Scotia-Canadian Ocean Research Exchanges (SCORE) Scheme

OFI/6/21 - Population connectivity in two scallop species: a comparative simulation study of controlling factors in Scottish and North American stocks

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(1) Summary of the exchange and of the work undertaken

This study focused on adapting a modelling framework developed by researchers at the University of Dalhousie to Scottish scallop stocks.

The key goals of this study were to: (1) adapt the Lagrangian Particle Tracking in use at Dalhousie *to P. maximus,* (2) identify the major biophysical factors affecting larval dispersal, (3) compare larval dispersal patterns of distinct species under different environmental and biological forcing.

In the first two weeks of my placement, I received training in the use of Ocean Parcels. The bulk code was in Python, a new language for me, so it took some time to familiarise myself with it. The first stage was to explore tutorials provided on the Ocean Parcels webpage, followed by running the Parcel simulator code through a Spyder terminal on the Mac PC I was given to use during the exchange. Pre- and post-processing code for analysis of outputs in MATLAB also had to be edited for use with my outputs.

In parallel, I investigated options for hydrodynamic data to be used as an input for the model. Ocean Parcels requires NEMO-based flow fields. Hence, following the initial research proposal and my supervisors' suggestion, I looked into the NEMO-MEDUSA outputs held at Strathclyde. However, after some investigation it became clear that a better resolution model was needed, so we opted for using outputs from BNAM model which were given to me by Dr W. Zeliang from the Bedford Institute of Oceanography.

To determine the initial locations of my particles, I attempted to use Scottish shelf sediment type datasets from Wilson et al. (2018) and scallop survey datasets from Marine Scotland Science (MSS) to predict scallop presence using statistical models. In June, I learnt about random forests (RF), a supervised machine learning algorithm based on decision trees, and how to implement this in R. I was advised by Dr F. J. Murillo Perez at Fisheries and Oceans Canada to compare predictions from RF with a GAM model. After weeks of investigation, it became clear that sediment data alone was not enough to predict scallops' presence. I sourced bathymetry data from the European Marine Observation and Data Network (EMODnet) and combined this with the sediment type to obtain more accurate results for my initial conditions. To improve on this result, I also added presence of scallops from fishers' data which had been made publicly available.

Following the same approach as in Davies et al. (2014), I also obtained data on scallop's weight from Marine Scotland Science which we hoped would helpful in determining the timing of spawning events. This aspect of the project is still ongoing.

At the same time, I was also trained to use a FVCOM-based particle tracker (called ptrackProg) which has been developed over the past decade to simulate Canadian scallop larvae among other species. Between June and July, I arranged the transfer of FVCOM flow fields from MSS. I also had to manually edit these fields before they could be used with ptrackProg, a task which took a few weeks. The simulations were hosted on Compute Canada servers, a valuable resource I was able to access thanks to my exchange in Canada. During this period, I learnt more about hydrodynamic models and different types of grids, how to write simple bash code, how to interact with Compute Canada servers through a terminal, and some basic FORTRAN code editing. I also became more familiar with NetCDF files and what hydrodynamic variables were needed by the tracker to run simulations.

Between May and June I was also allowed to sit in classes on planktonic ecosystem modelling. This gave me a better understanding of how nutrients and different species may be connected to each other in the marine environment, as well as equipping me with more computational modelling skills which I acquired during the weekly tutorials in MATLAB.

To summarise, the work undertaken can be divided into three main stages: pre-processing, running simulations, post-processing.

Pre-processing

- I investigated suitability of habitat using data from Wilson et al. (2018) and survey data from MSS. Statistical methods were employed in this part, including standard GAMs and RF algorithms.
- Based on the results from the habitat, survey data provided by MSS and publicly available fishers data, I generated initial conditions for both particle tracking models using R software package. Fishers' data and bathymetry data were the principal sources of ICs predictors.
- In MATLAB, I created NetCDF files from BNAM outputs to be used by the Ocean Parcels code.
- I edited FVCOM fields to ensure all variables needed to run with our particle tracker were present in the files. Some of these had been previously removed for ease of transfer as such files can be very large.
- I edited the Ocean Parcels code in Python to reflect the nature of my data (e.g. fixed mixed layer depth, different spawning times), and debugged it with the help of my research team.

Running Simulations

- I set up FVCOM experiments on the remote servers of Compute Canada. The average time for a 42-day-long simulation experiment with forty thousand particles takes about 8h.
- Different experiments with different start times and numbers of particles were (or are planned to be) run.
- I set up Ocean Parcels experiments to be run via Spyder interface utilising an external drive for storage of data.

Post-processing

- I edited MATLAB code (provided by the research team at Dalhousie) for extracting and plotting data from the FVCOM outputs to work with my own outputs.
- I wrote MATLAB code for plotting of Ocean Parcels outputs based on the original code provided to me by Wendy's student Emma.
- Outputs are currently being analysed to produce a transport matrix and assess the predicted exchange of larvae between different areas of Scotland.

