Institution: University of the West of Scotland		
Unit of Assessment: 7: Earth Systems and Environmental Science		
Title of case study: Improving Health and Welfare of Animals in Aquaculture		
Period when the underpinning research was undertaken: 2016 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Mhairi Alexander	Senior Lecturer	2015 - 2020
Prof Fiona Henriquez	Professor	2005 - 2020
Dr Iain McLellan	Senior Lecturer	2015 - 2020
Prof Brian Quinn	Professor	2013 - 2020
Prof Katherine Sloman	Professor	2010 - 2020
Period when the claimed impact occurred: 2016 - 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

University of the West of Scotland's ground-breaking research has resulted in (i) the use of a pioneering fish health management model based on rapid, non-lethal blood testing to shape husbandry practices (various Scottish and multinational salmonid companies), currently being commercialised through Scottish Enterprise funding; (ii) adoption of a protocol to automatically assess attractability of shrimp feeds (Skretting), used globally to test feed attractants and (iii) adoption of less stressful transport methods within the ornamental trade which globally transports approximately 35,000,000 pet fish annually (Pets at Home, Mars Inc.). Ensuring the health of aquaculture animals (approximately USD250,000,000,000 globally) has important sustainability, economic and ethical implications.

2. Underpinning research

The research team at UWS (**Quinn**, **Henriquez**, **Sloman**, **Alexander**, supported by post-doctoral fellows **Barisic**, **Currie**, **Van**, **Rezvy**) have worked with the Scottish and international (Norway, Spain, Ireland) aquaculture industry since 2016 to develop and implement a novel **pro-active health management model** based on continuous and rapid health assessment through blood clinical chemistry. This revolutionary approach - a game-changer for the aquaculture industry - reduces dependence on slow, lethal histopathology, enabling data-informed husbandry decision-making and facilitating predictive health forecasting. The science underpinning this novel approach involved the repurpose and validation of human medical high throughput clinical chemistry instruments and kits for use on fish serum. Linear ranges and background levels for 30 biomarkers enable clinical interpretation via machine learning algorithms and the development of early warning signals for health. This approach identified the cumulative effect of chemical sea lice treatment on aquaculture reared rainbow trout, resulting in intravascular haemolysis and chronic kidney injury **[3.1]**. **Henriquez** and PhD student **MacPhail** established that *Neoparamoeba* species – the causative agent of **amoebic gill disease** (AGD) - harbour potentially pathogenic bacteria, such as *Vibrio,* which may influence the outcome of disease **[3.2].** In terms of the treatment of AGD - which affects the aquaculture industry on a global scale - this research is ground-breaking, as it will influence the drug discovery pipeline in AGD.

In shrimp aquaculture, (global value in 2018 of USD39,000,000,000), feed attractants ensure shrimp find food quickly to reduce food wastage. Evaluating novel attractants is time consuming thus the team involved in this research (**Sloman**, **Alexander**, **Alcaraz-Calero** (UWS Computing UOA11), PhD student **Bardera**) were approached in 2016 by Skretting ARC (Norway) to develop a novel **protocol to automatically assess attractability of shrimp feeds** based on shrimp behaviour. We provided an in-depth understanding of shrimp behaviours, identifying moult status, periods of feed-deprivation and sex as confounding factors when designing nutritional trials, due to the influence of these factors on behavioural variability **[e.g. 3.3].** The team validated a commercially-available software against manual behavioural observations, demonstrating its ability to distinguish responses of shrimp to different attractants **[3.4].** The team additionally demonstrated

how, within groups of shrimp, social interactions can affect feeding behaviours. This research underpins the protocol that will now be implemented on a commercial scale (Impact section).

An estimated 35,000,000 pet fish per year are farmed globally and transported live. The transportation of fish to and within the UK is the greatest welfare concern within the ornamental fish trade. Identifying **less stressful transport methods** therefore has significant welfare and economic impacts. UWS research (**Sloman**, **Henriquez**, **Alexander**, **McLellan** and PhD student **Vanderzwalmen**) documented conditions experienced by ornamental fish during commercial transport, including water quality and fish behaviour at each stage from international aquaculture farms, through to UK pet stores. This was done in collaboration with Pets at Home, the UK's largest pet retailer and the WALTHAM Centre for Pet Nutrition (part of Mars Inc.). We identified areas for welfare refinement, trialling the use of fish tank water treatments **[3.5]** and enrichment which both had positive effects on welfare.

