Executive summary

The IDREEM (Increasing Industrial Resource Efficiency in European Mariculture) project was a four-year project funded under FP ENV two stage scheme. It consisted of 15 partners in eight countries across Europe. The objective of the project was to increase resource efficiency, reduce waste and increase production in the key European aquaculture industry through the development of Integrated Multi-Trophic Aquaculture (IMTA) across Europe. The concepts of the circular economy are at the heart of IMTA. Traditional monoculture of fed fin-fish aquaculture is very much characterised by the fast replacement linear economy where raw products such as fish meal and energy go in at one end, and fin-fish and waste streams come out the other end. In IMTA the concept is to take those waste streams, and use them as nutrients and energy for other organisms (known as extractive organisms such as seaweeds and shellfish) that are grown in proximity to the fin-fish. In doing so there is a reduction in waste entering the wider environment and an increase in productivity at the site through the production of additional crops. Although the idea is not new and has been practised in Asia for many centuries and the concept is at the centre of terrestrial food production, there had been no commercial uptake of the idea in Europe prior to the IDREEM project. The IDREEM project worked with seven fin-fish producers across Europe to implement and monitor the social, economic and environmental interactions associated with the development of IMTA, as well as to benchmark the performance of the technology and provide industry and regulators with tools to help manage the new production systems.

IMTA systems were developed and deployed at all the partner fin-fish producer sites. The extent of this development and deployment was variable between the partners and served to highlight a number of bottlenecks which companies face when trying to implement IMTA. These bottlenecks included: unfavourable environmental conditions especially true in the Eastern Mediterranean where levels of productivity are too low to support the growth of many extractive organisms; regulatory barriers such as delays in getting licences or classification of waters; and economic issues such as under developed markets for some of the IMTA products. It also became clear from the benchmarking and modelling work that the scale of IMTA required to show a significant environmental benefit would be beyond the scope of this project for some producers. However, in some cases there was a significant reduction in some waste streams (over 80% in one case) and there was a 5% increase in aquaculture production across all partners. Of equal importance was the development of new products for the European Aquaculture industry from the IMTA development. These included a number of seaweed products as well as new production of shellfish. In addition to the new products the project also recorded a number of milestones for the development of more eco-efficient aquaculture in Europe including the first IMTA licence in Norway, the largest seaweed aquaculture production licence in Ireland, the production of the first IMTA shellfish and seaweed products in Europe. By the end of the project all the fin-fish producers had made a clear commitment to continue with the commercialisation of the IMTA developments. For this technology to undergo wider European adoption the IDREEM project identified a number of areas that need to be further developed. These include the development of a European market for cultured seaweed, the regulatory flexibility for fin-fish producers to develop IMTA at a water body scale, as opposed to a site by site approach, the development of appropriate technology for benthic (seafloor) IMTA and the need for the development of a definition of IMTA that can be used as the basis of an industry standard. However given the constraints discussed above, and if the scale of implementation is sufficiently large, the IDREEM project has clearly demonstrated that IMTA can work in Europe, that there is a willingness to adopt this technology amongst fin-fish producers, and that when adopted, IMTA can reduce environmental impact and increase the productivity of the European Aquaculture industry.

Project context and the main objectives.

Aquaculture production of fish, shellfish and seafood products for human consumption already exceeds that caught in the wild; but it is predicted that the aquaculture sector needs to produce an additional 50 million tonnes of production by 2030. European aquaculture needs to expand at a steady rate over the next 10-15 years to keep pace with expansion in other locations, and ideally more than this to increase self-reliance on seafood production, rather than imports. If aquaculture is to expand in Europe it needs to develop innovative, sustainable and profitable practices that: are ecologically efficient; are environmentally benign where possible; allow for product diversification and are societally beneficial. In this context Integrated Multi-Trophic Aquaculture, or IMTA, offers the potential to increase production of both primary and additional species whilst at the same time reducing the overall environmental burden through the re-use of materials. Re-use of materials refers to using the wastes generated by one species group by other species lower in the trophic scale, which use the energy and nutrients in that waste material for growth and development.

Currently, aquaculture supplies over 50% of fin- and shellfish consumed worldwide. This represents a paradigm shift in our exploitation of the sea that for centuries was dominated by capture fisheries. With global population growing and the European population expected to rise to 520 million by 2030 (currently 499 million), the demand for aquaculture products is expected to expand. In fact, the demand for aquaculture products will probably be disproportionally large because global fisheries have generally been stagnant or in decline since the mid 1980's and aquaculture will fill the widening gap between demand for marine products and ability of traditional fisheries to satisfy it. In addition, a shift to healthier food will increase the consumption of aquatic products. Notwithstanding these trends, there are serious questions over the environmental and economic sustainability of Europe's current aquaculture industry. Europe represents the largest single market for seafood products; however the European aquaculture industry is stagnating, and has typically exhibited growth of approximately 1% over the last decade compared to a global average of around 7% per annum growth.

