



**An Roinn Talmhaíochta,
Bia agus Mara**
Department of Agriculture,
Food and the Marine

Food Institutional Research Measure

Final Report

**'MOREFISH -
ENHANCING PRODUCTION AND SUSTAINABILITY IN IRISH FRESHWATER AQUACULTURE'**

DAFM Project Reference No: 14/SF/872

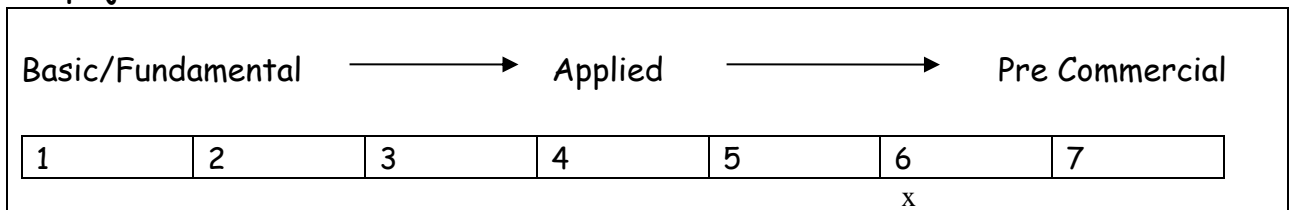
Start date: 01/01/2015

End Date: 31/08/2017

Principal Coordinator and Institution: Eoghan Clifford (NUIG)
Email: eoghan.clifford@nuigalway.ie

Collaborating Research Institutions and Researchers:
Athlone IT (Prof. Neil Rowan Principal Investigator AIT)

Please place one "x" below in the appropriate area on the research continuum where you feel this project fits



Please specify priority area(s) of research this project relates to from the National Prioritisation Research Exercise* (NRPE) report;

Priority Area (s)	H Food for Health
	I Sustainable Food Production and Processing

Key words: sustainability, technologies, trade effluent licences, model trout farm

1. Rationale for Undertaking the Research

There is an important need for an intensification of aquaculture processes due to higher fish demand and lower fishing capacity in seas worldwide. The increases in global populations and the need to develop new, sustainable food sources further drive the need to increase global aquaculture outputs. However, like any industrial activity, the sustainability (e.g. environmental, economic etc) of the sector need to be continually monitored. The national strategic development plan for aquaculture (DAFM, 2015) proposes an increase in the Irish aquaculture output to 45,000 tons a year by 2023 (from its 2015 level of 40,000 tons). Furthermore Irish agriculture (including aquaculture) is expected to grow by 85 % to €19 bn in exports by 2025 (FoodWise 2025). This growth should be achieved using the principle of sustainability and a focus on contributing to the green economy (NESC, 2016).

European aquaculture has experienced stagnation over the past 20 years and in particular the Irish sector has seen continued decline & shrinkage over the same period with total Irish aquaculture output declining from about 63,000 tonnes in 2002 to 40,000 tonnes in 2015. Between 2005 and 2015 both the trout and salmon smolt freshwater production experienced considerable fluctuation; the trout industry declined from a high of approximately 900 tonnes annual production in 2009 to an output of 705 tonnes in 2015. While there are a number of factors contributing to this decline, some of the more challenging for the sector include (i) the increased production & operational costs driven by increased competitiveness, (ii) the cost of meeting ever-increasing environmental compliance & regulatory requirements, and (iii) under-investment within the sector. It was against this backdrop in the freshwater sector that the MOREFISH project was developed.

The primary objective of MOREFISH was to assist the national freshwater aquaculture sector in increasing their production efficiencies in a sustainable manner. Within this overall objective, the following aims were identified:

1. benchmark the industry in terms of the type of production systems, methodologies, operations and technologies.
2. enable increases in biomass output, productivity and stocking densities through testing and deployment of new/emerging technologies to bring efficiencies in the areas of aeration/oxygenation and disinfection within the culturing process.
3. develop a proposal to reduce production costs for the industry through the implementation of new technologies combined with a sustainability indicator toolkit for optimisation and tracking of process interventions/changes.
4. reconcile increased production with the needs of the water framework directive and achieve ongoing environmental compliance.
5. develop an advanced multidisciplinary research approach that is fully integrated with the needs of industry stakeholders and commercial operators.
6. develop & establish an industry platform encompassing all of the relevant stakeholders to proactively support the future development of the sector.