3. References to the research

3.1 Barisic, J., Cannon, S., **Quinn, B.,** (2019) Cumulative impact of anti-sea lice treatment (azamethiphos) on health status of Rainbow trout (*Oncorhynchus mykiss*, Walbaum 1792) in aquaculture. *Scientific Reports*, 9: 16217. https://doi.org/10.1038/s41598-019-52636-1.

3.2 MacPhail, D., Koppenstein, R., Maciver, S.K., Paley, R., Longshaw, M., **Henriquez, F.L**., (2020) *Vibrio* species are predominantly intracellular within cultures of *Neoparamoeba perurans*, causative agent of Amoebic Gill Disease (AGD). *Aquaculture,* 532: 736083 https://doi.org/10.1016/j.aquaculture.2020.736083

3.3 Bardera, G., Owen, M.A.G., Pountney, D., **Alexander, M.E., Sloman, K.A.,** (2019) The effect of short-term feed-deprivation and moult status on feeding behaviour of the Pacific white shrimp (*Litopenaeus vannamei*). *Aquaculture* 511: 734222. https://doi.org/10.1016/j.aquaculture.2019.734222

3.4 Bardera, G., Owen, M.A.G., Facanha, F.N., Alcaraz-Calero, J.M., **Sloman, K.A., Alexander, M.E.,** (2020) Assessing feed attractability in Pacific white shrimp (*Litopenaeus vannamei*) using an automated tracking software. *Aquaculture* 529: 735692. https://doi.org/10.1016/j.aquaculture.2020.735692

3.5 Vanderzwalmen, M., Edmonds, E., Carey, P., Snellgrove, D., **Sloman, K.A.,** (2020) Effect of a water conditioner on ornamental fish behaviour during commercial transport. *Aquaculture* 514: 734486. https://doi.org/10.1016/j.aquaculture.2019.734486

Grants

3.A Quinn, B., **Henriquez, F.L**., *Development of diagnostic techniques to assess fish health and the impact of sea lice treatment in aquaculture*. SAIC (Scottish Aquaculture Innovation Centre). 2016 to 2018, GBP94,457.

3.B Quinn, B. *Investigation into the causes of failed fish in Rainbow trout*. SAIC (Scottish Aquaculture Innovation Centre), 2018, GBP69,846

3.C Quinn, B., **Henriquez, F.L**., *Development of high throughput Immunology and haematology techniques to assess fish health in aquaculture*, BBSRC (Biotechnology and Biological Sciences Research Council), October 2018 to March 2020, GBP178,391

3.D Quinn, B., Henriquez, F.L., **Sloman, K.A**., *To develop in-house diagnostics and fish health assessment knowledge and capability in support of rapid business expansion*, Innovate UK KTP, May 19 to Apr 22, GBP185,459

3.E Quinn, B., Henriquez, F.L., Alexander, M., *Development of rapid diagnostics to assess fish health for the aquaculture sector,* Scottish Enterprise, High Growth Spinout Programme, December 2019 to March 2021, GBP191,000.

3.F Quinn, B., **Alexander, M.E.**, *The clinical significance of blood biochemical parameters as a rapid diagnostic indicator of health status in salmonid aquaculture*, CEFAS SIF (Seafood Innovation Fund). February 2020 to September 2021, GBP200,775.

