DISPERSAL OF AQUACULTURE PATHOGENS – FINDING PARALLELS BETWEEN HEMISPHERES

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SUMMARY

The awarded grant was used to fund a visit by one Scottish researcher seeking new collaborations with Chilean researchers working in the field of biophysical dispersal applied to salmon aquaculture. The visit took place in January 2017. The schedule for the visit was:

Date	Location	Activity
Mon 15/01/2017	IFOP Castro	Initial meeting: focus on IFOP work
Tues 16/01/2017	IFOP Castro	Focus on SAMS (and other Scottish) work
Wed 17/01/2017	IFOP Castro	Define future path, stages, goals, funding sources
Sun 22/01/2017	Travel to Punta Arenas	Continue discussion of goals and context
Mon 19/01/2017	Punta Arenas	Workshop with national researchers and stakeholders

The visit was principally based at Instituto de Fomento Pesquero (IFOP, Putemún-Castro, Chile). Groups at both SAMS and IFOP are engaged in similar activities, namely the application of numerical modelling techniques to provide tools and information aiding sustainable development of the aquaculture industry.

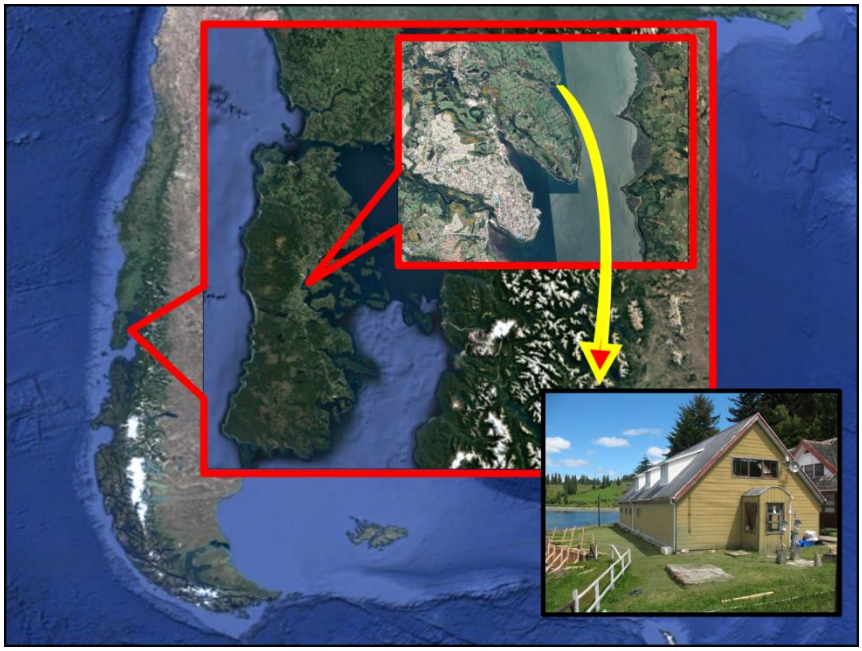

Figure 1: Map showing location of IFOP lab visited.

Figure 2: Castro. (i) IFOP laboratory just outside Castro. (ii) Castro town. (iii) Traditional waterfront "palafitos".

A wide range of stakeholders pay close attention to the impacts of the industry, and the role of (networks of) sites in assisting the spread of pathogens and parasites (Infectious Salmon Anaemia - ISA, and sea lice, for example) has been the subject of intense debate for many years. To allow governmental production targets to be met sustainably, it is therefore essential that sites are optimally arranged with respect to biological connectivity, and that biomass may be allocated appropriately between available sites. To tackle this challenge, researchers in several institutes in the two countries have independently carried out regional modelling and empirical studies, investigating hydrodynamic properties of the water bodies occupied by aquaculture, and how sites may be managed within units to minimise the spread of pathogens and parasites. Studies working towards these objectives have been in progress for over 15 years, with steady advances made in complexity and realism over this time.

