Modelling the Impact of Treatment Cooperation in Scottish Salmon Aquacultures

or

Why Altruistic Farming is Unavoidable

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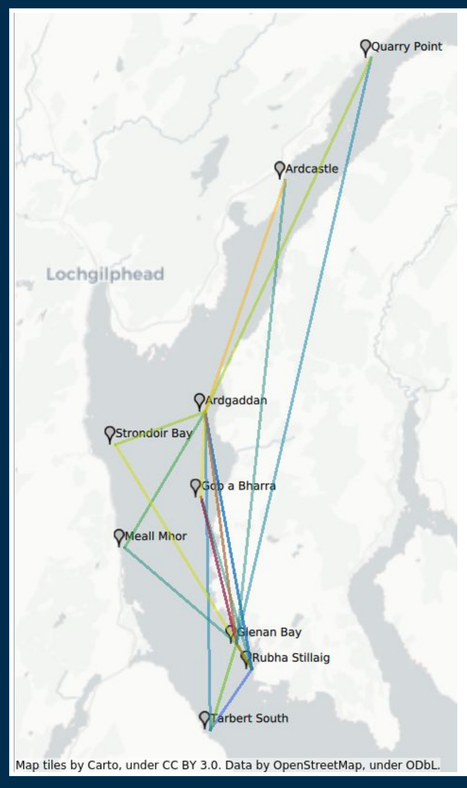
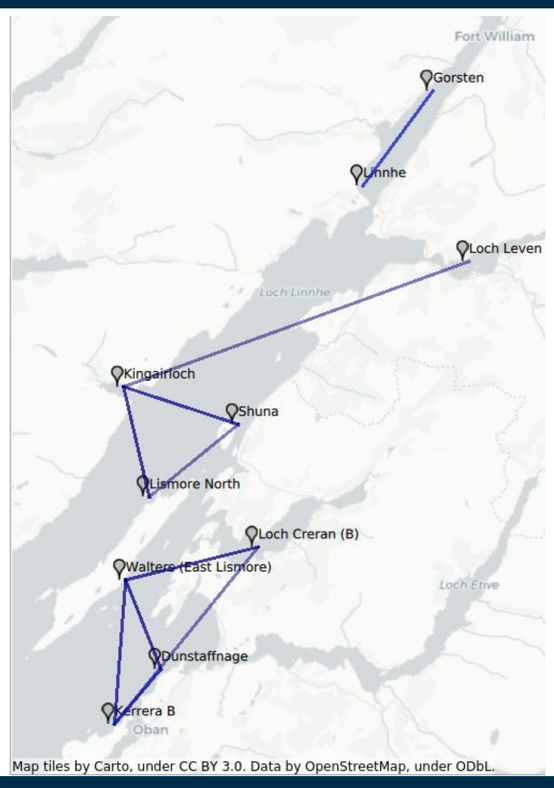
Sea lice infestation represents a major barrier to the sustainability of salmonid aquaculture and, in the context of evolving resistance to treatment and environmental factors, treatment is highly regulated. We have developed a simulation model with the aim of investigating the complex economic-epidemiological-ecological interactions of sea lice, farmed and wild fish, and treatment decisions.





Salmon farming organisations rent a number of sites to individual farmers (agents) who have some freedom in stocking and treating. Farmers must keep lice counts under control.

If farmers **treat**, the lice level decreases but fish welfare may temporarily decrease.
If farmers **do not treat**, the lice level increases. The reservoir behaves like an implicit cage of wild salmon, making previous treatment cycles less effective.

When to treat is key. Fixed thresholds may not work well for inconveniently situated farms. Eg. Rubha Stillaig (Loch Fyne, left picture) is more interconnected with other farms compared to Meall Minor.