The European aquaculture industry is dominated by monoculture of carnivorous finfish and has therefore contributed to aquaculture's doubled share of fish oil and fishmeal demand over the last decade [1] despite a growing trend in substitution of marine with terrestrially derived proteins and lipids. Moreover, all waste by-products of monoculture are discharged directly into aquatic ecosystems. To overcome these issues the IDREEM project has worked with seven fin-fish producers across Europe on the rapid development of an alternative system of production termed Integrated Multi-Trophic Aquaculture (IMTA). This technology is based on the principle of eco-efficiency – turning waste streams into secondary raw materials for further production. The IDREEM project has addressed the challenge of creating **smarter and greener growth** for European industry and in doing so has created **more sustainable patterns of production**. IDREEM has **developed, demonstrated and bench marked** this innovative production technology for the European aquaculture industry. The IDREEM project has clearly **enabled and accelerated the development** of Integrated Multi-Trophic Aquaculture (IMTA) across a range of European aquaculture sectors, and in doing so **creating new opportunities for SMEs in terms of developing new products and services**. IMTA has two principal objectives: reduce pollution, and increase productivity and profit. It achieves these by **recycling waste streams** from conventional monoculture fed finfish aquaculture and providing them as secondary raw materials (food) for the growth of additional aquaculture products. To do this the IMTA system mimics natural food webs, and the design of an IMTA system is similar to the designing of a model ecosystem. The waste stream from fin-fish production can be characterised as two main fractions, dissolved waste and particulate waste. The dissolved waste is rich in inorganic nutrients such as nitrogen and phosphorus. As these wastes are dissolved in the water column around the fish farm they have the potential to be carried significant distances from the fish farm. These inorganic nutrients are important for the growth of seaweeds which readily uptake these nutrients out of the water column, and as such where significant nutrient are available in the environment the culturing of seaweeds are an important component of IMTA systems. The other fraction, the particulate waste, tends to sink from the water column at a rate dependent on both the particle size and the currents and tides around the fish farm. These particles can be ingested by filter feeding bivalves such as mussels, scallops and oysters. As such the development of a designer ecosystem around the fin-fish production site consists of those species which can utilise these waste streams, by assimilating them from the environment and converting them into high value products. In doing so we produce the combined benefits of reducing environmental waste, and increasing productivity and profitability of the aquaculture site. This win/win situation has its roots deeply buried in the eco-efficiency philosophy that aims to simultaneously increase both the economic and environmental performances of an industry or business. Alternately, it can be thought of in terms of eco-intensification, where the

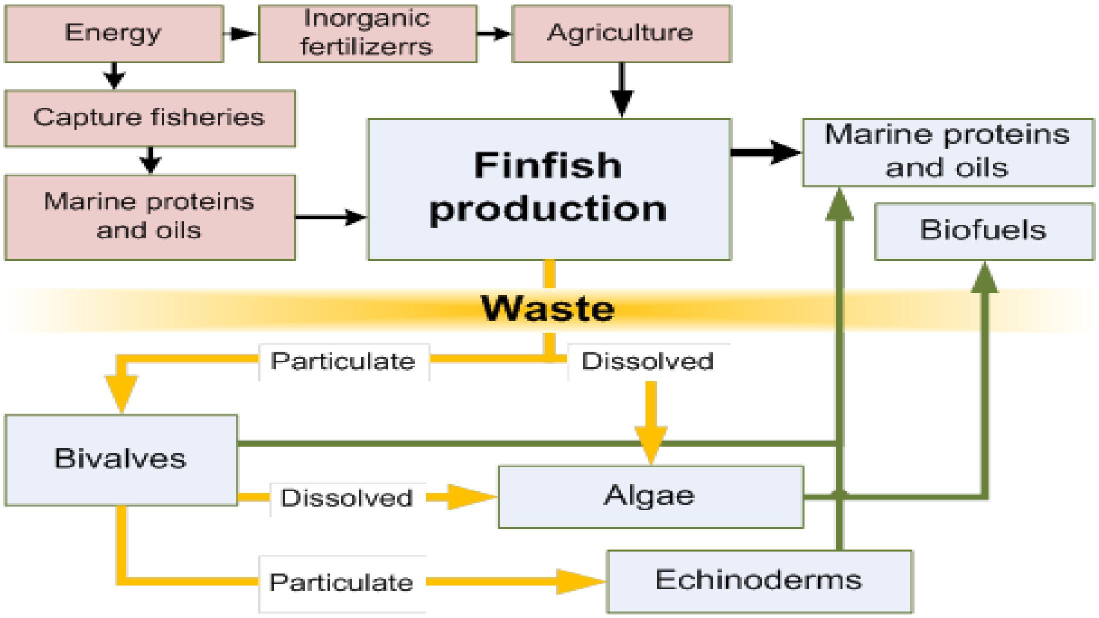


Figure 1 Schematic representation of the inputs and outputs of a modern IMTA production process (species given are examples of filter feeders, detritivores and primary producers. Red boxes represent inputs, blue boxes outputs, yellow flows waste and green flows

productivity per unit input is increased. In Europe the model for fed fin-fish aquaculture has been very linear, in line with a fast replacement economy where the inputs to the industry lead to consumption of natural resources with high energy and water consumption, with externalised wastes. This is in contrast to the principles of IMTA which aim to create an industry based spiral or loop systems (now termed the circular economy) that minimise energy flows and environmental deterioration, without restricting economic growth or social progress.

