Exploring community perceptions of Scottish fin-fish aquaculture

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Full Abstract
The fin-fish farming industry in Scotland is expanding, aiming to double production by 2030. However, concerns have been raised by advocacy and conservation groups over this expansion, with numerous petitions, campaigns, and some legal challenges, resulting in the perception that Scottish fin-fish farming is no longer socially acceptable. A qualitative, grounded, case study approach was taken to explore this perception in-depth, using the theoretical framework of social license to operate. The Isle of Lewis and Harris and the county of Argyll and Bute were chosen due to their shared maritime cultures, the prominence of fin-fish aquaculture, and cultural and socio-economic differences between them. Thematic analysis of semi-structured interviews shows that perceptions of fin-fish farming are complex and influenced by several elements including; identity and place attachment, community benefits, and industry-community relationships. Perceptions of the current identity of the industry appeared to be shaped through comparisons with its historic structure and embeddedness in community, with some advising that the current industry has moved too far from its original form. The increasing scale of the industry was also highlighted as contentious. Juxtaposed with this was the pragmatic recognition of the benefits that are provided such as employment and sponsorship schemes do provide incentive for communities to accept fin-fish aquaculture in their areas. The interviews also made clear the role that place attachment can play within community-industry relationships, with the fish-farming industry portrayed as outsiders to the local community. Using a grounded theory approach provided insight into the nuances of how opposition to fin-fish farming can arise including how elements, such as place attachment, can be influential in forming such perceptions. Understanding these influences could help ensure fairer marine spatial planning and sustainable fish farming expansion.

Twitter Abstract
Using qualitative methods to examine the social license of Scottish fish-farming shows that perceptions of fish-farming are complex and are tied to community identity, the history of the industry and the relationship and benefits shared between industry and communities. (Twitter name @ellieford_)

Acknowledgements
I would firstly like to thank all the participants who gave them time and knowledge to this project. Secondly, thanks must be extended to the other authors, who as my supervisory panel have helped enormously in the development of my PhD. Finally, thanks must also be given to the funders, the European Social Fund and the Scottish Funding Council.

FUNCTIONAL STUDIES OF MUCOSAL GILL HEALTH IN ATLANTIC SALMON (*Salmo salar*)

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Tweetable Abstract

Understanding gill health in Sea farmed Atlantic salmon, gross scoring does not represent the transcriptome and histopathology Can machine learning predict histopathology? **#MASTSasm2020.**

Abstract

There is a growing interest in gill health of economically important species such as Atlantic salmon (*Salmo salar*). Numerous pathogens and environmental factors including sea temperature increase are contributing to inflammation of the gills in farmed (aquacultured) species. The underlying causes of gill inflammation are poorly understood and the terms "Complex Gill Disease" (CGD) and "Proliferative Gill Disease" (PGD) are now being put forward to refer to this multifactorial condition. Marine stage farmed salmon are assessed weekly for PGD by gross scoring. To identify potential biomarkers associated with gill health a BioBank of gill arches has been generated from Atlantic salmon sampled from three marine sites in Scotland. Whole transcriptome profiling revealed a large number of candidate genes consistently altered expression in relation to the histopathological scores for the gill sample of origin. A panel of significant genes were selected for real-time qPCR assay development. These potential biomarkers demonstrated a strong correlation between the expression values from RNA-seq and the fold changes from qPCR. Multivariate analyses revealed that gross scoring does not reflect the underlying complexity of gene expression and histopathology. Using a predictive modelling approach, the genes of interest were analyzed to determine if gene expression can predict histopathology. The outputs of this research will contribute to improved salmon gill health management.

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Egg quality determinants in Lumpfish (*Cyclopterus lumpus. L*)

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There is increased commercial interest in the production of Lumpfish (*Cyclopterus lumpus*, Linnaeus, 1758) as a biological control for sea lice infections in Atlantic salmon (*Salmo salar*). To ensure sustainability, reliable captive broodstock management is required however many aspects are still unknown. A key component in closing the life cycle of any species is improving survival within the egg. Thus determining the components that affect egg quality is a key step in improving the sustainability of any captive breeding program. At present, several small lumpfish broodstocks have been produced for scientific purposes, but none have yet been on a commercially significant scale, with many failing to produce significant numbers of juveniles.

The present study attempts to assess the current difference in egg quality between wild and captive broodstocks. Egg samples and quality data have been collected from Norwegian wild (n=40) and Captive Scottish (n=44) stocks. There was a significant difference between wild and captive egg performances at all stages (fertilization, eyeing and hatch rates). There was high variation in hatching success in wild batches (0%-75%), whereas the majority of captive eggs did not reach hatching (6/44), those that did, hatching rates were significantly lower than wild eggs.

There was significant compositional difference between wild and captive stocks at the point of stripping, in lipids, fatty acids, minerals and pigments. The captive eggs were deficient in EFA's such as EPA and DHA as well as overall lipid levels 1/3rd lower than the wild stocks. The captive eggs were deficient in 8/12 measured minerals and overall pigment levels were 1/3rd of those in the wild stocks.

