

AQUAEXCEL

KEY ACHIEVEMENTS

2014 - 2015

BOOKLET 4
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Aquaculture Infrastructures for Excellence in European Fish Research





A REFLECTION ON AQUAEXCEL'S ACHIEVEMENTS FROM MARC VANDEPUTTE, PROJECT COORDINATOR

After four years of fruitful collaboration, **AQUAEXCEL** has fulfilled its strategic objectives through the integration of 17 key partners and 27 top class infrastructures, and has been rewarded by numerous applications from Europe and beyond to access our facilities, resulting in 97 innovative and highly original Transnational Access (TNA) projects taking place.

AQUAEXCEL has also successfully delivered four new pioneering technical training courses that focus on different aspects of aquaculture experimentation, and put emerging aquaculture infrastructure centres of excellence at the forefront. All four courses were hugely successful and the feedback from the trainees was extremely enthusiastic with more sessions requested across the board.

AQUAEXCEL's interactive map is currently the most comprehensive and dynamic inventory of aquaculture Research Infrastructures (RIs) in Europe and now allows for the addition of more information on fish lines, such as management data and performance data for relevant traits at each facility.

To further contribute to the growth of the sector by relevant R&D operations, an analysis of the research needs of European aquaculture was compared with an analysis of RI capabilities and expertise. This highlighted perceived gaps in European aquaculture RIs which were discussed in depth with the partners at the project's final meeting.

Lots of work has been devoted to analysing and spreading best practices, for example, guidelines for sanitary issues linked to fish transport between infrastructures, for measuring and accurately defining traits and phenotypes, and for developing traits and environmental conditions ontologies. This was an important task, and efforts to promote its adoption by a wider circle of aquaculture scientists should be encouraged and continued.

A tailored and targeted dissemination strategy has made **AQUAEXCEL** well known in the aquaculture community. A selection of publications including our project newsletters and **AQUAEXCEL** Key Achievements booklets were complemented by an industry focused

workshop at the Aquaculture Europe conference 2014 in San Sebastián, which gathered over 140 participants from the whole aquaculture sector.

At the scientific level, our work on remote access now allows researchers to access their on-site experiments at **AQUAEXCEL** facilities such as IMARES, Nofima, NTNU, SINTEF, and WU-Aquaculture and Fisheries Group, from their living rooms. A study on how this e-Infrastructure affects the design, outcome, cost and collaboration in an experiment has also been carried out. In addition, **AQUAEXCEL**'s work on upscaling has now confirmed that yes - even in fish tanks and in bio filters - size matters! Such studies are a useful link between research and industry and show how the scale of an experiment can influence its validity in industrial conditions; and also propose explanatory factors and models that can help extrapolate small scale experiments to industry size application.

AQUAEXCEL also provided the scope to integrate knowledge on measuring more precise phenotypes of individual fish by combining experimental approaches on fish, genomics and bioinformatics. Very interesting results on the importance of mitochondrial pathways in stress response were produced, and scoring methods developed.

A significant effort was committed to produce isogenic fish lines for major species like salmon, sea bass and carp; a priceless experimental resource for reproducibility of results and genetic studies. The road has been tough, and we have not yet reached the end of the story; with the first isogenic salmon about to hatch in 2015, while the prospects are good to obtain isogenic carp and sea bass within the next two years.

For us, **AQUAEXCEL** has been a successful experience, and we hope it will have a lasting impact on the EU aquaculture sector. To build on this success, an enlarged **AQUAEXCEL** consortium has submitted a new project, **AQUAEXCEL**²⁰²⁰, to the EC. We look forward to continuing this aquaculture challenge towards 2020, further developing Transnational Access with more than 170 projects scheduled, going deeper into modelling and optimisation of experimental setups, development of isogenic lines and databases on experimental fish.

KEY OUTPUT 1

ESTABLISHMENT OF AN AQUACULTURE RESEARCH INFRASTRUCTURE WORKING GROUP WITHIN THE EUROPEAN AQUACULTURE TECHNOLOGY AND INNOVATION PLATFORM (EATiP)



Photo courtesy of AquaTT

SUMMARY: AQUAEXCEL partners have formed a Research Infrastructure (RI) Working Group under the auspices of EATiP. This has, for the first time, created a single European contact point for RI and knowledge management issues in the aquaculture sector which represents the views of both Research & Development (R&D) organisations and industry companies.

AT A

GLANCE

FULL TITLE: European Aquaculture Technology and innovation Platform (EATiP) Research Infrastructure Working Group

KNOWLEDGE TYPE: Working Group

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INTRODUCTION

AQUAEXCEL, through its networking activities, has strongly contributed to the strengthening of cooperation between key European aquaculture RIs. In order to ensure the continuation of the progress made in this area, AQUAEXCEL and EATiP have come together to collaborate via the creation of an aquaculture RI Working Group. The Working Group will have as its chief objectives the strengthening of collaboration and improvement of cooperation among the organisations and facilities involved in the network, and beyond.

KEY INFORMATION

The RI Working Group's primary goals are as follows:

1. To strengthen collaboration between aquaculture RIs in Europe and internationally
2. To develop aquaculture RIs that can meet emerging needs for research and innovation
3. To correlate the capacities at existing RIs to actual industry Research, Development & Innovation (RD&I) needs in order to increase the awareness of the benefits of exploiting existing aquaculture RIs for all stakeholders

4. To further and promote knowledge exchange on research, technical and innovation progress in aquaculture

Foreseen Activities include:

- ✓ Providing a single and focused European contact point for aquaculture RI issues
- ✓ Liaising with all actors in the European aquaculture sector to promote industry driven experimental research and to stimulate the uptake of scientific results
- ✓ Disseminating progress on the EATiP Aquaculture Research & Innovation agenda
- ✓ Communicating a consolidated aquaculture RI strategy to decision makers on a national and European level
- ✓ Stimulate industry participation in experimental research
- ✓ Assemble and distribute prioritised RD&I needs from the aquaculture industry to the pool of European RIs

END-USER & APPLICATION

➔ END-USER 1: Aquaculture RIs.

APPLICATION: The EATiP Working Group will represent a definitive and singular European contact point for RI issues in the aquaculture sector. It will communicate the prioritised, region-specific and common European needs of the aquaculture sector to the existing RI pool. This will make them better suited to contribute to real challenges and to implement the EATiP Strategic Research and Innovation Agenda (SRIA).

➔ END-USER 2: Aquaculture Industry.

APPLICATION: Through input from SMEs and



industry, the EATiP Working Group will make a record of concrete needs for science based research and of project results that are ready for uptake. Industry stakeholders will also be aided in gaining access to public-owned aquaculture RIs to conduct experimental research related to their needs.

➔ END-USER 3: Policy makers.

APPLICATION: The EATiP Working Group will liaise with policy makers in order to assist them in developing a consolidated aquaculture RI strategy on both a national and European level.



IMPACT

The EATiP Working Group will dedicate much of its activities to RI requirements in response to industry needs. This will facilitate the dialogue between facility providers and end-users of results (industry, consumers, etc.), with a view towards market-driven tailored design of new installations and increased use of the existing installations. Its impact will be in ensuring the long-term integration of RIs within the commercial sphere.

Opportunities to develop a European integrated aquaculture RI in the European Strategy Forum on Research Infrastructures (ESFRI) framework will also be explored.

KEY OUTPUT 2

EVALUATION OF HOW AN AQUACULTURE E-INFRASTRUCTURE WILL CONTRIBUTE TO FUTURE AQUACULTURE RESEARCH



Photo courtesy of SINTEF

SUMMARY: One of the main objectives of the **AQUAEXCEL** project was to develop, implement and evaluate e-Infrastructure solutions for aquaculture research facilities in order to assess their potential contribution to future aquaculture research. Outcomes show that the use of an e-Infrastructure results in the collection of more and better quality data, facilitates data access between partners and makes sampling procedures easier, reducing the possibility of experimental failures.

AT A GLANCE

FULL TITLE: Evaluation of how an aquaculture e-Infrastructure will contribute to future aquaculture research

KNOWLEDGE TYPE: Report

WHERE TO FIND IT: www.aquaexcel.eu

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INTRODUCTION

An e-Infrastructure is an electronic infrastructure to facilitate interchange of data and remote operation between research facilities over the internet. In general e-Infrastructures aim to provide researchers with easy and reliable online access to facilities, resources and collaboration tools. In the specific context of the **AQUAEXCEL** project, research activities were undertaken to develop, implement and evaluate technical solutions (e-Infrastructure) for providing remote access to highly

specialised aquaculture research facilities. It was envisioned that this would facilitate cooperation in new ways.

As the project concludes, a report has been compiled to evaluate how the e-Infrastructure will contribute to future aquaculture research. In particular, the evaluation concerns results in relation to experimental design, experimentation logistics, costs and potential outcome.

KEY INFORMATION

AQUAEXCEL succeeded in developing, implementing and evaluating technical solutions for providing remote access to some of **AQUAEXCEL**'s research facilities. The individual **AQUAEXCEL** partners have developed and adapted e-Infrastructures which suit their requirements. Given the diverse range of existing e-Infrastructures, a number of different solutions were investigated.

Five facilities were used for testing the developed e-Infrastructures. For each facility, a technical solution for external access (e-Infrastructure) was provided as follows:

1. IMARES: External accessibility of the system for monitoring water quality in Recirculating Aquaculture Systems (RAS) as well as using SharePoint to exchange data.
2. SINTEF/ACE: Remote access to the Aquaculture Engineering (ACE) industry scale salmon farming RI, including oceanography data, and a common model for storage of data on water quality.
3. Wageningen University: External data capture and access to the Metabolic Research Unit (MRU).
4. NOFIMA: Data exchange on water quality data in RAS.
5. NTNU: Client-less secure remote access to the CodTech Marine Hatchery Automation Laboratory.

From the outset, the e-Infrastructure was expected to be an enabling technology for cooperation within the **AQUAEXCEL** consortium.

The major conclusions detailed in the report include:

- ✓ E-Infrastructures are expected to have a positive role in the quantity and quality of the collected

data. They will increase the flexibility of the experimental procedures and also reduce the possible failures. Properly designed, they will provide data redundancy, data sharing and secure access to data.

- ✓ E-Infrastructures will increase the experimental cost, at least initially, due to the required equipment. The large amounts of data collected may require additional labour for the analysis and in some cases specific tools.
- ✓ E-Infrastructures will reduce the required travelling and the relevant cost of the investigators to the experimental sites.
- ✓ E-Infrastructures may reduce the amount of direct (face to face) communication between partners and may require the development of new schemes of collaboration.

END-USER & APPLICATION

➔ **END-USER 1:** Scientific community.

APPLICATION: Researchers can consult the report to get an overview of the possible effects of the e-Infrastructure as a basis for planning their own experiments at collaborating facilities.

➔ **END-USER 2:** Aquaculture facility managers.

APPLICATION: Facility managers can consult the report as input for planning development of their own infrastructures and facilitate remote access.

➔ **END-USER 3:** Policy makers.

APPLICATION: The implementation of e-Infrastructures could have potential impact on equality and disability discrimination by improving ease of access to aquaculture RIs.



IMPACT

The impact of this output could be observed in the increased utilisation of research facilities in general, as the technical solutions developed can be used as a basis for the implementation of e-Infrastructures in RIs within other domains. The positive effects shown in this report should contribute to increased focus on implementing such solutions. A potential consequence of this is increased quality and quantity of research as more researchers will be able to access highly specialised facilities. The impact could also be gauged in the adoption of new working methods based on incorporating elements of the e-Infrastructure solutions in diverse research domains. In addition, this research has potential to improve equality among researchers by providing an alternative means of access to aquaculture RIs, especially for those with disabilities and limited mobility.