2. Research Approach

This project drew together a multidisciplinary team from NUI Galway and Athlone IT encompassing areas of engineering, marine biology, toxicology and microbiology. Aquaculture, by its nature, is a complex & highly scientifically based animal rearing practice, requiring the practitioner to have an in-depth knowledge of fish biology, fish husbandry, process control, water chemistry, water treatment and hydrology combined with the business acumen required of any successful commercial activity. Thus this collaborative, multidisciplinary approach was leveraged to research various avenues for the development and growth of the Irish freshwater aquaculture sector.

A key aspect to MOREFISH was the development of a close working engagement with industry, representative bodies, regulatory bodies and other stakeholders to ensure alignment and partnership of the sector with the project. For example, the participating farms were specifically selected to give a cross sectional representation of the different production systems and models practiced within the sector. The project interacted strongly with the sector and was supported by an industry stakeholder platform comprising commercial operators, Bord Iascaigh Mhara, Irish Farmers Association Aquaculture Division and other stakeholders.

The key research methods deployed by the MOREFISH team included (i) benchmarking farms using available historic data and current data gleaned from onsite monitoring program, (ii) the development of proposals for farms that would enable productivity/efficiency improvements, (iii) the development of a strategy for rollout of positive interventions to the wider sector.

The team ensured the project was flexible enough to adapt to sectoral needs and commercial changes within industrial partners as they were identified in stakeholder workshops. For example, a comprehensive review of Discharge Licensing and associated emission limits, applied to the freshwater aquaculture sector in Ireland was completed and presented to the sector in January 2017; this was identified during the workshops as being of interest to the sector. Another example included collaboration with Keywater perch farm (a pilot scale pill-pond farm novel to the Irish aquaculture sector), to enable a programme of algal identification & interaction with microbial communities, dissolved oxygen profiling and bacterial loading assessment. Keywater perch farm is the precursor to a planned large scale production unit for perch with annual production volume of 2000 tonnes, thus laying the basis for a significant development in the future of the Irish freshwater aquaculture sector.

3. Research Achievements/Results

The following are the main achievements/results of the programme:

Compliance with discharge limits

- The environmental performance of the freshwater industry (representing 85.1% of the trout industry production and 36.6% of the freshwater industry output) were benchmarked. The results of this benchmarking process indicate that the freshwater aquaculture performed well in terms of environmental performance as measured by compliance with discharge criteria.
- A comprehensive analysis of trade effluence licence parameters for the sector was completed thus establishing a profile of the current regulatory framework of discharging licensing criteria and enforcement. This project also identified challenges for both industry and regulatory authorities in interpreting and implementing discharge limits particularly with regard to ammonia/ammonium nitrogen.

Technology development:

- The new/emerging oxygenation technologies trialled indicated potential for high performance application with multiple use profiles within the current oxygenation process. In particular, one of the technologies (MikroForme) demonstrated the potential to deliver increased performance

in both a supplementary and emergency oxygenation application, over existing best performing technologies used within the sector.

- Pulse UV disinfection efficacy was determined for a range of pathogens identified as being the main causes of disease & mortalities within the freshwater aquaculture sector.

Process control

- Recommendations were provided to the industry stakeholders in terms of energy potential savings and farm operation based on the intensive monitoring of the studied farms.
- Recommendations for water re-use and implementation of water treatment technologies (solids, organic matter and nutrient removal) were developed and presented to the industry based on analyses of the studied farms, future WFD challenges and developments in other EU countries (e.g. Denmark with the implementation of model trout farms).