There are similarities and differences between the agents affecting the two regions (for example, ISA and sea lice are present in both areas but louse species differs, and the bacteria Piscirickettsia salmonis is found only in Chile). Similarly, the physical environments share common features, but also distinct differences. To take the next steps towards providing validated models able to provide reliable information on the likely impacts of changes to the site network structure, distribution of biomass within it, and alterations to management protocol (coordinated chemical treatments and fallow periods, for example), it is necessary to take a more collaborative approach building upon the experience in both regions. During the visit, we laid the foundations for future work collaboration, identifying similarities and differences between the industry and research environments, and parallels between the research activities in the two regions. We discussed the future direction of work in the two regions and ways in which we might help each other moving forward. IFOP also organised a workshop to which they will invited national collaborators and government stakeholders such as Subpesca (National Secretary for Fisheries Issues).

Figure 3: Punta Arenas, location of workshop meeting on 19/01/2017.

CONTEXTUAL INFORMATION

Chile is the world's third largest producer of marine finfish through mariculture, producing around 5 times as much as Scotland annually (over 700,000 t/yr). Growth of the industry occurred over a similar period to Scotland, beginning to increase rapidly in the mid-1980s and peaking in 2007. The industry was self-managed by producers to this point, with limited government regulation. In 2007, the industry in Chile met with a crisis due to an Infectious Salmon Anaemia (ISA) infection. This cost approximately $800m, and production was reduced by 65%, with 25,000 jobs lost. Sea lice are also present but considered not to pose such a significant issue. Most salmon farming in Chile is in the northern Patagonia region, as indicated in Figure 4. More recently, some development has taken place in fjords in southern Patagonia. The industry is now subject to somewhat increased regulation with respect to new farm sites, but sites existing before new legislation was introduced are not always subject to new restrictions. Aquaculture sites in Chile are managed within "macrozonas" (shown by red outlines on Figure 4). These are intended to assist in the control of ISA spread. Neither ISA levels nor sea lice abundances are reported publically.

Chile has a vast coastline, which is likely to have many locations that are suitable for aquaculture operations. However, much of the coastline is incredibly remote, with no road access and very long boat journeys required. For this reason development has not taken place in central Patagonia. Development of further areas is now much slower due to increased environmental legislation, following the health issues the industry has had to date.