KEY OUTPUT 3

INVENTORY OF AQUACULTURE RESEARCH INFRASTRUCTURE GAPS IN EUROPE



Photo courtesy of HAKI

SUMMARY: The fields of expertise and type of facilities at existing aquaculture Research Infrastructures (RIs) in Europe were compared to those required to be able to carry out the research goals as defined by the European Aquaculture Technology and Innovation Platform (EATiP). This was achieved by carrying out a gap analysis for each EATiP thematic area which relies on the use of aquaculture RIs. Conclusions show that the current pool of European RIs largely cover the fields of expertise and facilities that are needed to comply with the main challenges in the European aquaculture sector. However, several subgoals from different thematic areas of the Strategic Research and Innovation Agenda (SRIA), as developed by EATiP, are not sufficiently covered by current RIs in Europe and rely on expertise and/or facilities from third countries or on the development of new research teams and infrastructures.

**AT A
GLANCE**

FULL TITLE: Inventory of aquaculture Research Infrastructure gaps in Europe

KNOWLEDGE TYPE: Report

WHERE TO FIND IT: AQUAEXCEL Deliverable D2.5 (Public), www.aquaexcel.eu

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INTRODUCTION

AQUAEXCEL aims to integrate key aquaculture RIs across Europe, in order to promote their coordinated use and development. This entails research undertaken to evaluate the appropriateness of the pool of existing aquaculture RIs in Europe compared with the needs for research and development expressed by the European aquaculture industry and research communities. This report identifies the main aquaculture RI gaps in Europe, based on the European aquaculture research needs and the inventory of available RIs.

KEY INFORMATION

In order to achieve the aims of the AQUAEXCEL project, considerable research was undertaken related to infrastructure mapping, strategic planning and sustainability. Through these activities, AQUAEXCEL aims to uncover potential inconsistencies between research needs and capacities, while promoting synergies across scientific fields, systems and species.

A consolidated list of needs and suggested actions was created through multi-stakeholder workshops

and consultations under the coordination of EATiP, and supported by the strong involvement of **AQUAEXCEL**. At the same time, the **AQUAEXCEL** online RI map was launched, providing the aquaculture sector with a new tool to provide and retrieve information about existing facilities and fields of expertise.

In order to evaluate the appropriateness of European infrastructures to deal with the main research challenges faced by the aquaculture sector, a gap analysis was carried out. This in-depth study was based on the conclusions found in the EATiP SRIA and on the currently available expertise and properties in existing RIs in Europe.

The overall conclusions from this report show that European RIs cover a large part of the expertise that is needed to comply with the main challenges in the aquaculture sector. However, several subgoals from different thematic areas of the SRIA are not sufficiently covered by European RIs, and there is a need for new facilities, services, expertise and for collaboration with RIs outside Europe.

END-USER & APPLICATION

➔ END-USER 1: Industry

APPLICATION: Identification of RIs that can contribute to reaching the goals that have been set by the aquaculture sector (through EATiP), leading to solving sector-specific challenges.

➔ END-USER 2: Policy makers.

APPLICATION: Assisting in the decision-making, on a national and European level, of science planning and funding that is adjusted to the sector needs and knowledge gap area. This will lead to better use and development of RIs.

➔ END-USER 3: Scientific community - aquaculture.

APPLICATION: RI providers can relate their expertise and facility properties to the needs for research expressed by the aquaculture sector.



AQUAEXCEL European Aquaculture Research Infrastructures interactive map. Shortened link: <http://bit.ly/1EeEGXQ>



IMPACT

The inventory is a step in the direction of implementing the EATiP SRIA (as part of the Knowledge Management thematic area). EATiP will also be a central stakeholder in the process of further exploitation of the results.

This report has the potential to impact the sector in the following ways:

- ✓ Stimulation of more industry-relevant aquaculture research in Europe
- ✓ Stimulation of more industry-relevant aquaculture education in Europe
- ✓ Adjustment of European aquaculture RI properties and expertise making them better suited to carry out experiments in line with the sector's needs, reducing the length of the process between research results and commercialisation

KEY OUTPUT 4

MODEL FOR SUSTAINED AQUACULTURE RESEARCH INFRASTRUCTURE COLLABORATION IN EUROPE



Credit: ©HCMR-Souda

SUMMARY: Based on collaboration priorities as perceived by the aquaculture Research Infrastructures (RIs) in the **AQUAEXCEL** consortium and on the particularities of aquaculture research, five different organisation models for structured RI collaboration were analysed using the SWOT (Strengths, Weaknesses, Opportunities, Threats) methodology. The analysis resulted in the recommendation of a project-based collaboration in the short term, and the constitution of a European Research Infrastructure Consortium (ERIC) as a longer term strategic aim. The report will be of interest to existing aquaculture RIs of international value in the European Research Area, and the stakeholders, both public and private, that depend on them for their research, training and testing activities.

AT A GLANCE

FULL TITLE: Model for sustained aquaculture Research Infrastructure collaboration in Europe

KNOWLEDGE TYPE: Report

WHERE TO FIND IT: **AQUAEXCEL** Deliverable D2.6 (Public), www.aquaexcel.eu

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INTRODUCTION

The objective of this report is to recommend a suitable model for sustained and coordinated collaboration of aquaculture RIs in Europe. In a previous study undertaken by the **AQUAEXCEL** consortium (see pages 6 - 7) the priorities for RI collaboration of **AQUAEXCEL** members were mapped, analysed and prioritised. Five different organisation models were suggested as possibilities

for future RI collaboration. This report evaluates these models using the SWOT methodology. Its purpose is to ascertain the first step towards a future integrated European aquaculture RI, as considered by the **AQUAEXCEL** consortium and to provide direction to the next stages of the change process as **AQUAEXCEL** comes to an end.

KEY INFORMATION

This report complements previous research carried out by the **AQUAEXCEL** project, where the priorities for collaboration between RIs as perceived by the **AQUAEXCEL** members were mapped, analysed and prioritised. Based on these collaboration priorities and the particularities of aquaculture research, a selection of organisation models for structured RI collaboration were presented, namely:

1. Project based collaboration
2. Memorandum of Understanding (MoU) between participating RI providers
3. EATiP RI Working Group
4. European Research Infrastructure Consortium (ERIC)
5. Internationally acting not-for-profit association

The report found that all five analysed models stimulate collaboration among existing RIs in some way – with varying intensity and/or perpetuity. There is no “one model fits all” option. A given situation, with external influences, existing RI landscape, and maturity of collaboration; will have a strong influence on the suitability of each model and its feasibility. During the analysis, it was noted that there are strengths, weaknesses, opportunities and threats that are common to any collaborative infrastructure initiative, regardless of the model.

Project based collaboration was evaluated to be the most suitable model for continued collaboration in the short term. There are several reasons for this, but outstanding among its strengths as a model is the fact that it accommodates all the priority areas identified by **AQUAEXCEL** partners, namely:

- ✓ Transnational Access
- ✓ Collaborative research
- ✓ Staff exchange
- ✓ Joint development of common standards & methods

It is also a model which is adequately and securely resourced through external funding. The fact that



Photo courtesy of Patrick Maitre, INRA

this model has a robust structure and clear roles and responsibilities governed by a detailed contract was also perceived as advantageous.

The formation of an ERIC was considered the most viable model for consolidating aquaculture RIs, sustaining their development, and maximising their impact in the long term. The European Strategy Forum on Research Infrastructures (ESFRI) Roadmap identifies RIs of pan-European interest corresponding to the long term needs of European research communities, covering all scientific areas. However, regrettably, the European aquaculture sector is not currently represented on this roadmap. The report concludes that this should now become a strategic aim for the sector in order to secure the place of European aquaculture RIs in the long term. Ascertaining the will and commitment of prospective member states in forming an ERIC for the advancement of aquaculture research in Europe was recommended as the next step forward.

END-USER & APPLICATION

➔ END-USER 1: Scientific community

APPLICATION: Advice on how to organise a collaborative network of RIs in the most efficient and satisfactory way.

➔ END-USER 2: Policy makers.

APPLICATION: Identification of critical factors towards the establishment of an aquaculture European Research Area (ERA) that can support the development of sustainable aquaculture production in Europe.

➔ END-USER 3: RI projects in other sectors.

APPLICATION: The conclusions can be used to establish common RI services between RIs from other sectors and aquaculture RIs.

➔ END-USER 4: Industry - aquaculture.

APPLICATION: Generating ideas on how the European aquaculture industry can contribute to the operation of a network of complementary aquaculture RIs, including the role of privately owned research facilities.



Photo courtesy of SINTEF



IMPACT

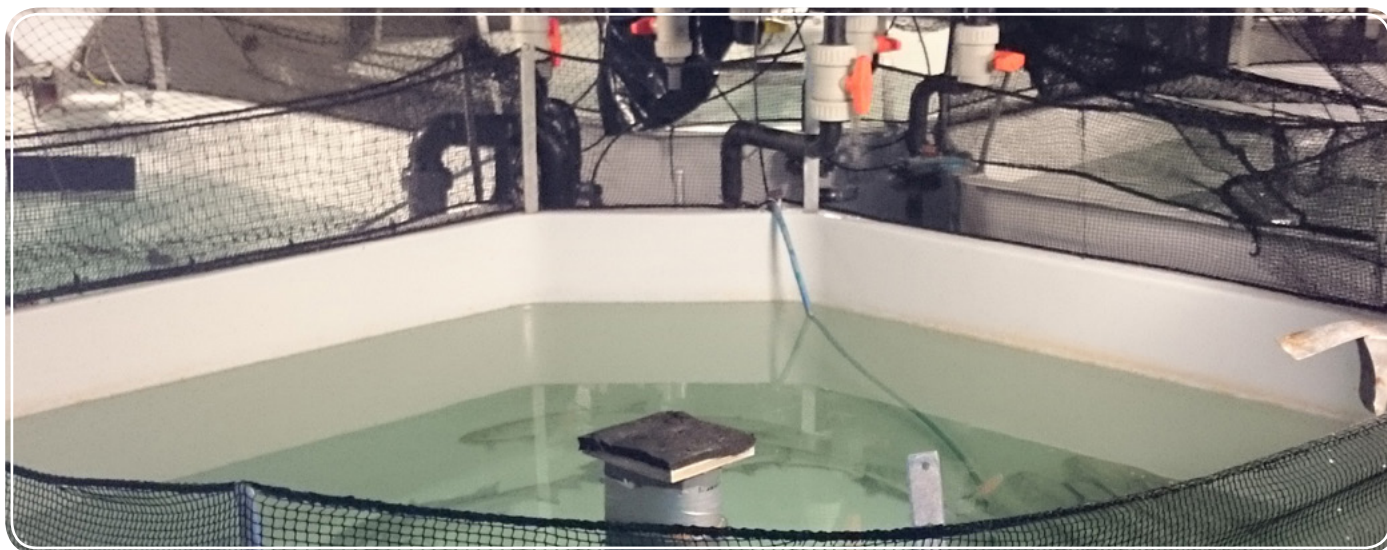
Findings from this report can be applied to RI networks from all sectors of aquaculture. It will also have relevance to RIs with a comparable structure (small and medium-sized infrastructures, geographically spread and with a diversity of facilities and fields of expertise) in other sectors beyond aquaculture.