Industry and sector engagement

- MOREFISH engaged with a novel pilot scale novel configuration (i.e. pill ponds) which is due to ramp up to large scale production volume next year, establishing a whole new high value export sector for the freshwater industry potentially tripling the current total trout production. This has led to a new research programme (ECOQUA) funded by Bord Iascaigh Mhara.
- A series of stakeholder meetings was organised. These meetings were targeted at bringing together a critical mass of industry, academic and regulatory expertise and experience with a view to addressing concerns regarding implementation of the water framework directive. As a direct result of this engagement MOREFISH has been invited to form a working group with the County and City Managers Association of the Local Authorities, to provide expertise in determining wastewater discharge licenses.
- MOREFISH also facilitated exchange of knowledge between international experts from France and Denmark and their experiences with the implementation of the WFD.

Sustainability indices

- Development of methods to assess the sustainability of the sector including the use of life cycle assessment which incorporated metrics to assess the biodiversity impacts of the sector.
- Development of sustainability indicator toolkit that enables farms to effectively monitor the impact of interventions and process changes on the operation of the farm.

Publications

- Extensive coverage on the project in national, international, industry and research media. These included Hatchery International, Engineers Journal of Ireland, EPA Catchments Newsletter and local newspapers.
- Production of a report detailing the evolution of discharge licensing and the aquaculture sector and a review of current and historic licenses.

4. Impact of the Research

4(a) Summary of Research Outcomes

(i) Collaborative links developed during this research

During the programme, several important and relevant links were developed as outlined below:

Industry engagement through the organization of 3 industry meetings that gathered all freshwater stakeholders together for the first time. The MOREFISH project received support from industry, representative bodies and other public bodies for the continuation of this forum.

International links: The team expanded and built upon existing academic and network linkages in Europe leading to ongoing discussions with a range of leading EU academic and industry partners on the development of an outline program in the area of sustainability for future funding calls. A number of leading international experts were invited to participate at the MOREFISH workshops and these contacts will be leveraged to develop international research partnerships.

Policy links: Engagement with representatives from the environmental section of County Councils culminating in an invitation to join a working group on assessment of training programs for interpretation and implementation of appropriate trade effluent licensing criteria for the aquaculture sector to take in the challenges of the water framework directive (WFD) implementation.

Training links: Participation in:

- international researcher training and networking initiatives including EU Cost Actions, such as Foodborne parasites.
- Recirculating Aquaculture System (RAS) Technology training workshop in Sete delivered by AquaExcel2020
- Advanced life cycle assessment training in Aalborg, Denmark focusing on consequential, hybrid and input output LCA.

(ii) *Outcomes where new products, technologies and processes were developed and/or adopted*

Oxygenation/aeration: The oxygenation/aeration technologies piloted and analysed during the project could bring increased levels of dissolved oxygen within the culture water thereby facilitating improved fish welfare, growth performance/production at a reduced cost over existing technologies. In addition to the improved supplementary performance of these technologies, there is also the potential for significantly improved emergency supply of oxygen in cases of water flow interruption etc., where fast response times for re-oxygenation becomes critical for biomass survival.

Pathogen removal: The further development and application of pulsed UV in the aquaculture sector will benefit to the industry in terms of biosecurity, alternative option to chemical disinfectants/antibiotics, reduced environmental impact due to chemical emissions and compliance with future directives on animal husbandry & therapeutic emissions. There remains significant capacity to look at leading edge LED UV technology as a result of the project.

Farm reconfiguration proposal: Based on comprehensive on-site monitoring a reconfiguration of farm layout and water re-use was developed which could potentially increase production whilst freeing up ponds for water treatment (sedimentation).

(iii) *Outcomes with economic potential*

Energy audits: Extensive energy and oxygenation/aeration audits were conducted on two sites with potential cost saving interventions clearly identified with costed recommendations presented to the industry at MOREFISH workshops. A projected payback period of less than 1 year was calculated for recommended energy usage interventions, with the opportunity to reduce oxygen usage by 13% at one farm.

Oxygen/air delivery: The implementation of higher performance oxygen transfer technologies has the potential for decreased energy consumption yielding an associated cost saving whilst also delivering reduced oxygen usage due to increased transfer efficiencies over conventional technologies.

