BMBF). We are grateful for the open source community that facilitated this research, amongst them the developers of and contributors to NetLogo, Python, R, pandoc, and LaTeX.

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