Salmon Parasite Interactions in Linnhe, Lorn, and Shuna: Sea lice dispersal model evaluation using an ensemble approach

Meadhbh Moriarty[1], Rory O'Hara Murray[1], Stevie Brain[2], Philip A. Gillibrand[3], Thomas Adams[4], Alexander G. Murray[1]

[1] *Science, Marine Laboratory, Aberdeen, UK - Meadhbh.Moriarty@gov.scot*
[2] *Scottish Association for Marine Science, Dunstaffnage, UK*
[3] *Mowi Scotland Ltd, Fort William, UK*
[4] *Scottish Sea Farms Limited, Barcaldine Hatchery, Argyll, UK*

Continued growth of the blue economy requires a strong scientific evidence base underpinning relevant, timely and fair regulation, developed in consultation with stakeholders. Sea lice are ubiquitous, endemic ectoparasites of salmonids in the North Atlantic Ocean. The potential negative effects of sea lice on wild salmonid fish populations are regarded as one of the most serious limitations to sustainable growth of salmon aquaculture. Due to their planktonic larval stages, lice can be transmitted over distances of several kilometers, so management must focus at the area rather than farm level.

To understand area interactions, in order to mitigate negative effects of sea lice on aquaculture and wild salmonids, coupled biophysical models are used to calculate dispersal rates of sea lice from farms. State-of-the-art hydrodynamic models have been developed, which, when coupled with a biological model, can be used to inform on dispersal rates of sea lice. We evaluated three coupled bio-physical models, each describing sea lice dispersion in Loch Linnhe, Scotland's largest fjordic system and home to around 20 salmon aquaculture sites. We carried out physical model validation and biological inter-model comparison, through comparison with field data. We assessed use of ensemble modelling techniques to provide estimates of uncertainty within the Loch Linnhe system. Relative within-model between-scenario changes resulting from different control strategies or resource constraints in different scenarios were found. Although there were differences between the models in absolute outcomes, model comparisons with the field data provided similar results. This first use of an ensemble approach for sea lice dispersal modelling allows quantification of model uncertainty, providing management and end-user a level of confidence in predictions made by these models.

Modelling brown algae individual growth using dynamic energy budget theory under various climate change scenarios

Cabanillas, Alejandra G[1], Adams, Thomas P [2], Begg, Tracey [3], Burrows, Michael T[2], Speirs, Douglas C[1], and Heath, Michael R[1]

[1] *Marine Population Modelling Group, Department of Mathematics and Statistics, University of Strathclyde – a.g.cabanillas@strath.ac.uk*
[2] *Scottish Association for Marine Science*
[3] *Scottish Natural Heritage*
;

Seaweed forests are a significant feature of coastal ecosystems. They are not only of economic importance, but also play a role in carbon capture, primary production and in creating a structurally complex habitat that enhances biodiversity,. However, there are few models which describe the dynamics of forests.

Here we follow a dynamic energy budget (DEB) theory approach to model the individual growth trajectories of two contrasting species of brown seaweeds - *Laminaria hyperborea* and *Fucus vesiculosus*. Our DEB model tracks the pathways of carbon and nitrogen from environmental uptake thorough to storage and assimilation into new tissue and reproductive structures. Parameters for the models were determined partly from the literature, and partly by fitting the models to experimental data on individual plant growth patterns.

The parameterized models are used to predict the effect of changing environmental conditions on biomass, for both *Fucus* and *Laminaria*. The baseline results for both species are the current environmental conditions in Scotland. The results show that the model can predict the biomass of the individual, both for lifetime growth curves and seasonal fluctuations. The model runs are then repeated for future environmental conditions under the IPSS RCP8.5 emissions scenario, to show how growth and biomass will be affected by the changing conditions that we could be seeing in Scottish water in the near future.

Physiological process-based models such as the one developed here provide a mechanistic alternative to statistical models for predicting changes in species distributions in response to climate change.

Acknowledgements

This studentship has been funded under the NERC Scottish Universities Partnership for Environmental Research (SUPER) Doctoral Training Partnership (DTP) and University of Strathclyde.

Consequence of small-scale sea lice movements on their dispersion: A sensitivity study in Lower Loch Linnhe, Scotland

Soizic Garnier[1], Meadhbh Moriarty[1], Rory O'Hara Murray[1] and Sandy Murray[1]

[1] *Marine Scotland Science – Soizic.garnier@gov.scot*

Sea lice are ectoparasites causing significant problems to fish health and aquaculture costs. The high density of suitable hosts in salmon farms supports a high number of sea lice. Their planktonic larvae can be released back in the surrounding waters where they can infect wild migrating salmon smolts, making sea lice a potentially contributing factor in the decline of wild salmonids in Scotland.