Recommendations given in the report have the potential to be taken further by those aquaculture RIs that have the aspiration and capacity to integrate their operations with other infrastructures in Europe. In the long term, by gaining the commitment of EU member and associated states, a separate legal entity such as an ERIC could be founded to secure the place of European aquaculture RIs into the future. The report has scope for impact in the following ways:

- ✓ Stimulation of collaboration among aquaculture RIs in Europe
Indicator ➔ joint publications, joint research applications
- ✓ Simplification of access to key RIs by the development of common RI services
Indicator ➔ increased staff and student mobility
- ✓ Development of a RI organisation model that is in line with prevailing needs and regulatory environment on a national and international level
Indicator ➔ establishment of a distributed aquaculture RI as a separate legal entity

KEY OUTPUT 5

3D MONITORING OF FISH BEHAVIOUR: TECHNIQUES AND COMPARISON



Example of a tank used for fish rearing in aquaculture. Photo courtesy of Dr Petr Císař.

SUMMARY: Comparison and evaluation of three systems for monitoring of fish behaviour in 3D: stereo vision, structured light and infrared (IR) reflection. The novel IR reflection system is recommended as an inexpensive solution for real-time fish behaviour monitoring at indoor aquaculture facilities. This knowledge will be of interest to aquaculture facilities looking to implement new 3D fish monitoring techniques or those who wish to improve upon existing techniques.

AT A GLANCE

FULL TITLE: 3D Monitoring of fish behaviour: techniques and comparison

KNOWLEDGE TYPE: Paper in proceedings of a conference

WHERE TO FIND IT: Aquaculture Europe 2014

<https://www.was.org/easOnline/AbstractDetail.aspx?i=3373>

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PATENTS OR OTHER IPR EXPLOITATIONS: No

This research was carried out under the AQUAEXCEL Transnational Access Programme at the Nofima Centre for Recirculation in Aquaculture (NCRA), Norway

INTRODUCTION

Fish behaviour analysis is a growing area of interest in fish related research areas as it can be used to answer many research questions in the fields of nutrition, welfare, health and pathology, environmental interaction and aquaculture systems design. The basis of fish behaviour analysis is determining fish position and orientation in 3D space at a particular time (called tracking). The analysis of fish tracks can provide information about individual fish behaviour, interaction and school behaviour.

The first systems for video monitoring of marine and fresh water biology date back to 1952. Since that time much research has been undertaken in order to improve upon existing monitoring hardware, and software analysis of the recorded data. This study analyses and compares the available approaches for 3D fish monitoring with a new method based on the IR reflection in order to find the best system for 24/7 fish behaviour monitoring in real conditions.

KEY INFORMATION

Several approaches exist for fish detection and tracking. The most widely used approach is based on stereo vision and involves processing of synchronous images from two video cameras to get the 3D coordinates of the objects, in this case fish. The method has several issues. Both cameras used in the system have to be synchronised and calibrated. The 3D coordinates are calculated using the disparity map and determination of the corresponding points in the views of both cameras. These issues make the system expensive and computationally intensive.

A second approach currently in use is based on processing the images of the objects illuminated with a structured light pattern. It requires only one video camera and allows double the rate of 3D coordinates calculation in comparison to the stereo vision system. The main limitation of the system based on the structured light is the monitoring depth (how far the system can see under water). The system based on Microsoft Kinect is limited to just 45cm.

The third approach is based on using an external source of light with a wavelength which is highly absorbed by water. The brightness of the objects on the images from the camera will then depend on the distance the light travels from the external illumination source to the object and then to the camera.

Each fish monitoring technique was tested within the following parameters:

1. Octahedron shape fish tank with fresh water height 0.83m and diameter 2m
2. All the cameras and light sources of the systems were placed in a horizontal plane above the tank at a height 1.21m above the water level in the vicinity of the central axis of the tank

3. The fields of view of the cameras were not including the fish tank borders
4. The experiments were conducted using Atlantic salmon with lengths 29.5 ± 2.5 cm and weight 295 ± 73 g

All three systems have approximately the same horizontal plane accuracy of 0.5cm which depends on camera resolution and image segmentation algorithms. The highest fish depth calculation accuracy of 2.5cm was obtained from the stereo vision system. The structured light and IR reflection systems showed 1cm and 5cm error on vertical (depth) axes, respectively.

The stereo vision system showed a maximum monitoring depth of several metres which was mainly limited by water transparency. The maximum monitoring depths of structured light and IR reflection systems depend on the water absorption coefficient and the optical power of the illumination sources. For the structured light system the maximum obtained water depth was 20cm. After increasing the Kinect sensor's IR camera integration time it can be increased up to 45cm but at the expense of reducing the frame rate to ~10 frames per second (FPS). The maximum obtained depth for the IR reflection system was ~75cm at 10FPS.

The stereo vision based system showed the best accuracy in comparison to other tested systems but it requires two cameras and high computational power for detection of the stereo pairs in both views. For above water use it requires calibration for each different position relative to the fish tank.

The advantage of the structured light system based on a Kinect sensor is the commercial availability and relatively low price of the hardware. However, recalibration of the system is required for depth calculation in water. The

	Stereo Vision System	Structured Light System	IR Reflection System
Depth Calculation Accuracy	2.5cm	1cm error*	5.3cm error
Maximum Monitoring Depth	Several Metres	20cm (up to 45cm at 10FPS)	~75cm at 10FPS

disadvantage of the system is its relatively low water depth monitoring range. Increasing the optical output power of Kinect's internal dot pattern generator and sensitivity of the IR camera module can slightly increase the monitored water volume. In addition, an increase can be obtained using a light source with less water absorbed wavelength (e.g. closer to visible range).

The IR reflection system can be used in circumstances where high accuracy of 3D coordinates calculation is not required (fish behaviour monitoring). The advantages of this system include the low price of the components and relatively low required computation power. Increase of the monitored water volume can be obtained by using a more powerful external illuminator.

END-USER & APPLICATION

➔ END-USER 1: Aquaculture facilities.

APPLICATIONS: The monitoring methods detailed confer the ability to noninvasively monitor fish behaviour in real-time and to indicate behavioural abnormalities. These technologies have application across a broad range of aquaculture sectors including: nutrition, welfare, environmental interaction, health and pathology.

➔ END-USER 2: Aquaculture systems design.

APPLICATIONS: This knowledge will be of interest to aquaculture facilities looking to implement new 3D fish monitoring techniques or those who wish to improve upon existing techniques.



Placement of the 3D monitoring system above the fish tank. The system monitors the tank in real time and provides the information about fish behaviour. Photo courtesy of Dr Petr Císař.



IMPACT

Further research is necessary to improve the accuracy and monitoring range of the IR reflection system. Future measurement of impact can be gauged by uptake and implementation of the IR reflection system in aquaculture facilities.

KEY OUTPUT 6

EFFECT OF BIOFILTER SCALE ON TOTAL AMMONIA NITROGEN (TAN) REMOVAL RATE IN CLOSED AQUACULTURE SYSTEMS



Medium scale (200L) experimental MBBR. Photo courtesy of IMARES.

SUMMARY: In the farming of fish, Moving Bed Biofilm Reactors (MBBRs) are used increasingly in closed aquaculture systems for the removal of ammonia and soluble organic matter produced by the fish. Scaling is an important issue in general bio-reactor design since mixing behaviour of water and soluble matter will differ between small and large scales. Research is mostly performed on a small scale and the question is to what extent this can be upscaled to a commercial level. This research finds that the scale (volume) of biofilters has a significant effect on TAN (Total Ammonia Nitrogen) removal rate (performance). In general, the larger the scale the better the performance.

AT A GLANCE

FULL TITLE: Effect of biofilter scale on Total Ammonia Nitrogen (TAN) removal rate in closed aquaculture systems

KNOWLEDGE TYPE: Scientific Abstract

WHERE TO FIND IT: Presented at Aquaculture Europe 2014, Donostia–San Sebastián, Spain.
<https://www.was.org/EasOnline/AbstractDetail.aspx?i=3659>

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PATENTS OR OTHER IPR EXPLOITATIONS: No

INTRODUCTION

In aquaculture MBBRs are used increasingly for removal of ammonia and soluble organic matter produced by fish in closed systems for farming of fish. Scaling is an important issue in general bio-reactor design since mixing behaviour of water and solubles will differ between small and large scales, leading to differences in fish performance. Research is mostly performed on a small scale and the question is to what extent the research findings and results obtained can be upscaled to a commercial level. Conversely, taking the commercial situation as a starting point, the question is whether

large units can be scaled down to answer specific research questions in a representative way.

KEY INFORMATION

This report investigates the effects of scale on performance of a specific type of biofilter, the MBBR. This type of biological water treatment is widely used in the treatment of sewage. In recent years the same technology has been applied on fish farms where biofilters are used as a water treatment unit in Recirculating Aquaculture Systems (RAS) for removal of ammonia and soluble organic matter produced by fish.

The experimental research on upscaling of MBBRs was focused on three different scales:

- A small scale, in this case 0.8L
- A medium scale, in this case 200L
- A large scale, in this case >20,000L

The small scale is often used in kinetic experiments to test biofilm performance. The medium scale selected was one which was easy to maintain in the laboratory and served as a homogenous pool for biofilter media which were then used in the comparison between small and medium scale. Performance of the medium scale system was monitored regularly and this system was maintained over a long period.

The effects of upscaling to a commercial level were studied by bringing the small scale system to a number of aquaculture farms and testing performance in parallel with measurements of the large MBBRs at the site. In both the comparison between small and medium, and small and large MBBRs, biofilter media from a medium/large system was transferred to the small system. Inflow to the reactor was taken from a common source while flows of water and air were scaled according to reactor volume. This experimental set-up ensured a true evaluation of scale-effects irrespective of biofilm history or pollution load. When comparing the small and medium scale MBBRs, the geometry of the MBBR and the aeration applied was strictly standardised. At farm level this standardisation was not possible since different dimensions and aeration systems were applied.

CONCLUSIONS

MBBR scale has a significant effect on TAN removal rate. In general, the larger the scale the better the performance. TAN removal at small scale (0.8L) is approximately 80% compared to that at medium scale (200L). The difference between small scale and large scale (>20,000L) is even higher.

Findings of note in the report include:

- ✓ MBBR scale has a significant effect on TAN removal rate. In general, the larger the scale the better the performance.
- ✓ Superficial air speed is not a good scaling factor for MBBRs. Upscaling while maintaining geometry



Small scale (0.8L) experimental MBBR. Photo courtesy of IMARES.

implies increasing air injection depth and therefore increased energy input at comparable air speed.

- ✓ Air speed and media filling percentage have a strong effect on mixing time at small scale. An airspeed below a threshold of 5 m h^{-1} (metres per hour) decreases TAN removal at both small and medium scale.
- ✓ Intense mixing at small scale increases TAN removal at low TAN concentration. At a high TAN concentration, the small scale MBBR always performs at approximately 80% of the capacity of the medium scale system irrespective of the mixing conditions.
- ✓ Capacity of full scale systems will be underestimated when based solely on small scale experiments.

These findings warrant further studies on whether a plateau is reached in TAN removal efficiency at a certain scale.

END-USER & APPLICATION

➔ **END-USER 1:** Aquaculture industry (farming, technology)

APPLICATION: Aquaculture industry end-users can use this information to learn about possible effects of installing biofilters of different scales, i.e. results may have impact on facility design and dimensioning.

