Proposal for E^3 PhD studentship

Title: Development of novel analytical and molecular techniques for the investigation of finfish aquaculture impacts and validation of the depositional model "DEPOMOD"

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Project background

Marine finfish aquaculture operations are one of the fastest growing sectors in the food industry. There has been significant growth, particularly in Atlantic salmon farming, with aquaculture currently accounting for 50% of global fish consumption worldwide[1], and demand predicted to expand by another 50% by 2020[1]. However, the consequence of this growth is an increasing level of concern regarding the environmental impacts of aquaculture operations worldwide, emphasising the need for adequate management measures. The most significant form of waste arising from aquaculture production is particulate organic waste in the form of uneaten food and faeces. The waste material causes a net influx of organic carbon and nitrogen onto the seabed in close proximity to the fish cages. Minimising the deposition of waste below aquaculture sites has become a crucial element in the monitoring and regulation of marine aquaculture operations around the world to ensure sustainable development of the industry. This has led to the development of a number of models to allow prediction of the impact of depositional waste, notably the commercialized aquaculture waste modelling suite referred to as DEPOMOD.[3]

DEPOMOD was developed for use by industry, consultants and regulatory agencies to improve the predictive capabilities of the impacts of aquaculture operations on the benthos, as well as improve the objectivity in the regulatory decision making processes. It is currently used as a tool for risk based management of finfish aquaculture throughout the world. The distinction of DEPOMOD comes from the validation of parameters through comparison with field observations.[3] These are usually based on sulphide measurements as an indicator of carbon enrichment, due to reduced oxygen concentrations and enhanced sulphate reduction under increased carbon deposition. The relationship between carbon enrichment, sulfide levels, and the biodiversity of benthic infauna organisms is thought to be generally understood. Low level fluxes of organic material can have both positive and negative impacts on the biodiversity of fish habitat. However, at high flux rates, it is generally accepted that organic material is likely to cause a harmful alteration in fish habitat, a reduction in biodiversity, and changes in benthic species composition.

Although DEPOMOD is generally accepted to be the best model available for impact prediction, some studies have indicated that at high organic load, and therefore highest potential impact, DEPOMOD may be limited and uncertainties around fish feed waste need to be more fully investigated[5]. This studentship project will add novel aspects to the assessment of finfish aquaculture impacts by providing field data on a range of new parameters aimed to enhance the validation of DEPOMOD and provide new impact indicators that regulatory bodies could utilise.

A great deal is now known about impacts on larger benthic fauna, but sulphate reduction and decomposition of organic compounds is carried out by key microbial populations, and relatively little is known about the impact on these microbial communities, and the biogeochemical processes they drive. MSc dissertation projects carried out in Professor Hatton's group have shown that methane production by distinct groups of Archaea can be detected under and around salmon farms, even in early stages of the 2-year production cycle. This supports a previous modelling study which suggested that by the end of a finfish production cycle methanogenesis could account for 89% of the carbon flux beneath the farm[4]. Despite this significant hypothesis, our data is the first to quantitatively measure methane production through both gas chromatography and functional gene analysis, further highlighting the need for proper assessment of the impact of finfish aquaculture on key biogeochemistry processes.

Research by Professors Hatton and Black at SAMS have also been assessing the use of astaxanthin to determine the amount of fish food waste coming from the farm. Astaxanthin is a pigment added to food in high concentrations which is broken down in the gut of the fish. Methanogenesis is an indicator of low oxygen and high carbon load and astaxanthin is an indicator of undigested feed pellets, therefore measurements of these parameters, used in combination with standard sulphide measurements, would allow a more complete multidimensional approach to the validation of DEPOMOD and provide exciting and novel aspects to the studentship.

Key research questions: This research studentship will address three broad questions allowing us to not only assess an important environmental question from an end-user perspective, but to enhance fundamental understanding of the impacts of finfish aquaculture on local microbial communities and biogeochemistry:

1. Can astaxanthin be used as an indicator of fish feed wasted over a two year finfish aquaculture cycle?
2. What is the impact of finfish aquaculture on methanogenesis over a two year cycle and can this be used as an indicator for high carbon load?
3. How will the sediment microbial population change over a 2-year cycle and what are the implications for key biogeochemical processes?

Methodology: The student will spend the first 6 months learning techniques, running test samples and writing their literature review, with the following 2 years dedicated to field sampling and analysis. Work will be conducted at the Scottish Seafarms' site B in Loch Creran, which will start its two year cycle in spring 2016. Benthic cores samples will be collected every 2 months over the cycle using DEPOMOD derived contours to allow a temporal, vertical and horizontal analysis of the sediment. All cores will be analysed for standard parameters: solid, water content, organic carbon, nitrogen and sulphide, using standard analytical techniques. In addition sample will be collected and analysed for pigments, including astaxanthin by HPLC, methane by GC and quantification of functional genes by qPCR. Additional samples will be collected to assess microbial diversity through sequence analysis should we successfully obtain additional funds (see below). All data can then be cross referenced against predicted outputs from DEPOMOD for this site and used as part of a model validation exercise.

Training: This studentship will be located in the microbial biogeochemistry group at SAMS, providing the student with the opportunity to work closely with experienced researchers. The student will be trained in a range of fieldwork, analytical and molecular techniques. Model parameterisation skills are not required, as DEPOMOD is a well-established model, but the student will compare field data to the outputs of the model, and so will be trained in basic modelling skills through an introductory course run at SAMS. The student will also acquire a range of transferable skills including project and time management, experimental planning, data analysis and professional development skills. The combination of specialist facilities and expertise at SAMS and Edinburgh is unique within the UK and will provide the student with a stimulating environment and valuable training opportunity.

Requirements: The student should have, or be expect to obtain, a first class or upper second-class honours degree in an appropriate discipline, such as biology, chemistry or marine science, and have an interest in marine impacts and end-user engagement. They should demonstrate an aptitude for careful laboratory practice and analysis, and interest in cross-disciplinary science.

References: (1) World aquaculture 2010, Technical Paper. No. 500/1. Rome, FAO.2011. 105 pp; **(2)** Cromey *et al.* 2002, Aquaculture 214, 211-239; **(3)** Currie *et al*., 2013, Canadian Technical Report 3027; **(4)** Brigolin *et al*., 2009, MEPS 388, 63-80.

Summary Development of novel analytical and molecular techniques for the investigation of finfish aquaculture impacts and the validation of the classic depositional model "DEPOMOD".