(2) Promoting collaboration between marine researchers in Canada and Scotland

Firstly, this research exchange allowed me to build academic connections with researchers in Nova Scotia which have been essential in the progress of this project. While I was in Canada we held regular zoom meetings with my supervisors at Strathclyde to facilitate the knowledge exchange and collaboration. Now that I am back to my PhD in Scotland, we have scheduled remote calls with Dr W. Gentleman to continue this cooperation. I also continue to be in contact with Dr Gentleman's students and the rest of the Dalhousie team to keep each other updated on the progress of our research and further updates to the models we are using. We are currently exploring the possibility of one of Wendy's PhD students coming to visit the marine research group at Strathclyde in the future.

Throughout the exchange, I also attended weekly journal club meetings which focused on shellfish population modelling which are very relevant to my research. I had the opportunity to discuss with fellow researchers at undergraduate, graduate and faculty level, which greatly enriched my learning experience. In particular, I benefited from the support of Dr W. Gentleman, K. Krumhansl, and Wendy's students who helped debug codes and set up the modelling framework I am using to explore scallop connectivity in Scottish waters. I was able to have very informative discussions with Dr Claudio Di Bacco on the biology of scallops, especially on modelling fecundity and spawning timings. I also shared my knowledge of Scottish scallops, their biology, and typical assumptions we make in modelling with the team. I was given the opportunity to illustrate random forests modelling and their application for habitat prediction to the rest of the team, as well as explaining the steps I took to adapt the model to Scottish scallops. I believe this exchange of information contributed to highlighting some potential obstacles one might encounter when reconfiguring a modelling approach for another species.

Additionally, the outcomes of this research will be presented at the next international Scallops Working Group meeting in October, as well as at the Annual Science Meeting held by MASTS. Strathclyde and Dalhousie research teams also will be working together to publish the results on this project for the benefit of the wider marine community.

(3) Relevance to UN Sustainable Development Goals

This project falls under SDGs 12 (sustainable consumption and production), 13 (action to combat climate change), and 14 (life below water). Scallops are a valuable food and economical resource, and developing models to understand connectivity among scallop beds and testing their applicability across different regions and species is important for sustainable fishing, in alignment with SDG12. The larval simulations provided as outputs from this project give us a better understanding of how scallops grounds are connected to each other. This knowledge should then support policy-makers to legislate in favour of sustainable development and lifestyles, as promoted by SDG13, and to push for change in policies with the aim of safeguarding our oceans, a core goal under SDG14.

The United Nations Framework for Climate Change (UNFCC), and its decision-making body met in Glasgow last year (COP26) to set out international agreements on the sustainable management natural resources under climate change. Scallops, with important fisheries worldwide, are examples of such resources. As with many marine stocks, their resilience to climate change depends in a complex way on environmental factors, making management especially challenging. These factors include not just temperature but, critically, changing oceanic currents. This project outputs include particle tracking models for Scottish scallop stocks. These models have been used to characterise Canadian stocks, allowing for a comparison to be made between the two different species to which they have been applied. Through this, and the ensuing continued collaboration between the Dalhousie and Strathclyde teams, the project will contribute to the legacy of COP26 through the development of transferable modelling tools capable of predicting population level responses under climate change scenarios.

(4) Future Plans

1. Present results at the ICES Scallops Working Group (Oct 4th -7th), and add these to the annual report.
2. Present results at the MASTS Annual Science Meeting (Nov 8th – 10th).
3. Collaboration between Strathclyde and Dalhousie teams to produce a peer reviewed paper on scallops habitats in Scotland and initial conditions.
4. Collaboration between Strathclyde and Dalhousie teams to produce a peer reviewed paper on scallops connectivity.
5. Continue with regular zoom meetings, as well as updates via emails.

6. Explore options for international funding (e.g. NSERC Alliance International, NERC UK-CANADA Globalink doctoral exchange).

(5) Budget

Money from the OFI/SCORE funding was used primarily to support accomodation and travel expenses. Below is a table summarising the expenditure of the £4000 I was granted.

ITEM	COST
Rent in Halifax for May and June	£1417.5
Flights	£656.79
Storage of items in Glasgow	£1885
Admin fee for graduate registration	£70.18
<u>Total</u>	£3999.47

A further $6000 (around £3900) were given to me by Dr. W. Gentleman to help with daily costs (food, transport, medical expenses, university fees, phone bills, etc.) while in Halifax. Of these, around $680 were paid in taxes, so the net stiped I received was around $5320.

Other costs (work permit, rent for July and August, taxi fares to and from the airports, temporary accomodation between connecting flights) were covered using the TSG funds to help with internships from SUPER DTP.

The remaining costs came out of my own personal savings.