➔ **END-USER 2:** Scientific Community.

APPLICATION: This knowledge can be used to design experiments relevant to the aquaculture industry. Scientists can use this knowledge to improve the diversity and effectiveness of experiments involving biofilters, ultimately making them more applicable for implementation in the aquaculture industry.

➔ **END-USER 3:** RAS producers and aquaculture technology suppliers.

APPLICATION: This knowledge can be used in the testing phase of the design of new MBBRs.



Large scale (>20,000L) experimental MBBR. Photo courtesy of IMARES.

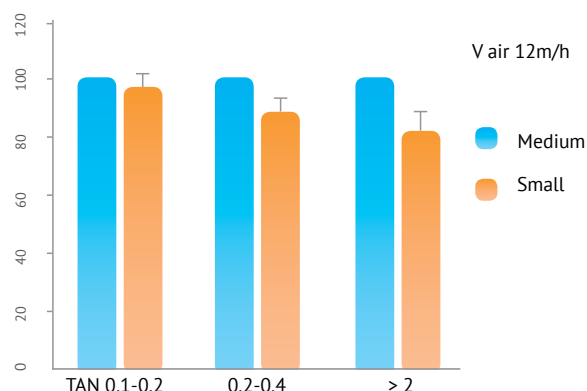


IMPACT

These findings warrant further studies on whether a plateau is reached in TAN removal at a certain scale; a study which will have considerable impact for RAS suppliers.

The study may also impact how the research community should be studying biofilters and TAN removal, since small-scale results cannot be directly transferred to large-scale situations. The study may also impact on how biofilters should be designed and dimensioned for commercial fish farming applications.

The results of this study will impact the following sectors: aquaculture engineering companies, producers of biofilters, associations of aquaculture engineers, such as members of the aquaculture Engineering Society and those engaged in commercial aquaculture.



TAN removal rate in a small and a medium scale MBBR filter at an air speed of 12 meters per hour, measured at three original TAN levels (0.1-0.2, 0.2-0.4 and >2 mg/L). In smaller filters, the capability to remove TAN from a system decreases. When TAN in the system is >2 mg/L, the TAN removal rate of the small filter is 80% of the removal rate that is achieved in the larger filter.

KEY OUTPUT 7

EFFECT OF BOTH MALE AND FEMALE PARENTAL NUTRITION ON THE DEVELOPMENT OF SEAHORSE (*HIPPOCAMPUS REIDI*) EMBRYOS



Photo courtesy of Francisco Otero Ferrer

SUMMARY: This research investigated whether or not parental nutrition in the time period around conception in adult seahorses affects the development and growth of their offspring. The study tested the hypothesis that because seahorse embryos develop inside the male's brood pouch, manipulation of the male's diet would affect offspring growth and development independently of the female's diet. The results support the hypothesis that the male's brood pouch does more than simply providing a suitable environment that sustains embryonic growth as it was demonstrated that the growth and survival of seahorse offspring is dependent on the quality of diet received by both parents prior to conception.

AT A GLANCE

FULL TITLE: Effect of both male and female parental nutrition on the development of seahorse (*Hippocampus reidi*) embryos

KNOWLEDGE TYPE: Paper in proceedings of a conference. Peer reviewed publication.

WHERE TO FIND IT: Otero-Ferrer F, Izquierdo M, Fazeli A, Holt WV. "Sex-specific effects of parental diet during pregnancy on embryo development in the long snout seahorse (*Hippocampus reidi*; Ginsburg, 1933)". *Reproduction, Fertility and Development*. 2014;27:153-153

Otero-Ferrer F, Izquierdo M, Fazeli A, Holt WV. "Embryonic developmental plasticity in the long-snouted seahorse (*Hippocampus reidi*, Ginsburg 1933) in relation to parental preconception diet." *Reproduction, Fertility, and Development*. *Reprod Fertil Dev*. 2014 Dec 17. doi: 10.1071/RD14169. [Epub ahead of print]

WHO TO CONTACT FOR MORE INFORMATION: William Holt, **E:** Bill.holt@sheffield.ac.uk

PATENTS OR OTHER IPR EXPLOITATIONS: No

This research was carried out under the AQUAEXCEL Transnational Access Programme at the Universidad de las Palmas de Gran Canaria (ULPGC) Warm Water Species Selection Unit (WWSSU), Spain

INTRODUCTION

Environmental influences (including diet and feeding conditions) experienced during embryonic development can modify an animal's phenotype, setting the scene for the future, with implications for their survival and reproductive ability. With their particular reproductive

behaviour, where males not only produce sperm but also are the sex which becomes pregnant, seahorses constitute an excellent and unique model for this type of study. The seahorse embryo undergoes an interaction with the male's pouch that resembles mammalian implantation, with each of the individual

embryos developing a kind of placenta. If this placenta truly provides sustenance and functional support to the developing embryos, the situation becomes very interesting in the light of relatively recent findings in mammals, where the quality of the maternal environment (especially in terms of nutrition) around the time of conception is now known to have major influences on the later life of the adult. The aims of this study were twofold:

1. To investigate the hypothesis that parental nutrition in adult seahorses affects the growth and development of their offspring, much as in the mammalian system
2. To validate the proposal that seahorses may be a valuable and highly effective model species for use in future epigenetic studies

KEY INFORMATION

The experimental design involved using either wild or commercial seahorse diets (frozen mysids) to influence the peri- and post-conception environment. Sixteen breeding pairs of captive-reared seahorses were divided between aquariums in pairs (male and female). The diets of males and females were manipulated separately for one month prior to mating as summarised in the table below.

Successful mating occurred and viable offspring were produced by each pairing from all combinations of dietary treatments. The experiment was continued for five months and approximately 3,000 offspring were born. Subsamples of 10 one-day old offspring from each brood were weighed and their physical dimensions measured for subsequent statistical analysis.

In the first brood, pairs in which the male parents

received commercial and females received wild diet, produced significantly ($P < 0.05$) larger offspring than controls (males and females both receiving wild diet). Offspring produced by females fed with commercial diet were consistently smaller than the controls, and their snout length/head length ratio was smaller than the controls, suggesting that maternal nutrition directly affects offspring development. These results demonstrated that the growth and survival of seahorse offspring is dependent of the quality of diet received by both parents prior to conception. It is of interest that when males were given a commercial diet (which is lower in polyunsaturated fatty acids than wild diet), their offspring were abnormally large. The results support the hypothesis that the male's brood pouch does more than simply provide a suitable environment that sustains embryonic growth and supports the hypothesis that the seahorse could be used as a valuable experimental model for studying the relationships between parental nutrition and offspring fitness.

END-USER & APPLICATION

- ➔ **END-USER 1:** Aquarium management.
APPLICATION: The findings of this study have applicability for those involved in seahorse breeding and seahorse nutrition and welfare.
- ➔ **END-USER 2:** Seahorse feed industry.
APPLICATION: The findings of this study have applicability for those involved in seahorse nutrition. The results obtained could be used to develop new feeds tailored for optimal perinatal nutrition.
- ➔ **END-USER 3:** Scientific and Research Community.
APPLICATION: These results are entirely novel and could have wide scientific significance across many

Dietary Treatment	
MW/FW	Male and female parents fed a wild-caught diet
MC/FW	Male parent fed a commercial diet and female parent fed a wild-caught diet
MW/FC	Male parent fed a wild-caught diet and female parent fed a commercial diet
MC/FC	Male and female parents fed a commercial diet

aspects of biology. Developmental biologists would be able to exploit the seahorse model for understanding the effects of periconception diet on offspring growth and survival. Indeed, the data obtained in this study will also have important implications for scientists studying the impact of nutrition on all aspects of embryonic development across diverse species.

➔ **END-USER 4:** Human medicine.

APPLICATION: The results of this study indicate that the seahorse could be used as a valuable experimental model for studying the relationships between parental nutrition and offspring fitness. Evidence from other species, including humans, shows that facial development requires tight synchronous gene expression in order to maintain correct body

patterning. These seahorse results have increased the knowledge in this area by revealing the importance of such fatty acids in maintaining such synchrony.



Photo courtesy of Francisco Otero Ferrer



IMPACT

1. These results are entirely novel and could have wide scientific significance across many aspects of biology. Developmental biologists would be able to exploit the seahorse model for understanding the effects of periconception diet on offspring growth and survival. The particular attraction of the seahorse lies in the possibility of modifying male and female diets independently of each other. Unlike the situation in humans and other mammals, where any attempt to modify egg quality by dietary manipulation will inevitably also affect placental function, this is uniquely not the case with the seahorse. As the male pouch is functionally equivalent to the placenta, this study has shown the feasibility of maintaining high egg quality in females while changing pouch function independently in the male.
2. It is suspected that some of the outcomes achieved in this study were produced as a result of changes in gene expression, and that the seahorse model would therefore be very valuable for studies involving epigenetics. Epigenetic influences are now widely recognised for their important impact on the development of organisms and it is therefore reasonable to suppose that they have had major impacts on the evolution of species in response to their environment. This study hypothesises that the diversity of seahorse sizes and shapes across the world may have arisen through the interaction of environment and epigenetics, and future studies of these interactions will lead to important and novel scientific insights.
3. The data obtained in this study will also have important implications for scientists studying the impact of nutrition on all aspects of embryonic development. The differences in embryo growth and survival produced by slight variations of the parental diet have implications for their sensitivity to changes in environmental conditions. If climate change affects the fatty acids present in prey species, it is clear that seahorse growth and survival could, in turn, be either positively or negatively affected. Moreover, we suspect that geographical differences in seahorse morphology and size might have arisen through differences in growth responses to local environments.
4. One particularly noteworthy outcome was the finding that reducing the proportion of polyunsaturated fatty acids fed to breeding males led to significant distortion of the snout to head length ratio in their embryos. Evidence from other species, including humans, shows that facial development requires tight synchronous gene expression in order to maintain correct body patterning; these seahorse results have increased the knowledge in this area by revealing the importance of such fatty acids in maintaining such synchrony.

KEY OUTPUT 8

EFFECT OF DIETARY ARGININE SUPPLEMENTATION ON THE EUROPEAN SEABASS (*DICENTRARCHUS LABRAX*) IMMUNE RESPONSE AGAINST VIBRIOSIS



Dietary treatments included two arginine-supplemented diets (1% and 2%) and a control diet without additional arginine. Photo courtesy of Rita Azeredo.

SUMMARY: The bacteria *Vibrio anguillarum* is a significant pathogen of cultured fish as it is the etiological agent of the disease known as vibriosis. It is responsible for causing some of the biggest losses in aquaculture worldwide. This study adds to the body of knowledge regarding the effect of arginine supplementation on immune mechanisms and disease resistance in European sea bass. The study found that arginine did not contribute to increased disease resistance, as fish fed arginine-supplemented diets showed higher mortalities (in a dose-response manner) than those fed the control diet.

AT A GLANCE

FULL TITLE: Immunomodulatory effect of arginine dietary supplementation on the European seabass (*Dicentrarchus labrax*) immune response against vibriosis

KNOWLEDGE TYPE: PhD thesis in progress

WHERE TO FIND IT: Not yet publicly available

WHO TO CONTACT FOR MORE INFORMATION: Rita Azeredo, **E:** ritazeredo@gmail.com, **T:** +351 223401850; Ariadna Sitjà-Bobadilla, **E:** ariadna.sitja@csic.es; Jaume Pérez-Sánchez, **E:** jaime.perez.sanchez@csic.es

PATENTS OR OTHER IPR EXPLOITATIONS: No

This research was carried out under the AQUAEXCEL Transnational Access Programme at the Agencia Estatal Consejo Superior de Investigaciones Científicas (CSIC) Instituto de Acuicultura Torre de la Sal (IATS) Experimental (EXP) and Analytical (ANA) facilities, Spain.