Lumpfish eggs are characterized by a high level of neutral lipid fraction similar to those found in other species which exhibit lipid globules within the egg, and high levels of pigmentation were found within the eggs, with large levels of variation of individual pigments, which appear to reflect the observed natural variation found in wild caught fisheries.

A Principal component analysis was conducted to determine egg composition relationships with hatching rate, a total of 139 different nutritional components were analyzed in this way. A total of 52 nutritional components were identified as having strong positive or negative relationships with the component associated with hatching rate (>0.5, <-0.5). A total of 49 nutritional components were identified as having significant positive or negative relationships with hatching rate. EFA's such as EPA and DHA and Total N- 3 PUFA showed strong significant positive relationships with hatching rate as well as levels of saturated FA's such as 16:0. High levels of N-6 PUFAS especially ARA were strongly associated with poor egg quality in this species.

The present study is the first to address egg quality in Lumpfish, currently underperforming eggs are a substantial factor in the creation of a commercially viable broodstock. the present study has confirmed significantly poorer egg quality in captive derived broodstock, than the wild caught stocks, displaying significantly lower fertilization, eyeing and hatching rates. Poor egg quality is a major hurdle in successful commercial production of this new species. This work can provide key information to inform the creation of broodstock diets for lumpfish, as well as an important bassline in further egg quality work within the species.

Acknowledgements

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Lipidomics and broodstock management during mussel hatchery operations: identification of markers of ovary maturation in the blue mussels (*Mytilus* sp.)

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Tweetable abstract:
Broodstock conditioning (BSC) is an important practice for mussel hatchery production. In this work we used lipidomic tools to highlight candidate markers for ripe and undeveloped ovaries. We found 46 lipid molecules for markers of the two ovary classes. Such proxy will assist in avoiding mass spawning or atresia during BSC.

Twitter handle: @alessandro.laudicella

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Acknowledgements

All the Authors are kindly thanked for having submitted an abstract formatted according to this template.

References

Authors (Year). Title. Journal title, number (issue) and page numbers.

Lipidomics and broodstock management during mussel hatchery operations: identification of markers of ovary maturation in the blue mussels (*Mytilus* sp.)

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Mussels constitute an important economic and food source especially for coastal and rural countries, however their production has decreased by approximately 20% in the past 20 years (Avdelas *et al.*, 2020). To strengthen and expand the mussel aquaculture sector, the growth and establishment of industrial hatcheries has been regarded as a possible solution to such problem (STECF, 2016). The improvement of existing hatchery practices is a necessary step to ensure the production of cost-effective seed (BLUESEED, 2008). Broodstock conditioning (BSC) is an important hatchery practice, aiming to enhance the quality and number of gametes released by broodstock (Kamermans *et al.*, 2013) and to avoid uncontrolled spawning or pre-spawning atresia.

Gonad histological analysis (GHA) is the traditional method employed to assess the gonad maturation status of mussels during BSC. For large scale industrial applications, GHA presents a few drawbacks such as limited processing outputs, a degree of subjectivity in scoring transitional gonad maturation stages and the necessity of experienced and skilled operators. Lipids may become important indicators of gonad maturation, as they cover essential functions during gonad maturation in bivalves, including structural, energy storage and signaling roles.

In this work, mussel ovary ultrastructure is integrated with liquid chromatograph-mass spectrometry (LC-MS) global lipidomics aiming to identify suitable markers for female gonad maturation. Ovaries were classified as either mature or undeveloped via GHA, and markers distinguishing between the two classes are identified by the combined application of different chemometrics approaches including volcano analysis, orthogonal partial least square discriminant analysis (OPLS-DA) and RandomForest. Candidate markers were ranked via receiving operating characteristics (ROC) curves according to their area under the curve (AUC).

A panel of 45 lipid molecular species with high discriminatory power between the two gonad maturation stages (AUC>0.8) could be identified from global lipidomics data. Out of this panel, ceramide phosphonoethanolamine (PE-Cer) 40:2 and the saturated glycerophosphocholine (PC) plasmalogen O-30:1/P-30:0 were the two molecules with largest discriminatory abilities between ripe and undeveloped ovaries (respectively AUC 0.905-907). Lipid ontology (LiOn) enrichment analysis indicated significant differences in functional roles of lipid candidate markers between fully developed and undeveloped ovaries; lipids abundant in the former of the gonad classes resulted connected with storage lipids and triglycerides terms, whereas in undeveloped ovaries lipids abundant were connected with membrane lipids and lysosomes.

The results of this study show the benefits for mussel hatchery operations such as BSC. Providing a fast and reliable method for the monitoring of gonad maturation will reduce the risk of uncontrolled spawning or pre-spawning atresia in the broodstock, aiding the development of mussel hatchery production.