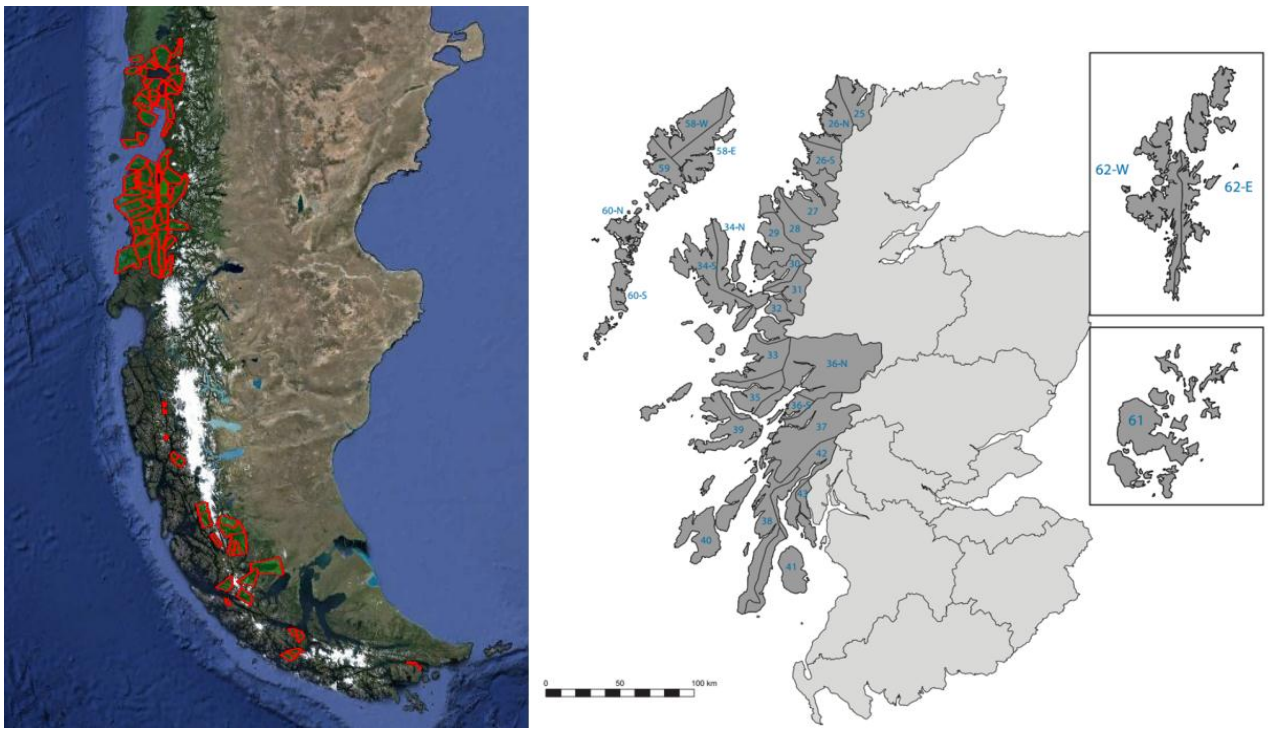

Figure 4: (a) Map indicating currently licenced zones for salmon production in Chile (IFOP). (b) Map of "Fish Health Management Reporting Areas" in Scotland (Scottish Salmon Producers' Organisation).

Scottish salmon production is around 160,000 t/yr. In Scotland industry bodies (e.g. SAIC, SARF, SSPO) show a keen interest in sea lice but ISA is not considered a threat due to there having been no large outbreak in the past. Sea lice are one of the principal environmental concerns relating to salmon production in Scotland, and there have been a number of instances of large outbreaks over recent years. Sea lice abundances at farm sites are published on a quarterly basis by the SSPO, aggregated over large areas. Sites are managed in synchrony within smaller areas known as Farm Management Areas (Code of Good Practice Management Group 2011).

The industry is Scotland covers almost all major loch systems; the limiting factor to development being space, and local acceptance of environmental impacts (real and perceived). The challenge at present entails identifying how to reduce the environmental impact of existing operations, but also (considering the Scottish government's intention to increase production to around 210,000 t/yr) to identify areas where expansion may be possible, or methods to allow increased production while limiting environmental impacts.

CURRENT RESEARCH

The focal topics of work studying pathogen and parasite spread in both countries are determined by a mixture of industry and government-led objectives.

In Chile, the primary concern is Infectious Salmon Anaemia (ISA). The model framework used is MIKE3, with particle tracking carried out using an off-line module supplied by that model's developers. At present, a switch to using Ecolab to model the spread of particles with biological properties is under consideration. The model used does not have open-source (or editable) code, so adding specific features may be limited in some cases. IFOP's model divides the considered domain into a regular array of rectangular cells, computing connectivity (probability of particle movement) between all possible pairs of cells throughout the model domain.

IFOP is largely government funded on a continuous grant, defining overlapping 18 month projects on an annual basis (running January-July the following year. The IFOP group's current project is working to assess macrozona connectivity for ISA. For next year's project, there is the potential to incorporate an objective to redesign macrozonas based on connectivity considerations. ISA biology and environmental dependencies not included in model yet, also not reviewed thoroughly. Lifespan of ISA particles is considered to be 3 days. For ISA,

concentration of infectious particles is the key concern; there is a known threshold for infection of salmon. Some researchers in Chile are interested in sea lice (Caligus sp.) but no such work is planned by IFOP at present.

The model framework used by SAMS (and Marine Scotland Science from 2016 onwards) uses the FVCOM hydrodynamic model (Chen, Beardsley & Cowles 2013). SAMS particle tracking is carried out by an in-house model coded using Java. Particles are released from aquaculture sites within the model domain, with probability of connectivity between each possible pair calculated. These probabilities are aggregated to give estimates of management area connectivity (Adams, Aleynik & Black 2016). Estimated density plumes from each site are also calculated. Environmental dependencies have been studied by various authors (Stien *et al.* 2005; Bricknell *et al.* 2006; á Norði *et al.* 2015) but have not been fully integrated into model. Salinity dependent mortality has been implemented, but not published. Norwegian researchers are further ahead in this respect, having incorporated temperature dependent development and vertical migration (Johnsen *et al.* 2016).