Pathogen removal: The application of pulsed UV has the potential to reduce pathogen/disease/mortalities with associated benefit of increased productivity. This innovation can be seamlessly integrated as a bolt-on-technology into existing and potentially emerging aquaculture farming practices.

(iv) **Outcomes with national/ policy/social/environmental potential**

Trade Effluent Licences Review: The trade effluent license report forms the basis for review and development of a working group encompassing regulatory authorities, industry stakeholders and independent scientific bodies such as the MOREFISH team with the aim of harmonizing the regulatory framework relevant to the aquaculture sector.

MOREFISH industry platform: MOREFISH platform established as a forum and scientific repository for the sector on which to establish a roadmap for the development of the industry.

Life cycle assessment: A life cycle assessment was conducted on one of the case study sites. The results of the study are broadly in line with previous studies published from France and Canada i.e. the production of aqua feeds exert the greatest environmental impact associated with the production system. The project also investigated merging biodiversity and water analyses into life cycle assessment to provide a more holistic representation of the impacts of freshwater aquaculture. Significantly the team also proposed the expansion of life cycle assessment as a tool to enable improvements to production efficiency and the promotion of aquaculture as a sustainable business.

4 (b) Summary of Research Outputs

Key dissemination outputs included presentations given at both national and international peer reviewed conferences, strong online and social media presence (via www.morefish.ie), participation in two different international aquaculture training events on recirculating aquaculture systems and life cycle assessment and the presence of international experts at MOREFISH events.

(i) **Peer-reviewed publications, International Journal/Book chapters.**

- Tahar, A. Kennedy, A., FitzGerald, R., Clifford, E., Rowan. N. 2018. Longitudinal evaluation of the impact of traditional rainbow trout farming on receiving water quality in Ireland. *PeerJ*, 6:e5281 <https://doi.org/10.7717/peerj.5281>.
- Tahar, A. Kennedy, A., FitzGerald, R., Clifford, E., Rowan. N. 2018. Full Water Quality Monitoring of a Traditional Flow-Through Rainbow Trout Farm. *Fishes*, 3(3), 28; <https://doi.org/10.3390/fishes3030028>.

(ii) **Popular non-scientific publications and abstracts including those presented at conferences**

Oral presentations at international/national conferences:

- Tahar, A., Kennedy, A., Naughton, S., Cooney, R., Behan, C., Fogarty, A., Fitzgerald, R., Rowan N., Clifford E. (2017) Full monitoring of a traditional flow through rainbow trout farm in Ireland – impact of water passes number. Accepted for oral presentation in Aquaculture Europe 2017, Dubrovnik, Croatia, 17-20 October 2017.
- Cooney, R., FitzGerald, R., Clifford, E. (2017). Biodiversity accounting in freshwater aquaculture life cycle assessments. Accepted for oral presentation in Aquaculture Europe 2017, Dubrovnik, Croatia, 17-20 October 2017.
- Tahar, A., Kennedy, A., Naughton, S., Cooney, R., FitzGerald, R., Fogarty, A., Rowan, N., Clifford, E. (2016). Long term evaluation of the impact of traditional rainbow trout farming on river quality

in Ireland – a 10 years case study. European Aquaculture Society, Aquaculture Europe 2016. Edinburgh, Scotland. 21-23 September.

- Cooney, R., FitzGerald, R., Clifford, E. (2016). Use of Life Cycle Assessment in Irish Freshwater Aquaculture Systems. 26th Irish Environmental Researchers Colloquium, Environ 2016. University of Limerick, Ireland. 24 March.
- Tahar, A., Walsh, R., Kennedy, A., Naughton, S., Fogarty, A., Fitzgerald, R., Rowan, N., Clifford, E. (2015). Morefish – enhancing production and sustainability in Irish aquaculture. Aquaculture Europe 15 – Aquaculture, nature and society. Rotterdam, the Netherlands. 20-23 October.
- Walsh, R., Tahar, A., Kennedy, A., Naughton, S., Fogarty, A., Fitzgerald, R., Rowan, N., Clifford, E. (2015). Morefish – enhancing production and sustainability in Irish aquaculture. World aquaculture conference. Montpellier, France. 15-19 August.