4. Details of the impact

Impact for Salmonid Aquaculture

The industry partners supporting our **pro-active healthcare model** cover 100%, 43%, 9% and 66% of salmon production in the UK, Norway, Chile and Canada (respectively), collectively contributing 93% of global salmon production (USD15,400,000,000), demonstrating the wide-scale international importance of this model. This approach forms the basis of the fish healthcare programme at Kames Fish Farming, (internationally renowned producers of steelhead trout since 1972) established through an Innovate UK KTP project. In Kames, data-informed husbandry decisions are currently shaping fish handling and sea lice treatment events **[evidenced in 3.1]**, estimated to result in cost savings and yield improvement contributing GBP280,000 per year to profit. We recently used this approach to diagnose a hitherto unknown source of mortality (heart failure) enabling successful treatment. This approach is also helping Kames reduce mortality related to failed fish syndrome by up to 10% per cycle, resulting in significant economic and welfare benefits **[5.1]**. Every Scottish salmon producer is involved in the Seafood Innovation Fund project. The Scottish Salmon Company actively use clinical chemistry to inform husbandry decisions and are currently involved in 3 research projects with UWS, including a BBSRC-funded project involving the re-purpose of Nova Biomedical StatStrip point of care haematology analyser for rapid on-site haemoglobin (Hb) and haematocrit (Hct) measurement to indicate anaemia, replacing the more time-consuming micro-centrifugation method **[5.2].** Both Grieg Seafood **[5.3]** and Scottish Sea Farms **[5.4]** highlight the impact of this approach on fish health assessment in Scotland and internationally. This research is currently being commercialised through the Scottish Enterprise High Growth Spinout Programme (spinout September 2021), was a finalist in the Converge Challenge entrepreneurial competition (2020) and won the European Aquaculture Society Innovation Forum (2019) **[5.5]**.

The recent publication **[3.2]** with Fish Vet Group allows industry to improve and refine drug screening programmes for AGD. Matt Longshaw **[5.6]** from Fish Vet Group quotes: *"This groundbreaking work enables the veterinary drug discovery industry to improve drug molecule screening programmes"*.

Impact on Shrimp Aquaculture

Our research into the welfare and behaviour of shrimp in aquaculture led to the development of **an automated system for testing novel shrimp feeds** in collaboration with **Skretting**, the global leader in aquaculture feed production. The development of a suitable test arena, and identification of key shrimp behaviours that could be easily measured as proxies for feed consumption, allowed the design of a protocol that could be used to test novel diets.

As stated in their testimonial: *"the method developed by the UWS team will be used by Skretting within our Chinese shrimp research centre to evaluate raw materials for the best performing attractant properties".*

The upscaling of this protocol at their China research station was planned for March 2020 but has been delayed by Covid-19 travel restrictions. Feed represents approximately 50% of total production costs for shrimp aquaculture, and, as evidenced from their testimonial, as '*Skretting produces over 600,000 tonnes/yr of shrimp feed in South America alone [our work can] impact the quality and profitability of Skretting's global shrimp feed operations and contribute to the more efficient*

and sustainable use of formulated shrimp feeds' **[5.7].** As a result of the work, a member of the research team (Bardera, PhD student) was awarded a Nutreco Young Researcher Prize for outstanding research efforts to address the challenge of generating enough food for the world's growing population and a Scottish Universities Life Sciences Alliance (SULSA) travel award to work with Skretting China.

Impact on Ornamental Fish Retail Industry

Adoption of far less stressful transport methods by the UK's leading pet retailer, Pets at Home, was a direct result of our research into the welfare of fish within the ornamental trade. Working with the WALTHAM Centre for Pet Nutrition (part of Mars Inc.), Pets at Home and Aquasense (UK fish wholesaler for Pets at Home) we demonstrated the welfare benefits of a fish tank water treatment and enrichment during fish transport. The water conditioner is now used by wholesalers prior to transport and discussions are ongoing between these industries about how the water treatment could be utilised more widely on a national and international scale. While unwilling to release any sensitive commercial information regarding further developments in this area, including testing of new products, WALTHAM provided the following statement: "*Obtaining scientific evidence about a new product yields greater credibility for sales and marketing and an overall wider knowledge of the product itself beyond our in-house laboratories. Having research for any product from a reputable organisation such as University of the West of Scotland is a powerful tool for our business*". **[5.8]**

5. Sources to corroborate the impact

Pro-active healthcare model for the Scottish salmonid industry
5.1 Testimonial from Kames fish farm.
5.2 Testimonial from Scottish Salmon Company (SSC)
5.3 Testimonial from Grieg Seafood
5.4 Testimonial from Scottish Sea Farms (SSF)
5.5 European Aquaculture Society 'Innovation Forum' winner certificate
5.6 Testimonial from Fish Vet Group

Automated system for testing novel shrimp feeds
5.7 Testimonial from Skretting

Adoption of less stressful transport methods
5.8 Testimonial from WALTHAM Centre for Pet Nutrition