Funding for the Scottish work operates on a project-by-project basis, and SAMS has no automatic funding for this work (it must be applied for competitively from research councils). Marine Scotland Science are a government body, and so have a different situation, with work being defined by government objectives.

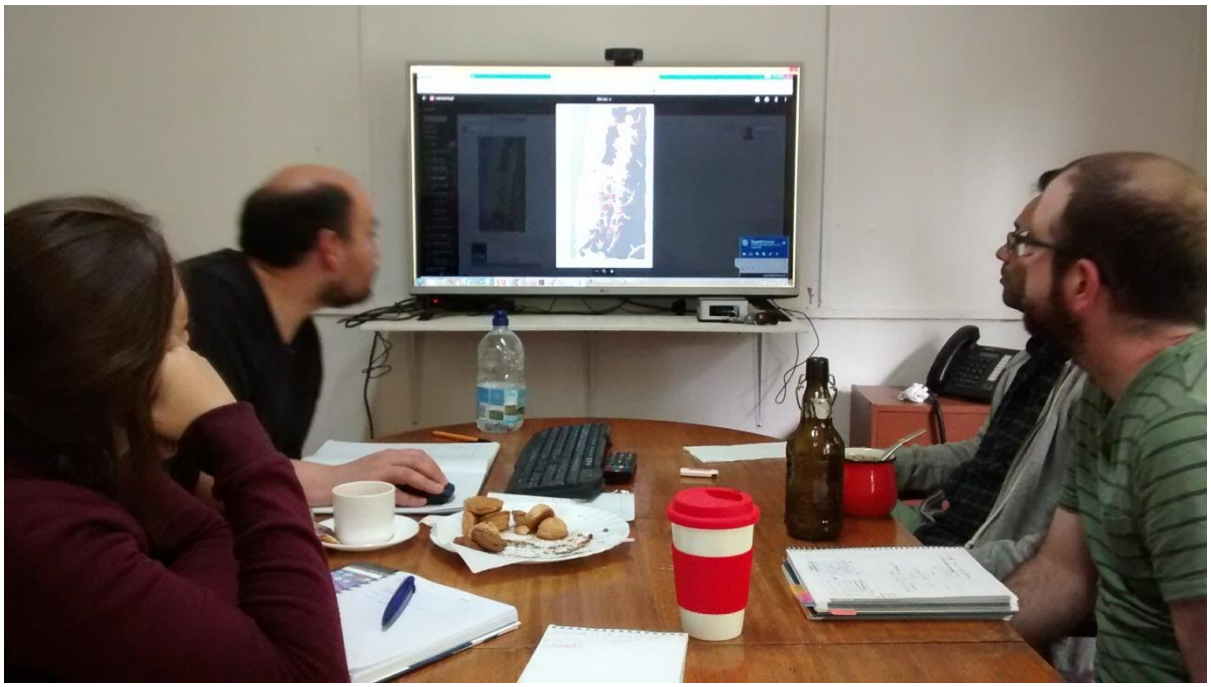

Figure 5: Discussing Chilean work at IFOP.

EXISTING COLLABORATIONS

IFOP researchers actively collaborate with Andres Sepulveda at the Departamento de Geofísica, Universidad de Concepción, working on operational hydrodynamic models (not connectivity work). They also work with Pablo Mata (Centro de Investigación en Ecosistemas de la Patagonia, Coyhaique). Other contacts that they have within the country are Caroline Parada (hydrodynamic modelling, fisheries, connectivity), Diego Narvaez (Concepcion; modelling, connectivity, scallops), and Susana Giglio (Subpesca).