Industry magazines

- MOREFISH Research Project: Engineering sustainability in Irish Aquaculture (2017). Engineers Journal of Ireland. <http://www.engineersjournal.ie/2017/04/24/morefish-engineering-sustainability-irish-aquaculture/>
- MOREFISH: Research on improving freshwater aquaculture production management, resource efficiency and sustainability (2016). EPA Catchments Newsletter Issue 3: June 2016. http://www.morefish.ie/wp-content/uploads/2016/12/morefish_epa_catchments_newsletter.pdf

(iii) National Report

- Cooney, R., Tahar, A., Kennedy, A., Fitzgerald, R., Rowan, N., Clifford, E. (2017). Trade effluent licenses – a review. Distributed to the Irish freshwater aquaculture sector.

(iv) Workshops/seminars at which results were presented

MOREFISH workshops

Three workshops were organized by the MOREFISH team in total, the first being an introductory meeting to communicate the objectives and strategy of the program to all the relevant industry stakeholders. The second workshop, held in October 2016, focused on delivery of progress updates/outputs from the MOREFISH program and also included 3 national guest speakers – Dr. Neil Bass, Watermark Aqua-Environmental, Martin Flanigan, Northern Ireland Aquaculture Initiative, Damien Toner, BIM - presenting on current sector challenges, particularly in the relation to the water framework directive. Additionally, an international guest speaker (Dr. J.P. Blancheton, senior researcher from IFREMER, France and lead scientist of the ORAQUA project – scoping on organic standards and direction, <https://www.oraqua.eu>) presented on organic production trends in Europe.

The third workshop, held in January 2017, had the primary focus of identifying potential solutions implemented in other EU jurisdictions that could be replicated/developed for the Irish context. Key speakers at this workshop were (i) P.B. Pedersen (Danish Technical University) who outlined the evolution of Danish trout farming industry, from traditional practices (similar to those encountered in Ireland at the moment) to model trout farming techniques facilitating compliance to WFD discharge criteria and (ii) Ray Spain, regional coordinator for local authorities water and communities office (LAWCO), who presented on the challenges facing local authorities/regulatory authorities in interpretation and implementation of the WFD. A cross section of the aquaculture sector attended these workshops as testified to by the Irish farmers association (IFA – aquaculture sector) and the Irish Salmon Growers Association. In addition, representatives from all the relevant sectors attended (i.e. industry, local authorities (Kilkenny, Sligo, Galway, Westmeath County councils/environmental sections), BIM, Northern Ireland Aquaculture Initiative, Marine Institute).

An outcome of these workshops was that the MOREFISH platform was established as the *de-facto* platform/forum for the freshwater aquaculture industry in Ireland. Technologies underpinning the

MOREFISH platform were shared with broad range of stakeholders as part of EI Innovation Agri-tech exhibits during National Ploughing Championships held between 19th and 21st September, 2017.

(v) Intellectual Property applications/licences/patents
none

(vi) Other

Media Exposure:

- MOREFISH and how to get them. Aquaculture and Seafood Ireland, May 2018. <http://www.morefish.ie/wp-content/uploads/2018/06/selection.pdf>
- MOREFISH: Research Project – Engineering Sustainability in Irish Aquaculture. Engineers Journal Ireland. April 19th 2017. <http://www.engineersjournal.ie/2017/04/24/morefish-engineering-sustainability-irish-aquaculture/>
- Great news for Athlone IT today. Westmeath Independent, Oct 7th 2016. <https://www.westmeathindependent.ie/news/roundup/articles/2016/10/07/4127981-great-news-for-athlone-it-today/>
- MOREFISH – research on improving freshwater aquaculture production management, resource efficiency and sustainability. EPA Catchments Newsletter, Issue 3. Jun 2016. http://www.morefish.ie/wp-content/uploads/2016/12/morefish_epa_catchments_newsletter.pdf
- Project poised to position Ireland as an innovator in aquaculture. Hatchery International. Feb 12th 2016. <https://www.hatcheryinternational.com/news/project-poised-to-position-ireland-as-an-innovator-in-aquacu-1093>
- MOREFISH to improve aquaculture management. AIT Life, p.23. Jan 23rd 2016. https://issuu.com/danielseery/docs/ait_life_vol7_issuu
- New project to significantly improve aquaculture efficiencies. Galway Advertiser, Dec 30th 2015. <http://www.advertiser.ie/galway/article/81834/newproject-to-significantly-improve-aquaculture-efficiencies>
- New Project To Significantly Improve Aquaculture Efficiencies. NUI, Galway Press Office. Dec 23rd 2015. <http://www.nuigalway.ie/about-us/news-and-events/news-archive/2015/december2015/new-project-to-significantly-improve-aquaculture-efficiencies.html>