In the context of a Blue Economy vision for Scotland, sustainable salmon aquaculture and conservation of wild salmon are both priorities for Scottish Government policy. This strategy requires the identification of areas of higher risk to wild salmon populations to facilitate the mitigation of sea lice impact.

Coupled hydrodynamic and particle tracking models are widely used to understand sea lice. The transport of a salmon louse is affected by physical processes and biological behaviours like vertical swimming. Parameterisation of these behaviours in particle tracking models is critical to provide a realistic picture of sea lice dispersion in the marine environment.

Here we perform a sensitivity analysis of adult sea lice residence times and distributions to vertical swimming velocity and maximum swimming depth using Loch Linnhe as a case study. In a fjordic system like Loch Linnhe, wind shear and water column stratification create a high vertical shear where vertical position of sea lice affect their horizontal trajectory. However, a review of previous sea lice studies shows no clear consensus on the implementation of these parameters for sea lice vertical movement.

While sea lice modelling has improved during the last 15 years, this study suggests that the use of numerical models for effective management of sea lice would benefit from more observational data to reduce uncertainties derived from the effect of sea lice vertical swimming behaviour.

Numerical modelling of exchange flows through sea straits and across submerged sills

Manel Grifoll[1,2], Alan Cuthbertson[2] and Jarle Berntsen[3]

[1] *Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya (UPC-BarcelonaTech)* *manel.grifoll@upc.edu*
[2] *School of Science and Engineering, University of Dundee, Scotland, UK. a.j.s.cuthbertson@dundee.ac.uk*
[3] *Department of Mathematics, University of Bergen, Bergen, Norway.*

This study presents the application of ocean numerical modeling to gain understanding of the dynamics of exchange flows through sea straits and across submerged sills. The restricted density-driven exchange flows are generated in oceans, seas and coastal margins when adjacent water bodies with different densities are connected by narrow channels (i.e. straits) and/or natural topographic obstructions on the seafloor (e.g. submerged sills). Numerical model simulations, combined with scaled laboratory experiments, have proven to be a powerful tool to help understand the restricted oceanographic flow processes occurring within these complex regions.

We have conducted laboratory-scale numerical simulations using a non-hydrostatic 3-dimensional model (Bergen Ocean Model, referred to as BOM) in both non-rotating and rotating frames of reference (the latter considering Earth rotation effects through inclusion of Coriolis accelerations). These BOM simulations are shown to reproduce the main dynamic flow patterns and density structure of the large-scale exchange flows generated through an idealized trapezoidal sill-channel, with a lower layer saline intrusion (see sill-channel geometry in Figure 1).

The numerical results also show that the saline intrusion flux across the sill is initially reduced and then eventually fully blocked under increasing net-barotropic flow conditions imposed in the counterflowing upper freshwater layer (Grifoll et al., 2022). The BOM simulations are also extended to consider rotating exchange flow dynamics, and demonstrate that the inclusion of Coriolis forces increases the overall blockage of the saline intrusion layer by the upper freshwater layer flow compared to equivalent non-rotating exchange flows. Based on these rotating exchange flow simulations, the numerical results reveal a distinct secondary cross-channel circulation pattern, characterized by Ekman dynamics in the lower dense water layer and the presence of two anticlockwise circulation cells in the upper freshwater layer. The strength and coherence of these secondary flow cells are also strongly controlled in the along-channel direction by the proximity of the overspill at the end of the trapezoidal sill-channel crest, with the significant increase in the densimetric Froude number (i.e. increase in inertial factors) at this location implying a relative decrease in the influence of rotation and dominance of non-hydrostatic flow effects.

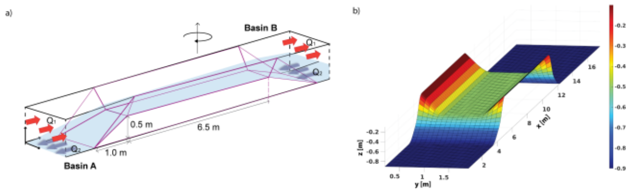

Figure 1. (a) Schematic representation of the trapezoidal channel-sill including counterflowing lower saline Q_2 and upper freshwater Q_1 layers. (b) Numerical mesh used for the BOM simulations.

Acknowledgements

This work is supported by ECOBAYS project (MCIN/AEI/10.13039/501100011033) funded from the Agencia Española de Investigación (Spanish Research Agency).

References

Grifoll, M., Cuthbertson, A., Berntsen, J., (2022). Numerical experiments of uni- and bi-directional exchange flows in a rotating trapezoidal sill-channel Proceedings of the 39 th IAHR World Congress 19-24 June 2022.