SAMS researchers in Scotland speak regularly with Sandy Murray and Berit Rabe at MSS (Marine Scotland Science). Nabeil Salama has carried out much recent work but has changed department within the organisation. MSS work covers many topics such as sea lice, wild fish (10 year project), SIR models, viruses and spatial management issues (Sandy). We also have links with Ingrid Johnsen, Lars Asplin and others at the Norwegian Institute of Marine Research (Bergen). A meeting between Scottish and Norwegian researchers will take place in February 2017.

SHORT AND MEDIUM TERM OBJECTIVES

The short to medium term objectives for researchers in both countries involved in this meeting are summarised below.

In Chile:

1. How well do firewalls work? Should the firewall system be redesigned?
    a. What is management unit effectiveness?
    b. Also consider sea lice (Chaligus) as well as ISA
2. Assess best locations for new sites (in Magallanes region, for example)
3. Identify whether increasing biomass at existing sites is better than adding new ones
4. Look at options for relocating sites e.g. Aisen fjord
5. Add biological components to tracking model

In Scotland:

1. Assess best locations for new sites
2. Identify whether increasing biomass at existing sites is better than adding new ones
3. Investigate benefits of offshore sites (west coast islands, East Lewis)
4. Assess effectiveness of DMAs for ISA
5. Add biological components to tracking model

It is clear that the main research objectives and questions in both countries are fairly similar, suggesting that continued collaboration will be beneficial to all parties.

AVENUES FOR FUTURE COLLABORATION

Both SAMS and IFOP researchers expressed a desire to improve their connectivity methodology. IFOP researchers are interested in developing pre- and post-processing of their model runs to present connectivity between "macrozonas". Development on this work will depend on the outcome of an EcoLab workshop that IFOP will attend in March to discuss future development and application of their tracking model.

It was suggested that methodology for sea lice and ISA spread simulations, and management area analysis, could be analysed using the same model. Such work has already been carried out in Scotland during the development of the Scottish Shelf Model (see http://www.gov.scot/Publications/2016/03/9472). Sea lice viable dispersal time is much longer than ISA, and management areas that work for sea lice should work very well for ISA. Or are there parts of ISA biology that affect this? Effectiveness of DMAs for ISA prevention has not been studied yet, but this should be possible using a variant on the existing model.

INDUSTRY COLLABORATION

Collaboration with industry partners is likely to be essential, both in order to validate spread patterns and to develop tools that have the highest utility in dealing with industry challenges. Marine Harvest potential collaborator (may contribute data/knowledge). Certain producers have indicated willingness in Scotland to collaborate, and these avenues should be developed further (potentially via Scottish Aquaculture Innovation Centre). In Chile, Sernapesca collect data from fish farms, and could be asked to collaborate on a project/provide environmental data.

PHD STUDENTSHIP

A useful avenue to bring together expertise between different countries might be a shared PhD (or other student) project, with time split between labs. This would allow time for a thorough comparison of the situation in both countries, involvement in modelling in-depth, comparable analysis using same methods in both countries. This could help to fill biological gaps in both models, and develop post-processing of results. Funding is available at IFOP to cover costs of UK students or staff visiting Chile for internship purposes.

UK VISIT

Pablo Reche-García from IFOP will visit Scotland in late 2017 (September/October, for two weeks to one month). Before this meeting, he will generate biophysical model tracking output and bring to analyse working with Tom.

He will stay in touch following a meeting with Ecolab developers (mid-March, with Valentina), as this will determine the biophysical capabilities going forward. It is hoped to apply some of the post-processing used by SAMS to analyse and represent Chilean connectivity output.

During the visit, Pablo will also spend time at Marine Scotland Science in Aberdeen with Sandy Murray's group, building upon the existing links between that laboratory and SAMS, and gaining insight into how biophysical modelling is being applied in the development of aquaculture planning and policy guidelines in Scotland.

Figure 6. From left to right: Gabriel Soto, Pablo Reche, Christian Ruiz, Elias Pinila, Tom Adams.

PARTICIPANTS

IFOP CASTRO COLLABORATION DISCUSSIONS

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Cristian Ruiz
Valentina Besoaín
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PUNTA ARENAS WORKSHOP

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