INTRODUCTION

For many years, dietary arginine supplementation has been used as a mechanism to boost the immune system. Results from several studies indicate that adequate provision of arginine is required for lymphocyte development and that dietary arginine supplementation enhances immune function. Arginine is considered a “conditionally essential” amino acid, and has a number of different functions including maintaining immune and hormone function. Considerable controversy, however, exists as to the benefits and indications of dietary arginine. Therefore, understanding arginine metabolism in all possible different contexts is of utmost importance as a next step.

KEY INFORMATION

The main objective of this study was to gain greater knowledge regarding the effect of dietary arginine supplementation on immune mechanisms and disease resistance in European sea bass (*Dicentrarchus labrax*). In particular, this study looked at the extent to which dietary arginine supplementation stimulates the innate immune status and whether arginine supplementation has a significant impact on disease resistance of European sea bass exposed to *Vibrio anguillarum*.

Vibrio anguillarum is a very prevalent pathogen causing vibriosis in more than 50 fish species, and resulting in considerable economic losses in marine cultures

worldwide. Infected fish can be treated, but drug resistant strains have appeared because of extensive use of these chemical drugs.

Nutritional immunology is a relatively new scientific discipline which integrates immunology research and nutrition methodologies to gain increased insight into the role of nutrients, such as arginine, in the metabolism and function of cells in the immune system.

The results of this study showed that 1% and 2% dietary arginine supplementation modulated the innate immune status of European sea bass by:

1. Inhibiting their basal humoral defences
2. Impairing cytokine production at gene expression level
3. Affecting the cell-mediated response (either by inhibiting cell proliferation or activation)

Accordingly, arginine did not contribute to an increase in disease resistance, as fish fed arginine-supplemented diets showed higher mortalities (in a dose-response manner) than those fed the control diet. It should be noted that in this study only two levels of dietary arginine supplementation were included (1% and 2% supplemented arginine level) and that results seem to point at a dose-response effect. Further research is needed to contribute to a better understanding of the mechanisms of arginine immunomodulation as it is very possible that the right level of dietary arginine

supplementation will boost fish immune systems and positively impact on disease resistance.

END-USER & APPLICATION

➔ END-USER 1: Fish feed producers.

APPLICATION: Once the right level of dietary arginine supplementation has been determined, fish feed producers, such as Biomar and Skretting, will eventually benefit from these results, as they provide useful information on the formulation of functional fish feeds.

➔ END-USER 2: Aquaculture Industry.

APPLICATION: Once the right level of dietary arginine supplementation has been determined, aquaculturists can replace therapeutic strategies such as chemical treatments by feeding their fish effective functional foods.

➔ END-USER 3: Veterinarian and Human Medicine.

APPLICATION: The findings of this study have applicability for those involved in veterinarian and human medicine. Existing studies on arginine effects on the immune system of mammals (including humans) suggest that dietary supplementation with arginine enhances the immune function. Studies also indicate that arginine has a role to play in relation to tumoral cell regulation/dynamics. This study adds to the body of knowledge regarding the impacts of arginine supplementation and its effect on immune response.



IMPACT

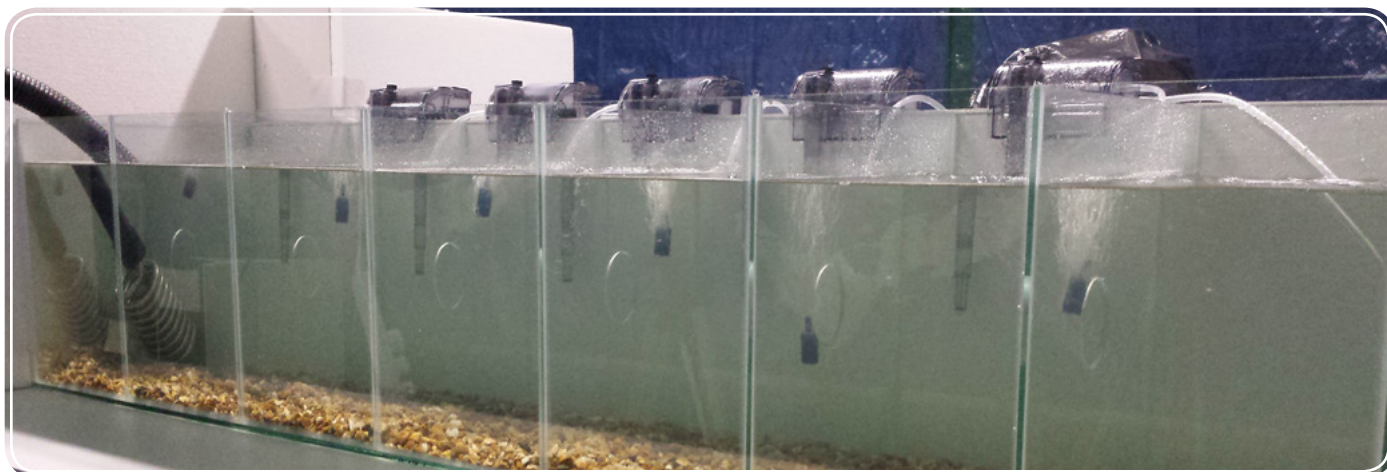
More RTD is needed to further understand and enlighten the processes behind arginine immunomodulation, so that this knowledge can be applied in aquaculture routines. Complementary studies should be developed throughout the next two years. These studies must include more *in vivo* experiments which should include dose-response trials. The present study included only two levels of arginine supplementation, but results seem to point at a dose-response effect. Therefore a dose-response study will deepen knowledge on how arginine modulates the immune response.

Furthermore, sampling after the bacterial challenge will give further insight into immune parameters after a bacterial infection. Blood cell counts would also complement these results and a control diet (a diet without replacement of fish oil and fish meal) should be included.

These additional results, when obtained, will contribute to a better understanding of the mechanisms of arginine immunomodulation and thereby increase the likelihood of safely developing supplement fish feeds which will improve the welfare of fish in aquaculture. The aquaculture sector and fish feed industries will certainly benefit from this knowledge, as they are the ultimate producers and consumers of the functional feeds which will be developed as a result of these further studies.

KEY OUTPUT 9

USING TEMPERATURE CHOICE IN A DYNAMIC ENVIRONMENT TO ASSESS PERSONALITY AND INFECTION SUSCEPTIBILITY IN NILE TILAPIA (*OREOCHROMIS NILOTICUS*)



Multi chamber experimental tank offering a choice of water temperatures. Photo courtesy of Marco Alexandre Cerqueira.

SUMMARY: This study shows that thermal preference is an indicator of animal personality and takes the first steps towards the development of a screening method which could increase the knowledge of both animal personality and 'welfare' within a population.

The results obtained show that proactive fish, generally characterised as more aggressive risk-takers, have a preference for higher temperature environments when challenged (infection with *Streptococcus iniae*), leading to higher survival rates. Reactive fish, which are shy, less risk-prone and more flexible, favour medium-cold temperatures. Control fish that were not offered a thermal choice displayed decreased survival under challenge. In contrast, a thermal choice favoured survival.

AT A GLANCE

FULL TITLE: Using temperature choice in a dynamic environment to assess personality and infection susceptibility in Nile tilapia *Oreochromis niloticus*

KNOWLEDGE TYPE: Scientific Abstract

WHERE TO FIND IT: Presentation in proceedings of EAS2014 San Sebastian, Spain - Advances in Diseases and Welfare plenary session <https://www.was.org/easonline/AbstractDetail.aspx?i=3462>

WHO TO CONTACT FOR MORE INFORMATION: Marco Alexandre Cerqueira, **E:** marco7cerqueira@gmail.com, **T:** +351 963440574

PATENTS OR OTHER IPR EXPLOITATIONS: No

This research was carried out under the AQUAEXCEL Transnational Access Programme at the University of Stirling (UoS) Institute of Aquaculture (IoA), UK

INTRODUCTION

Recently, animal personality has come to the forefront in many studies for the impact it may have not only upon animal welfare, but also upon animal production. Individual coping style variation within a population

contributes to the evolutionary fitness within a species and reflects lifelong differentiation in behavioural and stress responsiveness that in turn may impact upon vulnerability to disease.

It is now generally accepted that, in fish, individual variation in behaviour and physiology when exposed to environmental challenges reflects the existence of coping styles. This study aims to explore the possibility that thermal preference is an indicator of animal personality and takes the first steps towards the development of a screening method which can be used as an indicator of both animal personality and 'welfare' within a population.

KEY INFORMATION

Fish, being ectothermics, are unable to induce a blood temperature increase to fight infection in the way mammals do. However, when presented with an environment of varying temperature they can induce a behavioural fever, which is shown through an increased preferred temperature.

In this study Nile tilapia were housed in a multi chamber tank which offered a variety of water temperatures ranging from 22°C to 33°C. The fish were monitored over a 24hr period and their temperature preference was recorded. Depending on the thermal choice exhibited by the fish they were placed in one of three groups: Proactive, Intermediate and Reactive.

After screening, 60 individuals were subjected to a *Streptococcus iniae* challenge and their survival rates were analysed. Proactive and reactive animal personalities expressed significantly different thermal preferences within the temperature gradient. The results obtained show that:

1. Proactive fish, generally characterised as more aggressive, risk-takers and prone to routine formation, have a preference for higher temperature environments.
2. Reactive fish, which are shy, less risk-prone and more flexible, favour medium-cold temperatures.
3. Control fish that were not offered a thermal choice displayed decreased survival under challenge. In contrast, a thermal choice favoured survival.

When a thermal choice is made available, proactive fish display a clear preference for higher temperatures. In contrast, reactive fish seem to prefer lower temperatures. These results are of significant importance in relation



TNA researcher Marco Alexandre Cerqueira. Photo courtesy of Marco Alexandre Cerqueira.

to understanding the adaptive meaning of animal personality within a population.

Fish which are not offered a choice of temperatures and therefore cannot express behavioural fever show decreased survival under bacterial challenge. The thermal regime favours the immune response and thus promotes survival. These results highlight the importance and implications of environmental temperature choice on physiology and evolution that contributes to enhanced fitness and welfare in challenging environments.

END-USER & APPLICATION

➔ END-USER 1: Scientific and Research Community.

APPLICATION: The knowledge provided by this research will be of interest to those in the scientific community who work with animal welfare, since the thermal screening protocol can be used as a tool to improve the welfare of farmed fish.

➔ END-USER 2: Aquaculture Industry.