5. Scientists trained by Project

The two students have moved to PhD studies based on their work and their theses are due in 2019 (PhD programmes are 4 years). An additional Research Masters thesis which was funded outside of this project but was based on data developed during this project and the follow-on “EcoAqua” project has recently passed international external examination (November 2018) and will be published in 2019. The thesis was supervised by the project coordinator but is not included in the publications list as it has yet to be formally published by NUI Galway.

Thesis summary:

- Sarah Naughton (AIT) – expected completion Q4 2019
- Ronan Cooney (NUI Galway) – expected completion Q4 2019
- Conor Behan – completed December 2018 (will be published in January/February 2019 in a public repository at NUI Galway). Thesis title: ***Development Of A Novel Performance Assessment And Stock Management Tool (AquaStock), For Use In Fresh Water Aquaculture.***

Total Number of theses: 3 (2 PhD ongoing and 1 MAppSc (Civil Engineering) – completed).

6. Permanent Researchers

Institution Name	Number of Permanent staff contributing to project	Total Time contribution (person years)
NUIG	1	0.4
AIT	1	0.325
Total	2	0.735

7. Researchers Funded by DAFM

Type of Researcher	Number	Total Time contribution (person years)
Post Doctorates/Contract Researchers	4	7.027
PhD students	2	4
Masters students	0	
Temporary researchers	2	0.166
Other		
Total	8	11.193

Note: Dr. Richard Fitzgerald finished in his official capacity on the MOREFISH programme on 31/11/2015 however he continued to actively participate in the programme, with ongoing advise and direction, up to his untimely death in December 2016. He is sadly missed by all of the MOREFISH team.

8. Involvement in Agri Food Graduate Development Programme

N/A

9. Project Expenditure

Total expenditure of the project:	€ 594,364.71
Total Award by DAFM:	€ 599,577.17
Other sources of funding including benefit in kind and/or cash contribution(specify):	€ N/A

Breakdown of Total Expenditure

Category	NUI Galway	AIT	Total
Contract staff	107,136.33		107,136.33
Temporary staff		355.73	355.73
Post doctorates	83,729.56	90,096.53	173,826.09
Post graduates	38,943.86	41,299.59	80,243.45
Consumables	36,596.18	11,638.87	48,235.05
Travel and subsistence	24,338.82	10,819.91	35,158.73
Sub total	290,744.75	154,210.63	444,955.38
Durable equipment			-
Other	15,922.72	-	15,922.72
Overheads	87,223.43	46,263.19	133,486.61
Total	393,890.90	200,473.82	594,364.71

10. Leveraging

Knowledge Gateway Scheme Funding (total project value = € 348,871)

EcoAqua (European Maritime and Fisheries Fund and BIM funded October 2017 to Oct 2019) - Research on reducing the impact of aquaculture on the environment. The aim of this 2-year project is to identify and implement the appropriate technological solutions for the freshwater aquaculture industry posed by the water framework directive to the sector, and thereby achieve its growth potential in a sustainable manner. This will in turn facilitate a sustainable rural and coastal economy. A prime example of how sustainable expansion of the industry could be enhanced is removing barriers that limit the supply of smolts on an annual basis while ensuring industry must work within relevant environmental limits. This would dissociate production from licencing thereby allowing expansion but ensuring environmental regulation is adhered to. Such a move could provide the basis for the industry to embrace new production

methods and technology, increase output (and thus boost exports and the local economies) while reducing impacts per unit biomass produced to remain.

