COMPLETED PROJECT CASE STUDY

THE IMPACT OF FRESHWATER REARING ENVIRONMENTS ON ATLANTIC SALMON HEALTH AND PERFORMANCE: ROBUST SMOLT

PARTNERS

Institute of Aquaculture (University of Stirling) | University of Exeter | University of Aberdeen | Roslin Institute | Centre for Environment | Fisheries, and Aquaculture Science (Cefas) | BioMar | Cooke Aquaculture Scotland, PHARMAQ | Bakkafrost Scotland (formerly the Scottish Salmon Company) | Mowi Scotland | Scottish Sea Farms | Grieg Seafood Shetland

BACKGROUND

Scottish salmon farming is a vital contributor to both the UK economy and global seafood markets. With a worldwide retail value exceeding £1 billion, the sector contributes over £500 million annually to the UK economy and represents 40% of all Scottish food exports. Over the past two decades, exports have increased fivefold, reaching 55 countries worldwide.

As demand continues to rise, Scottish producers have been tasked with sustainably expanding production by 2030. Meeting higher targets depends on both the development of new farming locations and improvements in production efficiency. This, in turn, involves a need for improved survival and health outcomes in farmed salmon.

This project was a collaborative initiative led by the Institute of Aquaculture at the University of Stirling. Key partners included the University of Exeter, the University of Aberdeen, the Roslin Institute, Cefas, Cooke Aquaculture, PHARMAQ and others, each contributing specialised expertise in fish physiology, microbiology, and aquaculture practice.

AIMS

The primary objective of the project was to understand how freshwater environmental conditions - including water chemistry, temperature, photoperiod, and nutrition - impact fish health and performance, particularly in Recirculating Aquaculture Systems (RAS) compared to traditional open-water loch systems.

The project aimed to generate novel scientific insights into the physiological consequences of modern RAS systems, supporting sustainable industry welfare practices.

Specific objectives included:

1. Characterising the gut microbiome and its role in early immune development;
2. Investigating the effects of water chemistry, especially CO_2 levels, on early growth and later sea performance;
3. Assessing how photoperiod, diet, vaccines, and rearing systems affect smolt immune function;
4. Examining how freshwater rearing influences seawater performance and disease susceptibility;
5. Studying genotype-environment interactions across freshwater environments;
6. Conducting epidemiological assessments of disease prevalence linked to early rearing conditions;
7. Supporting Early Career Researchers through interdisciplinary training;
8. Implementing effective knowledge transfer strategies with industry partners.

PROJECT OVERVIEW

The project was structured into five interconnected work packages (WPs):

- Work Package (WP) 1 focused on the gut microbiome and mucosal barriers, exploring their interactions with early-life health under different rearing systems and their impact on lifelong immunity.

- WP2 examined how freshwater chemistry in RAS environments, specifically CO_2, affects physiology and performance, with experiments conducted in both laboratory and commercial settings.

- WP3 studied smoltification, particularly the influence of photoperiod, diet, and vaccines on immune function and growth.
- WP4 evaluated the long-term impacts of freshwater rearing on health and performance at sea, including susceptibility to diseases such as AGD, PGD, and sea lice, as well as the effect of genotype on health and performance.
- WP5 aimed to integrate early-life health data across environments to identify epidemiological patterns in salmon populations, though this was hindered by external factors.

RESULTS

The research revealed clear physiological differences between smolts reared in RAS and those from loch systems. RAS-reared fish displayed altered osmoregulatory markers, including ATPase and chloride levels, as well as changes in blood biochemistry. In salmon parr exposed to levels of carbon dioxide found in RAS systems, suppressive effects were seen on the expression of various genes with roles in immune function in the spleen.

Microbiome analyses showed that the skin, gill, and gut microbial communities were highly dynamic and influenced by early freshwater exposure. In RAS systems, gut microbial richness increased over time but declined after transfer to seawater. On the skin and gills, microbial composition was heavily influenced by tank water, particularly by the dominance of Hydrogenophaga, a denitrifying bacterium that affected microbial diversity.

Upon transfer to seawater, microbial communities on the gills and skin shifted significantly, suggesting a need for plasticity to adapt to new environments. In contrast, open-loch systems saw declining microbial diversity but increasing dominance of core taxa over time, suggesting a stabilisation of the mucosal microbiome.

Fish from RAS environments showed lower baseline immune gene expression in gills two weeks post-transfer, but mounted a stronger immune response when challenged with viral pathogen-associated molecular patterns (PAMPs), indicating latent immune potential.

Genetic analyses revealed that RAS-reared fish were smaller but more uniform, with higher heritability across traits. Loch-reared fish exhibited wider variability and lower heritability estimates, indicating stronger environmental influence. Genotype-by-environment interactions were observed, particularly in body weight, reinforcing the importance of considering early rearing conditions in breeding programmes.

The COVID-19 pandemic disrupted field trials, staff availability, and data collection, particularly affecting WP5. Restrictions limited access to sites, delayed recruitment, and led to the inability to complete some trials as designed, affecting project delivery.

IMPACT

The project's findings are expected to inform industry practices that enhance fish health and immune function through early freshwater conditioning. These insights are crucial for developing new husbandry protocols, health strategies and feeding regimes that support the competitiveness and sustainability of aquaculture in the UK.

Economic beneficiaries include salmon producers, who will gain tools to improve productivity and reduce losses. With farmed salmon contributing significantly to the UK diet, the project also supports public health through the stable supply of omega-3-rich food.

Academic partners benefitted from access to industry facilities and expertise, enhancing future research capacity and training opportunities. The consortium's collaborative model strengthens the UK aquaculture research community and aligns with the goals of ARCH-UK, promoting resilience and innovation across the sector.

FURTHER READING

- Press release: RAS-raised Atlantic salmon smolts are smaller but grow quickly as post-smolts: study - Hatchery International
- Marlene Lorgen-Ritchie, Tamsyn Uren Webster, Jamie McMurtrie, David Bass, Charles R Tyler, Andrew Rowley and Sam Martin (2023): 'Microbiomes in the context of developing sustainable and intensified aquaculture'. Frontiers in Microbiology 14 – 2023.
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- Lorgen-Ritchie, M, Chalmers, L, Clarkson, M, Taylor, JF, MacKenzie, S, Migaud, H & Martin, SAM 2024, 'Impact of freshwater rearing history on Atlantic salmon gill response to viral stimulation post seawater transfer', Fish and Shellfish Immunology, vol. 150, 109653.

- Lorgen-Ritchie, M, Chalmers, L, Clarkson, M, Taylor, JF, Migaud, H & Martin, SAM 2023, 'Time is a stronger predictor of microbiome community composition than tissue in external mucosal surfaces of Atlantic salmon (Salmo salar) reared in a semi-natural freshwater environment', Aquaculture, vol. 566, 739211.
- Lorgen-Ritchie, M, Clarkson, M, Chalmers, L, Taylor, JF, Migaud, H & Martin, SAM 2022, 'Temporal changes in skin and gill microbiomes of Atlantic salmon in a recirculating aquaculture system – Why do they matter?', Aquaculture, vol. 558, 738352.
- Lorgen-Ritchie, M, Clarkson, M, Chalmers, L, Taylor, JF, Migaud, H & Martin, SAM 2021, 'A Temporally Dynamic Gut Microbiome in Atlantic Salmon During Freshwater Recirculating Aquaculture System (RAS) Production and Post-seawater Transfer', Frontiers in Marine Science, vol. 8, 869.