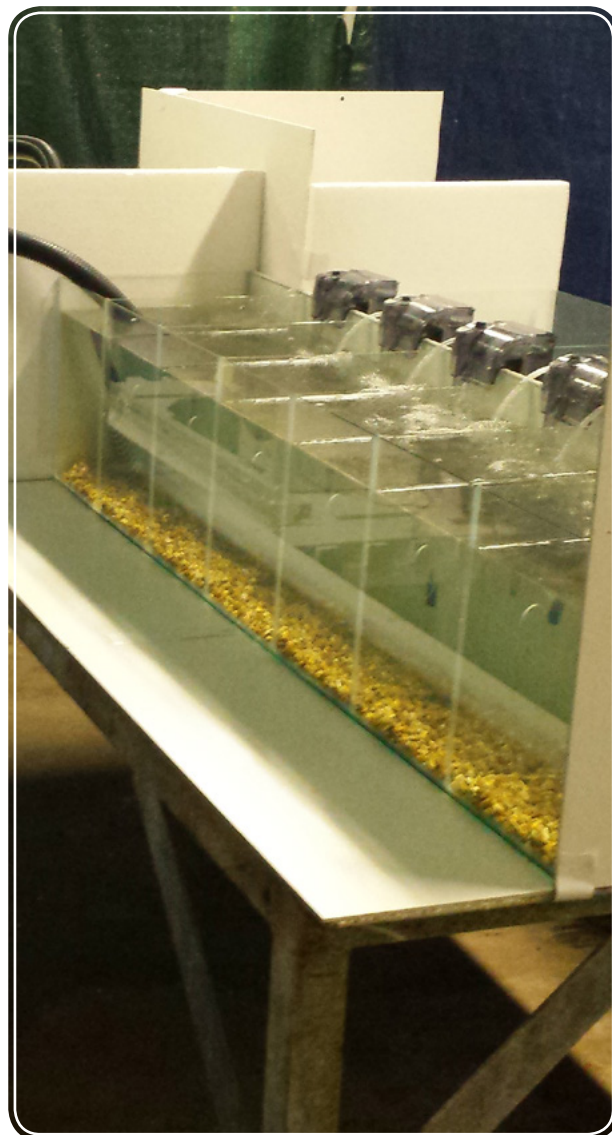
APPLICATION: This study adds to the body of knowledge regarding the different personality traits of fish. These different traits can indicate different susceptibility to diseases, growth performances, flesh quality or gametes quality, information which has high utility when designing and improving breeding programmes.

➔ END-USER 3: Aquaculture Industry.

APPLICATION: Thermal preference contributes to providing and extending the knowledge basis for the development of tools such as new group-based indicators for a better assessment of fish welfare, e.g. by identifying and verifying non-invasive indicators of coping styles.

➔ END-USER 4: Aquaculture Industry.

APPLICATION: In this scenario inter-individual differences in thermal preferences may be in parallel with inter-individual variation in stress responses and susceptibility to disease which may have a profound impact on husbandry procedures and on research results, if not taken into account.



Tank chambers offering fish a thermal choice. Photo courtesy of Marco Alexandre Cerqueira.



IMPACT

- ✓ It is now well documented that fish exhibit different personality traits and that different traits indicate different susceptibility to diseases, growth performances, flesh quality or gametes quality. The ability to gather further information of this type has high utility when designing and improving breeding programmes.
- ✓ A non-invasive intervention such as a thermal screening method would have wide utility as it could potentially reduce mortalities and improve fish welfare across a range of aquaculture systems and species. For example, the bacteria used in this study *Streptococcus iniae* is a principal fish pathogen in aquaculture operations, and it alone is responsible for annual losses of over US\$100M worldwide.
- ✓ Further research will be needed to understand whether thermal preference can be used to do a mass screening in terms of personality. The results obtained so far show that thermal preference is an indicator of personality traits; however, in order to further test these conclusions the temperature screening method should be applied to groups containing higher numbers of fish.

+ KEY OUTPUT 10

IDENTIFICATION OF NON-INVASIVE AND NON-LETHAL EARLY MARKERS OF PUBERTY PHENOTYPE IN MALE TROUT AND SEA BASS



SUMMARY: The age of first sexual maturation is an important reproductive trait in fish, and it can influence such things as genetic selection and the experimental design of research programmes. Currently, very few, if any, non-invasive markers for sexual maturation across all species of fish exist. This key output identifies that reproductive hormone concentrations (Luteinizing hormone (LH), Follicle-stimulating hormone (FSH) and Androgens) in the blood were interesting prospective candidate markers of maturation in male trout and in sea bass.

AT A GLANCE

FULL TITLE: Non-invasive and non-lethal early markers of puberty phenotype in male trout and sea bass

KNOWLEDGE TYPE: Scientific Publication, Report

WHERE TO FIND IT: AQUAEXCEL D7.6, www.aquaexcel.eu. Results from this research were presented at the EAS conference Aquaculture Europe 2014 in San Sebastian, Spain under the titles: “*Characterisation of a non-lethal indicator to predict puberty*” by A. Gómez, M. Blázquez, B. Crespo, A.S. Goupil, L. Goardon, S. Zanuy and F. Le Gac and “*Assessment of non-lethal markers for early detection of precocious puberty in sea bass *Dicentrarchus labrax* males.*” By Z. Ameur, M. Carrillo, S. Zanuy and A. Gómez.

WHO TO CONTACT FOR MORE INFORMATION: **Trout:** Florence Le Gac, E: florence.legac@rennes.inra.fr, T: 0033 223485017; **Sea Bass:** Ana Gomez, E: a.gomez@csic.es, T: 0034 964319500

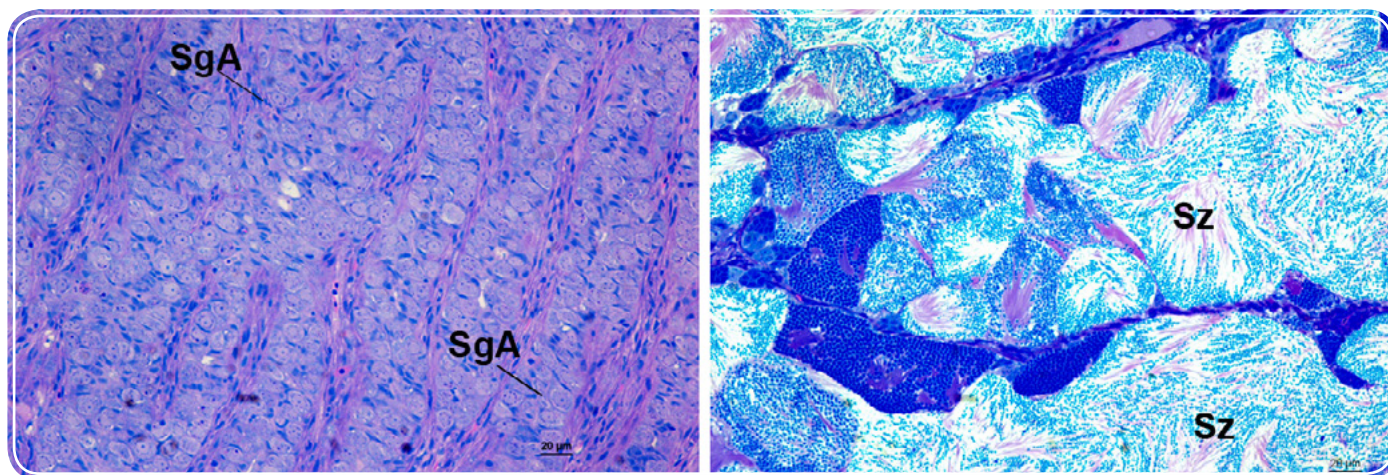
PATENTS OR OTHER IPR EXPLOITATIONS: None currently

INTRODUCTION

The age of first sexual maturation is an important reproductive trait as it can have implications for genetic selection or for the experimental design of research programmes. The detection of precocious puberty is also essential to plan cohort management in aquaculture.

Trout and sea bass males usually reach sexual maturity during the second year of life; one year earlier than

females. However, the accelerated rates of growth under culture conditions often result in a high percentage of early maturing males. For example, in populations of farmed sea bass (mostly composed of males), a very high percentage of fish mature at the first year of life before attaining marketable size. This impacts commercial aquaculture activities as final maturation is often linked to reduced growth, reduced flesh quality and lowered resistance to infectious diseases. A similar situation also



Testis histology from underyearling sea bass. Left: Immature testis only with spermatogonia A (SgA). Right: Precocious testis with spermatozoa (Sz). Photos: Z. Ameur (CSIC)

occurs in salmonids, with a critical percentage of early maturation being reached, in particular, in recirculated water systems.

Currently, the only early individual indicators of maturation that are reliable necessitate killing the fish. Therefore, there is a strong incentive to identify non-lethal and non-invasive markers in trout and sea bass that could accurately predict the maturational status of individual fish several weeks or even months before any visible sign of maturation, such as sperm production, ovulation or external secondary sex characteristics, could be detected.

KEY INFORMATION

Candidate markers for identification of maturation were selected based on the existing body of knowledge in this area. Then, validation experiments were set up to evaluate the efficiency and degree of reliability of the markers. Results were compared in trout and sea bass to formulate recommendations for other species. The main findings were:

1. In trout, a blood plasma measurement of 11-ketotestosterone (11KT) allows for efficient detection of maturation in males. This indicator is valid in trout if applied when gonadosomatic index (GSI) >1% : i.e. 3-4 months before peak spawning time. If utilised within this time period it results in a false negative proportion of less than 15% of the maturing males.

2. In sea bass, mean values of weight and length can help to predict the proportion of early maturation in a population before any histological sign of precocity. However, it is not validated as an individual marker of maturation. In one-year-old sea bass, FSH was validated as a marker of maturation but only in the late stages of spermatogenesis.

The report proposes a measurement of 11KT as a non-lethal and individual indicator to predict maturation in trout and possibly in other salmonids, months before any external signs of maturation are detectable. In order to use this indicator in practice, it is necessary to have previously characterised the typical trajectory of gonadal growth during maturation in the population of interest and to have evaluated the 11KT levels in immature animals.

Based on the differences between sea bass and trout concerning the validity of reproductive hormone levels as predictors of maturation, the report predicts that demonstration of hormonal markers for maturation will be needed for each fish genus.

END-USER & APPLICATION

- ➡ **END-USER 1:** Researchers and technicians in RIs.
- APPLICATION:** These non-invasive markers for sexual maturation can be used to measure the age of maturation as a trait in selection plans; or to better

design experimental plans by taking into account this parameter (for example if it were necessary to remove maturing fish from an experiment etc.).

➔ **END-USER 2:** Aquaculture Industry - Engineers.

APPLICATION: Final maturation is often linked to reduced growth, reduced flesh quality and lowered resistance to infectious diseases. It is anticipated that, in the future, hormone measurement would be possible through a rapid colorimetric reaction, necessitating only a drop of blood, and easily utilised on large populations, so that hormonal indicators have the scope to be applied by private industry for improved precision in fish farming. These markers will be of interest in the management of growing cohorts, for example, they can be used to select the maturing animals to sell them before final maturation and to

reduce health risks in the fish farm.