Atlantic Areas InterReg project (total value to Irish partners led by NUI Galway and AIT = € 495,525; total project value = € 2,312,013)

The MOREFISH team (NUI Galway, AIT and associated Irish aquaculture industry) were part of a successful Atlantic Areas InterReg project (NEPTUNUS – led by Universidad de Cantabria, Spain) whereby work in MOREFISH and the following EcoAqua project was the basis for the team to invite us on board. A number of Irish companies we have worked with through MOREFISH into the project are involved. NUI Galway are a workpackage leader in this project.

H2020

Under the H2020 Societal Challenge 2 (Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy) the MOREFISH team met representatives from the Danish Technical University (DTU), IFREMER (French research institute), NOFIMA (Norwegian research institute) and Wageningen University with whom a strong working relationship was developed during the MOREFISH program. These meetings were held in October 2017 with follow up discussions scheduled for November 2017 to further develop an outline programme for upcoming H2020 calls.

The NUI Galway MOREFISH team are participating in an NUI Galway coordinated application in the marine aquaculture sector again the idea being to utilise some of the ideas/tools developed in MOREFISH. This application is a H2020 one and will be submitted in early 2019.

11. Future Strategies

Research Infrastructure

- The Danish trout industry is a case model where the introduction of new processes & technologies has firmly re-established it as a profitable & sustainable industry coming from a position 10 years ago where it faced the same challenges now facing the sector in Ireland.
- ***Development of a national “Pilot phase/Demonstrator facility” for evaluation and demonstration of best available technologies*** leveraging best international practice (e.g. Danish ‘Model trout farm’ concept) to define a strategic roadmap for the industry growth and development, that enable it to meet and exceed targets set out under Food Wise 2025. Additionally, such a model would provide Ireland with highly skilled engineers, scientists and technologists trained uniquely in this area that can facilitate the informed and smooth uptake of new innovations (eg. RAS) and establish Ireland as being an international leader in “best in practice” in the freshwater aquaculture sector.

Technology Development

- Further development of oxygenation and pathogen removal technologies to bring them to commercial scale application with associated validation at farm level.
- Promote industry implementation of energy/oxygen reduction recommendations that were provided to the industry stakeholders based on the intensive monitoring of the studied farms.
- Implementation of improved water re-use and water treatment technologies and strategies identified in the benchmarking and monitoring programme.

Application of Trade Effluent Licence criteria to aquaculture sector

- Future compliance with discharge limits may require the industry to reduce water usage per unit biomass produced. Additionally, to reverse current industry stagnation and achieve sustainable

growth an increased focus on the use of water treatment technologies for WFD compliance is required.

- Review and standardization of discharge license criteria and parameters through consultation with relevant authorities and leveraging best practice models nationally and internationally. Consultation has begun with representatives from the Local Authorities in the form of a working group to proactively address the challenges faced by the sector.
- Analyse sectoral performance and impacts relative to other food production/processing activities. Such research is critical to establishing the capacity of the sector to help Ireland meet export targets for food, rural employment growth and international climate change targets for the agriculture sector.

Industry and sector engagement

- Expand engagement with leading EU institutions in the aquaculture sector. For example the team are liaising with Danish Technical University (DTU) to develop a workshop on the Danish roadmap that enabled the successful transition of the freshwater industry from traditional practices to the high performance model currently in place.
- Build on the platform that the MOREFISH program has established to advance the development of the industry through deeper engagement with all of the stakeholders encompassing regulatory authorities, academic institutions, state bodies, EU research programs etc.
- Build on the inherent expertise and knowledge base within the industry to further develop process optimization within the sector that can further be supported by some of the tools developed by the MOREFISH program (i.e. sustainability indicators, LCA).
- Leverage the MOREFISH (and upcoming ECOAQUA) project to support international mobility and exchange of researchers which will also act as conduit to embrace complex issues, such as impact of climate change on aquaculture industry and predictive risk assessment modelling.