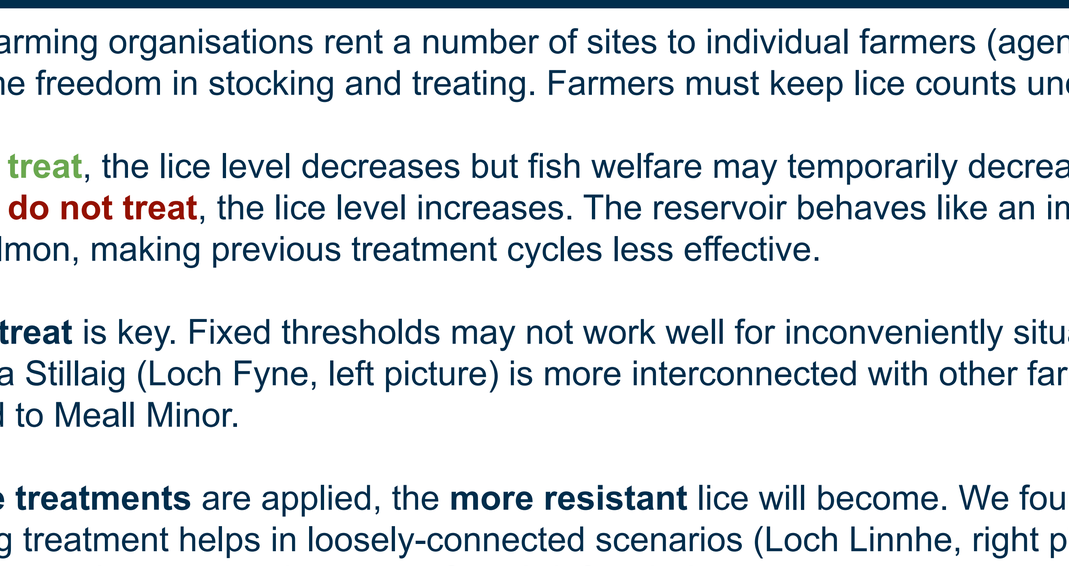
The **more treatments** are applied, the **more resistant** lice will become. We found that alternating treatment helps in loosely-connected scenarios (Loch Linnhe, right picture), and it does in strongly-connected ones too for a brief period.

Model description:

SLIM is an open-source Python model and includes:

- Genotype-based lice population with both Mendelian and mitochondrial genetic transmission mechanisms
- Chemical treatments (EMB) and thermo-mechanical treatments (thermolicer)
- Dynamic external pressure and farm-to-farm lice migrations
- Treatment policies: *bernoullian* (altruistic with probability *p,* bernoullian treatment policy), *mosaic* (round-robin) treatments;
- Lice-induced and treatment-induced fish mortality
- Reward function that factors in salmon welfare and treatment costs

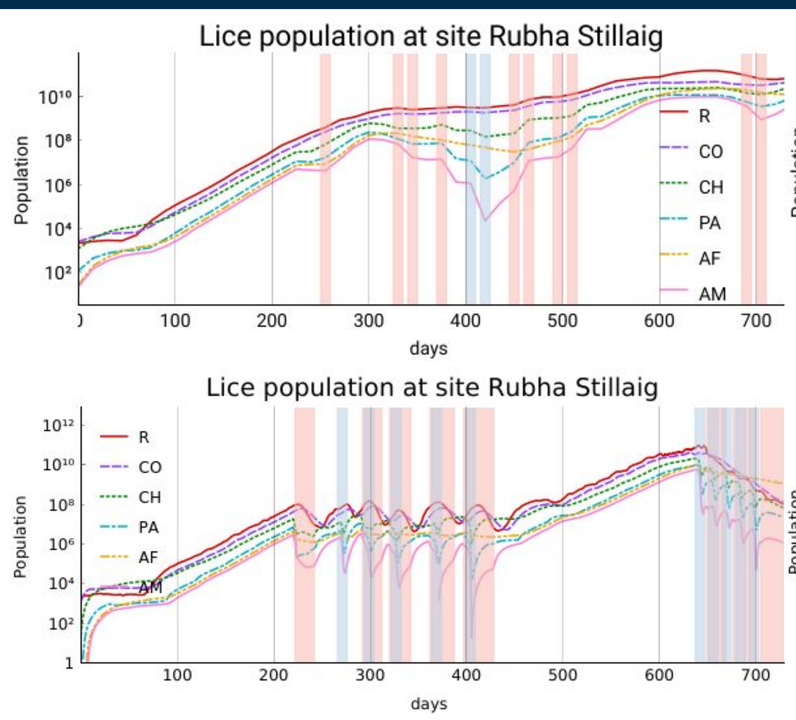
Check it out at slim.readthedocs.io



Preliminary results:

- Repeated applications of EMB drive resistance
- Threshold-based policies may be either excessive or unable to limit the epidemic
- Mosaic farming may do more harm than good if all farmers use the same treatment at the same time
- *Altruistic vertex covering* (everybody treats differently) sounds promising.

Top: egoistic treatment. Bottom: altruistic treatment. In both cases repeated applications of EMB incurs into resistance development.



Conclusion

Treatment drives selection for resistance and coordination between managers is key. We also find that position in the hydrologically-derived network of farms can impact individual farm infestation levels and the topology of this network can impact overall infestation and resistance.
Network topology drives infestation levels in cages, treatments, and hence treatment-driven resistance, thus farmer behaviour may be highly dependent on hydrological position and local level of infestation.

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