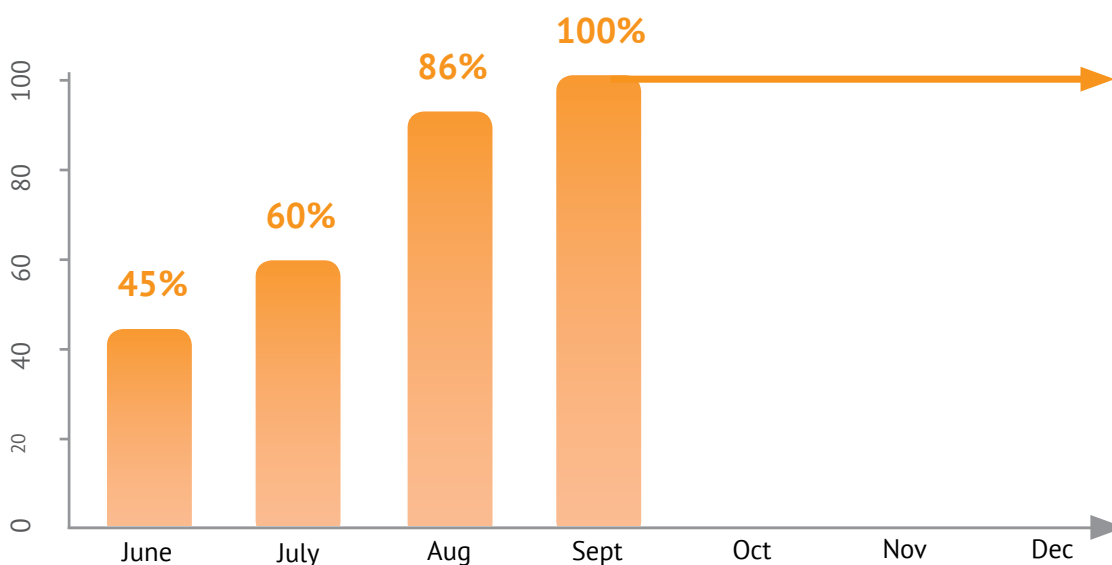
➔ **END-USER 3:** Environmental Managers.

APPLICATION: Global warming may modify the rate of early maturation in fish and the non invasive markers described here could help in understanding changes in the evolution of the fish population, with minimal impact on wild fish.

➔ **END-USER 4:** Veterinarian Research and Aquaculture Research/Industry.

APPLICATION: The development of a rapid colorimetric reaction to test hormone measurement will require collaboration between aquaculture RIs and veterinarian industry for the production of a ready to use device which has the potential to be commercialised.

🔍 DETECTION OF MATURING MALES



In trout, individual prediction of maturation using hormone level (11KT) in blood as an indicator (in orange = % of good prediction)



IMPACT

This output has potential to be applied by private industry and impact the efficiency of commercial aquaculture.

AQUAEXCEL'S TNA PROGRAMME BY NUMBERS

AQUAEXCEL united major aquaculture RIs with capacity to undertake experimental trials on a selection of commercially important fish aquaculture species and system types. As part of its Transnational Access (TNA) programme, the **AQUAEXCEL** project invited proposals from European research groups making their 27 research facilities available for utilisation by scientific researchers outside the consortium. Access to these RIs was administered through a series of nine calls.

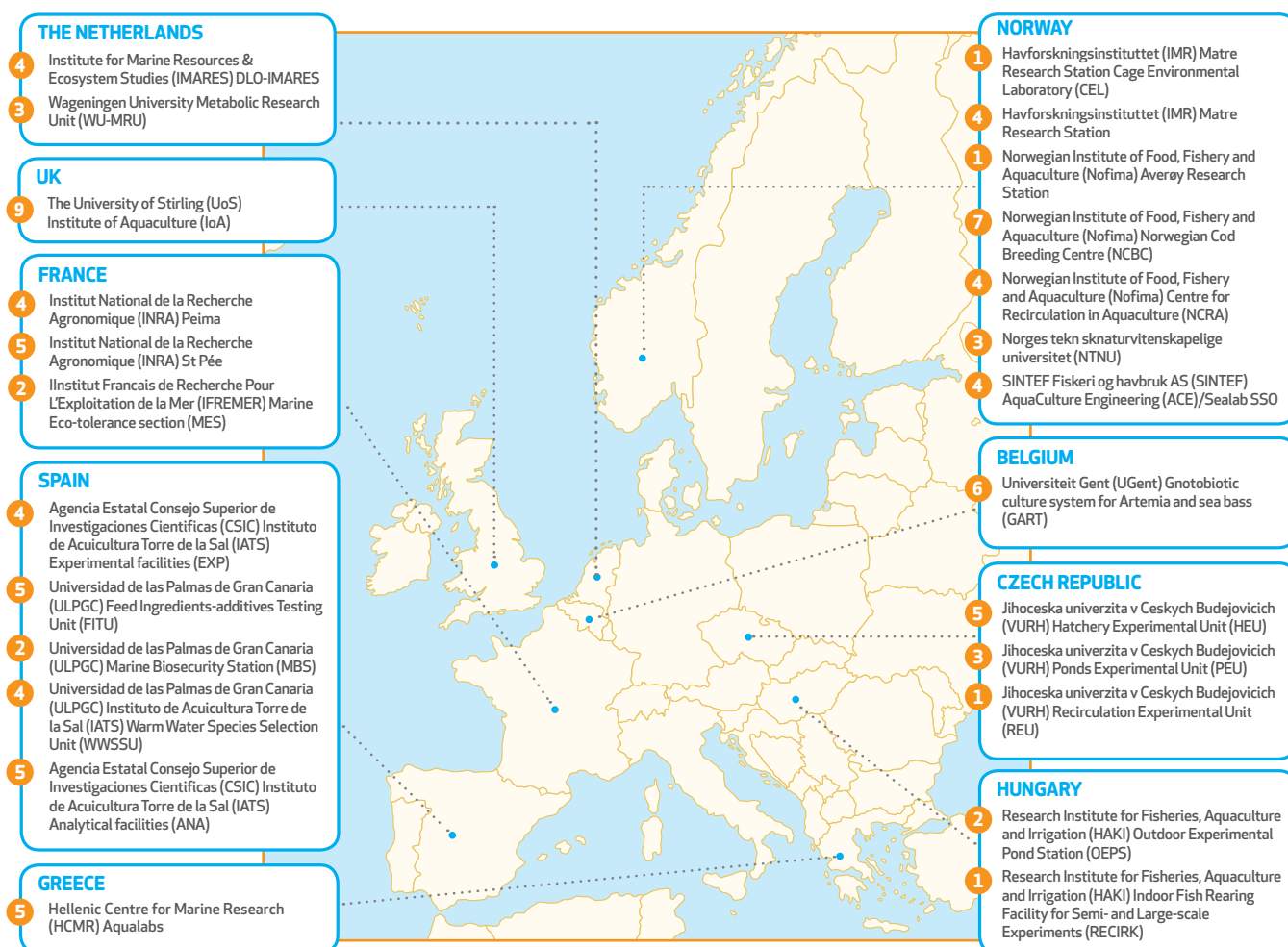
Access to the research facilities and associated travel and subsistence expenses were paid for under the project,

financed by the European Commission under the Seventh Framework Programme.

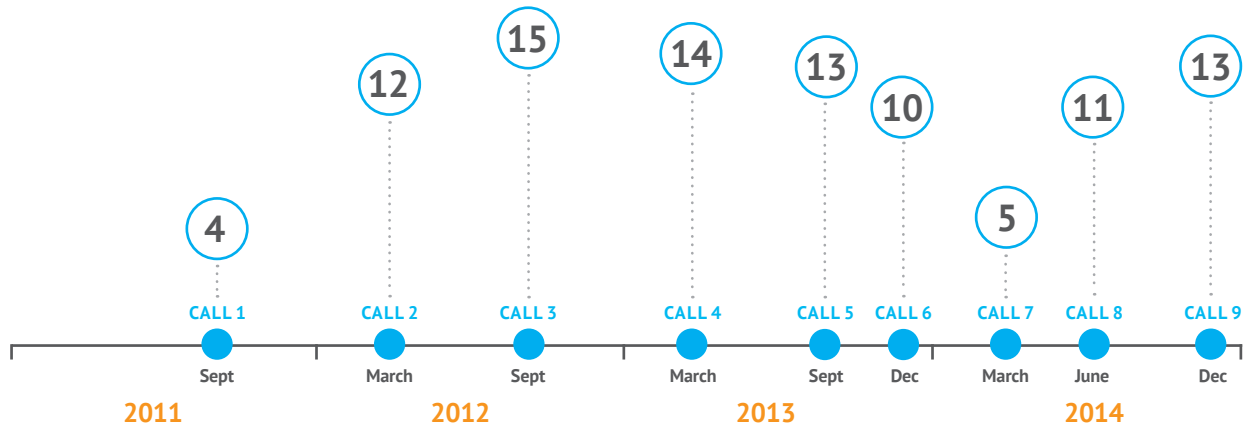
The available facilities covered the entire range of aquaculture production systems (recirculation, flow-through, cage, hatchery and pond systems); environments (freshwater and marine, cold, temperate and warm water); scales (small, medium and industrial scale); fish species (salmon, trout, sea bass, sea bream, cod, common carp etc.); and fields of expertise (nutrition, physiology, health and welfare, genetics, engineering, monitoring and management technologies).

AQUAEXCEL RESEARCH INFRASTRUCTURE ACCESSED

Number of Projects per Institute



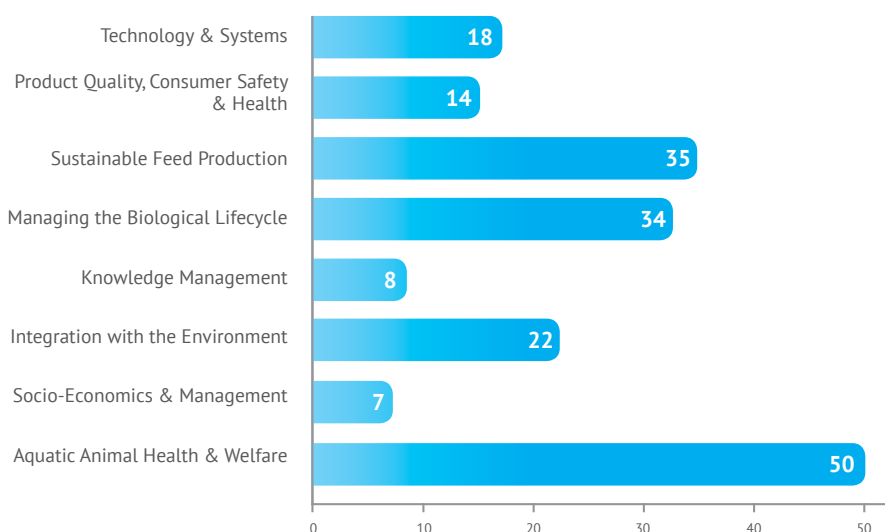
PROJECTS FUNDED PER CALL



Interested researchers were invited to propose projects that had to be compliant with the EATiP Strategic Research & Innovation Agenda, to ensure exploitation potential. Selected projects involved visits of one or

two people to a RI that provided facilities and support expertise which were not available in their own country, for periods of up to three months.