Acknowledgements

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Microalgal mixotrophy as a feed for *Mytilus* spp larvae

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Tweetable abstract

Mussel larvae need to eat large quantities of live microalgae, which makes a larval hatchery expensive to operate. Here @joepenhaul from @SAMSoceannews shows that costs may be reduced by using microalgae "fed" a source of organic carbon #MASTSasm2020 #algalbiotech

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Abstract

Mytilus edulis aquaculture represents an important section of the UK and EU economies. Current production mechanisms rely on the supply of wild larvae to be settled upon longlines and subsequently on-grown. This leaves larval collect and production of adult blue mussels reliant upon larval supply and so is one of a number of limiting factors in upscaling production n. In Scotland 7000 tonnes of mussels were produced in 2015 and mussel growers aim to double production by 2020. To do so, the limiting factor of larval supply must be overcome. One method of doing this is the creation of a *M. edulis* larval hatchery. The costs associated with microalgal culture, for use as feed, in a larval hatchery are currently around 40% of total costs. As a result, the creation of a larval hatchery is not economically viable (Hickman, 1992). This is due to the requirement for live microalgae. This study aimed to address this limiting factor through use of mixotrophically cultured microalgae as a feed source.

Microalgae are classically considered to be photoautotrophic and are cultured in the light, in seawater with additional nitrate and phosphate. Mixotrophy is the ability of a microalga to uptake organic nutrients, such as carbon or nitrogen, in addition to, or as an alternative to, photoautotrophic fixation of carbon. This ability to be cultured mixotrophically is considered to be ubiquitous in the marine environment (Borowitzka, 2013) and has a number of advantages. Mixotrophic culture often results in greater cell numbers and dry weight, as well as an increased culture stability (Morales-Sánchez & Martinez-Rodriguez, 2015). Furthermore, dependent upon the method of culture and the carbon source utilised, the biochemical profile can be tailored to create a "designer" feed.

Over the course of two feeding trials this study takes current "industry standard" microalgal species and compares larval growth and survival to mixotrophic "designer" microalgal feeds, then subsequently optimises the diet used. The "designer" feed can be considered to be as effective as the standard benchmark feed and subsequent optimisation shows that a diet that is tailored towards the development performs the most effectively in terms of larval growth. Mixotrophic culture requires an additional organic carbon source which has a significant cost implication. Therefore using first order modelling, the economics of use of mixotrophy as an alternative to photoautotrophic culture reveals a more complex picture in terms of the optimal methods of culture. Culture optimisation, a move to semi-continuous culture and alternative, low cost carbon sources potentially reveal a way forwards.

Acknowledgements
This work has been funded by the Scottish Funding Council and ESF.

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MANIPULATING MACRONUTRIENT CONCENTRATION (N, P, FE) TO ENSURE VEGETATIVE CULTIVATION OF KELP GAMETOPHYTES (SACCHARINA LATISSIMA) FOR THE AQUACULTURE INDUSTRY

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European seaweed aquaculture requires reliable methods to produce high-volumes of kelp gametophytes as a seedstock. These can be maintained vegetatively in seedbanks for year-round access, negating the need for natural spore collection (Westermeier et al. 2006). Additionally, since kelps are a source of valuable bioactive compounds, these vegetative gametophyte could be an alternative source, reducing harvesting of natural beds.

A number of abiotic factors influence growth and gametogenesis of gametophytes. Commonly, red light is used to maintain their vegetative growth. Yet, their growth rate is not optimal under red light and faster growth can be achieved under white light, but this also stimulates reproduction. The aim of this study was to identify the conditions that inhibits gametogenesis and maintains vegetative growth under white light.

Oogenesis was studied through factorial experimental on the female gametophyte of Saccharina latissima. Cultures were maintained under either red or white light ($30\mu mol\ m^{-2}s^{-1}$) at 10 °C , and 12:12 L:D photo period. The effect of concentration of phosphate and nitrate in culture media and the ratio (N:P range: 4.5:1 – 60:1) was

investigated over 35 days. In a separate experiment the iron concentration in artificial seawater (GP2) was manipulated (range 0 -0.0117 mM) and availability of this iron modulated using the chelator EDTA.

All cultures remained vegetative under red light. Under white light cultures with Nitrate at concentrations above 1.8 mM remained vegetative, while increases in phosphate reduced oogenesis. The culture remained vegetative when iron was excluded from the culture medium. Additionally increases in concentration of the chelator EDTA reduced the oogenesis.

The manipulation of macronutrient concentrations is an effective method to allow vegetative cultivation of gametophytes under white light. Alteration of the N:P ratio did not fully inhibit oogonia formation, yet high nitrate concentrations did; possibly due to toxicity.

Iron appears to be essential for gametogenesis, with similar results reported for other species of kelps (Lewis et al. 2013). Depleting the medium iron concentration may be an effective method to maintain vegetative gametophyte cultures as a seedstock for seaweed aquaculture.

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