AREAS OF THE EUROPEAN AQUACULTURE TECHNOLOGY AND INNOVATION PLATFORM (EATiP)'S STRATEGIC RESEARCH & INNOVATION AGENDA ADDRESSED



*Some TNA projects addressed more than one area

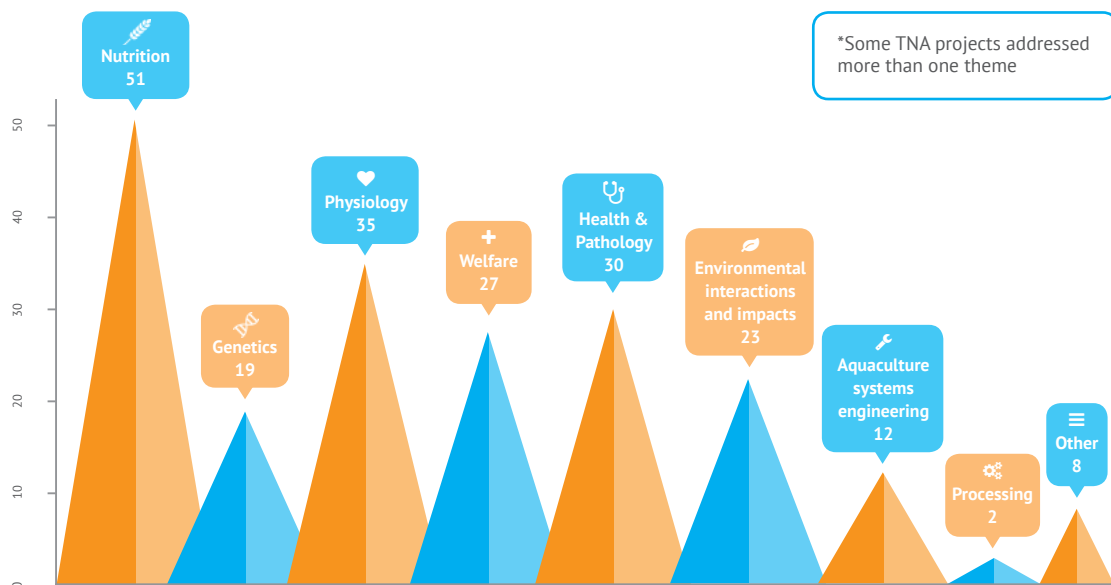
During the lifetime of **AQUAEXCEL** 136 applications were received over all nine calls with a total of 97 TNA projects carried out.

The greatest number of applications and approvals was in the area of nutrition, followed by physiology, welfare and health.

PROPOSALS FUNDED

TOTAL PROJECT PROPOSALS: 136	PROJECT PROPOSALS FROM NON-AQUAEXCEL INSTITUTES: 112	PROJECT PROPOSALS FROM AQUAEXCEL PARTNERS: 24
PROJECTS FUNDED: 97 (71%)	PROJECTS FUNDED: 79 (70%)	PROJECTS FUNDED: 18 (75%)

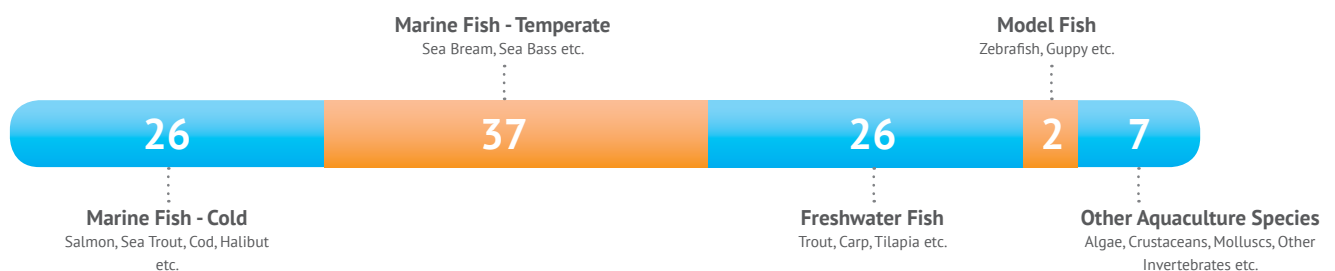
PROJECTS FUNDED BY THEME



Categorisation by EATiP Thematic Areas showed welfare to be most popular, followed by feed, lifecycle, and technology.

The classification of projects by species group revealed the largest number of applications for marine temperate species (e.g. Mediterranean), followed by marine coldwater and freshwater in more or less equal proportions.

PROJECTS FUNDED BY SPECIES



AQUAEXCEL PUBLIC DELIVERABLES

AQUAEXCEL's publicly available deliverables can be downloaded from the project website at:

www.aquaexcel.eu

- 2.1: Online interactive system for registration of research infrastructure properties
- 2.2: Directory of infrastructure facilities, services, biological resources
- 2.3: Inventory of research needs based on Strategic Research Agendas
- 2.4: Report on regulatory collaboration framework for research infrastructures
- 2.5: Inventory of Research Infrastructure gaps
- 2.6: Model for sustained research infrastructure collaboration
- 2.7: Updated lists and resources descriptions on the web sites from the Research Activities
- 3.1: Sanitary prescriptions and procedures for transfers and safety standards
- 3.2: Best practices & cross-applicability of methods to measure phenotypes
- 3.3: Fish-ontologic base (phenotyping/environment) and measure technical base
- 3.5: Experimental data repository
- 4.1: First call for Access and accompanying guidelines
- 4.2: Second call for Access and accompanying guidelines
- 4.3: Interim Evaluation of the call for access
- 4.4: Final evaluation of the call for access
- 5.1: Public website
- 5.2: AQUAEXCEL brochure
- 5.5a: First AQUAEXCEL newsletter
- 5.5b: Second AQUAEXCEL newsletter
- 5.5c: Third AQUAEXCEL newsletter
- 5.5d: Fourth AQUAEXCEL newsletter
- 5.6a: Short Intensive Training Courses - #1 (Recirculating Aquaculture Systems (RAS) Technology)
- 5.6b: Short Intensive Training Courses - #2 (Contribution of Genomic Approaches to the Development of Sustainable Aquaculture for Temperate and Mediterranean Fish)
- 5.6c: Short Intensive Training Courses - #3 (The Application of Chromosome Set Manipulations and the Importance of Gamete Collection and Management in Aquaculture)
- 5.6d: Short Intensive Training Courses - #4 (Efficient Utilisation of New Monitoring and Control Systems in Fish Experiments)
- 5.8a: Booklet describing key achievements of AQUAEXCEL, issue 1
- 5.8b: Booklet describing key achievements of AQUAEXCEL, issue 2
- 5.8c: Booklet describing key achievements of AQUAEXCEL, issue 3
- 5.8d: Booklet describing key achievements of AQUAEXCEL, issue 4
- 6.4: Technical solutions, including revision of implementation guide
- 6.5: e-Infrastructure open for TNA in IMARES, NOFIMA, WU and SINTEF
- 6.6: Effect of the e-Infrastructure
- 7.2: Development of new tagging tools and procedure for larvae and juveniles individual identification
- 7.3: Set of methodologies for health and welfare phenotyping in trout, salmon and sea bream
- 7.4: Set of methodologies for performance phenotyping in trout, salmon and sea bream
- 7.5: Set of methodologies for phenotyping complex trait in trout isogenic lines
- 7.7: Standardised waterborne challenge with *Flavobacterium psychrophilum* for phenotyping host resistance
- 8.2: Scale effects in tanks and cages on Atlantic salmon and sea bass
- 8.3: Biofiltration model including validation
- 8.4: Report on predictions by initial model, and listing of refined model modules
- 9.1: Optimisation of gynogenesis in salmon
- 9.2: Optimisation of androgenesis in carp and seabass
- 9.3: Phenotypic analysis in G1 offspring in salmon and A1 offspring in seabass and carp
- 9.4: Established isogenic lines in salmon, carp and seabass

AQUAEXCEL – AN EC SUCCESS STORY



AQUAEXCEL has been profiled by the European Commission in a press release entitled “EU research helps fish farmers become more competitive”. The article focuses on how **AQUAEXCEL** is connecting aquaculture scientists from across Europe to generate research that the European aquaculture industry can use to boost its competitiveness. European Research, Innovation and Science Commissioner Máire Geoghegan-Quinn said:

“ The EU has long identified aquaculture research as key to the economic development of coastal and remote areas, as well as a way to improve quality, while respecting animal welfare and the environment. We continue to invest in this type of research and innovation in our new Horizon 2020 programme. ”

AQUAEXCEL supports this vision by providing researchers from the EU and associated countries with access to top-flight aquaculture research centres and resources across Europe - including test sites, genomics data banks and imaging systems. **AQUAEXCEL** also fosters scientific excellence by bringing top scientists together to collaborate on innovative projects further improving the efficiency of aquaculture production and supporting European research activities in this area.

VIEW ONLINE: europa.eu/rapid/press-release_IP-14-1114_en.htm

AQUAEXCEL KEY ACHIEVEMENTS BOOKLET SERIES

Download the full series of **AQUAEXCEL** Key Achievement Booklets from the following links:

AQUAEXCEL Key Achievements Booklet 1, April 2013

↓ **DOWNLOAD:** aquaexcel.eu/images/Deliverables_2013/aquaexcel_key%20achievements_2011%20-%202013.pdf

AQUAEXCEL Key Achievements Booklet 2, August 2014

↓ **DOWNLOAD:** aquaexcel.eu/images/Deliverables_2014/aquaexcel_d58_2_%20key%20achievements%20booklet%202%202014.pdf

AQUAEXCEL Key Achievements Booklet 3, January 2015

↓ **DOWNLOAD:** aquaexcel.eu/images/Deliverables_2014/aquaexcel%20key%20achievements%20booklet%203_jan%202015.pdf







PROMOTING EXCELLENCE IN
EUROPEAN FISH RESEARCH THROUGH:

1

OPEN CALLS FOR ACCESS TO AQUACULTURE INFRASTRUCTURES

AQUAEXCEL invited proposals from European research groups for scientific research that utilised the facilities of any of the participating aquaculture Research Infrastructures. Interested researchers could propose projects that were compliant with the EATiP Strategic Research & Innovation Agenda and involved one or two researchers visiting a Research Infrastructure that provided facilities not available in their own country for periods of up to three months. Access to the research facilities and associated travel and subsistence expenses were paid for under the project.

www.aquaexcel.eu/call_for_access

✓ TRANSNATIONAL
ACCESS
PROGRAMME
COMPLETE

2

AQUAEXCEL'S AQUACULTURE RESEARCH INFRASTRUCTURES MAP

The AQUAEXCEL Aquaculture Research Infrastructure Map is an integrated online infobase listing aquaculture research infrastructures in Europe and associated countries, including non-AQUAEXCEL partners. To add your Research Infrastructure to the AQUAEXCEL online infobase, go to:

www.aquaexcel.eu/rimap

3

AQUAEXCEL'S AQUACULTURE TRAINING COURSES

For more information about these courses, please visit www.aquaexcel.eu/training_courses

COURSE 1

TITLE: Recirculating Aquaculture System (RAS) Technology

COURSE PROVIDER: Aquaculture and Fisheries Group, Wageningen University (the Netherlands), with the expertise of NOFIMA, IFREMER and IMARES

LOCATION: Wageningen University, the Netherlands

DATE: April 2013

✓ COURSE
COMPLETE

COURSE 2

TITLE: Applications of Genomic Information to Selective Breeding in Aquaculture of Temperate and Mediterranean Fish

COURSE PROVIDER: INRA

LOCATION: Rennes, France

DATE: October 2013

✓ COURSE
COMPLETE

COURSE 3

TITLE: Chromosome Set Manipulations and the Importance of Gamete Collection and Management, including Sperm Cryopreservation

COURSE PROVIDER: Institute of Aquaculture, University of Stirling

LOCATION: Stirling, UK

DATE: November 2013

✓ COURSE
COMPLETE

COURSE 4

TITLE: Efficient Design of Fish Larval Experiments Utilising New Monitoring and Control Systems

COURSE PROVIDER: NTNU and SINTEF Sealab

LOCATION: University of Science and Technology (NTNU), Trondheim, Norway

DATE: April 2014

✓ COURSE
COMPLETE

www.aquaexcel.eu



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