Despite a strong tradition in Asia, and the fact that the IMTA concept in various guises has been in the scientific literature for at least 40 years since the early 1970's but there was almost no commercial uptake of IMTA in Europe at the start of the IDREEM project. Given the significant uptake of the concept of the circular economy within Europe as a whole and the eco-efficiency potential of IMTA technology, this lack of uptake was on the face of it hard to understand. It was for this reason the IDREEM project sought to understand the reason for this lack of uptake within Europe and to work with the most innovative elements of the European aquaculture industry to develop IMTA across Europe. To achieve its objectives IDREEM brought together a unique consortium of some of Europe's leading aquaculture business and research institutions to cover the range of production systems and ecosystems encountered by the EU finfish aquaculture producers. In total seven fin-fish producers joined the IDREEM consortium, four on the Atlantic coast of Europe (Scotland, Ireland and Norway) and three in the Mediterranean (Italy, Cyprus, Israel). In the Atlantic area the partners were all farming Atlantic salmon, while in the Mediterranean there was a mixture of seabass and seabream farming. The consortium has been especially designed so that there is a pairing of a production SME and RTD in every country. This will ensure that the research activities have the maximum relevance to the SME producers, and in doing so will facilitate a rapid uptake of the technology by the SMEs. At the inception of the project it was decided that, to ensure that the research undertaken was of maximum benefit to the European aquaculture industry, industry fin-fish producers were put at the centre of the project and an industry related approach to the project implementation and data collection was taken. It was also envisaged that the main areas of interaction would fall into three broad categories, environmental, social and economic, and as such three of the work packages were structured around these themes. It was also understood that it would be important to benchmark the performance of the new technology against existing production systems and therefore a work package on Life Cycle Assessment was included. Further modelling was developed in WP7. The modelling work package was designed to provide tools for the aquaculture industry to provide a screening technique to evaluate growth of species and impacts from culture through both monoculture & IMTA. In addition from the outset of the project it was understood that direct measurement of the environmental impact of the deployment of the IMTA system would be challenging. To provide a cost effective alternative to expensive and risky environmental sampling campaigns it was decided that the modelling outputs would be used as data for input into other work packages.

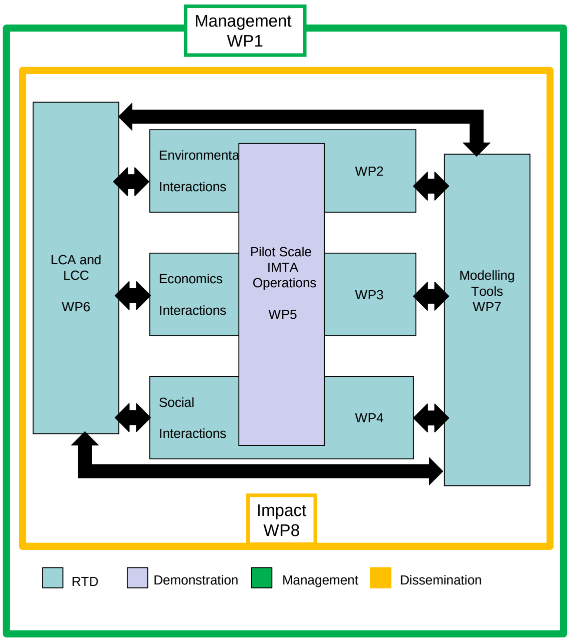


Figure 2Workpackage structure for the IDREEM project

To meet these challenges the IDREEM project highlighted five Objectives which the project would deliver.

Specific Objectives of IDREEM
1) To reduce input, maximize resource productivity and minimize waste in European aquaculture through the development, deployment, assessment and monitoring of IMTA technology.
2) To reduce farm effluent by converting waste products from one production stage (finfish culture) into secondary raw products in the additional production stages by culturing suspension-feeders, detritivores and macroalgae on site.
3) To demonstrate the combined resource and production efficiency of IMTA as compared to existing monoculture production systems using Life Cycle Assessment.
4) To provide the modelling tools for industry and policy makers that enable evidence-based decisions on the impacts of adoption of IMTA given environmental, economic, social, economic and organizational parameters.
5) To understand the reasons for low rate of adoption of IMTA in Europe and facilitate the industry-wide full scale adoption of the sustainable aquaculture practice (IMTA) by proposing/developing methods to address barriers (i.e. regulatory, market, social) to this approach.

Main S & T results / foregrounds

The development of IMTA operations within the IDREEM project

Core to the IDREEM project was the development of IMTA at the seven fin-fish partner site. The development of these was a crucial output of the project and all the fin-fish producers expressed a clear desire to maintain and develop their IMTA operations after the finish of the project. Development of IMTA systems were undertaken at four sites in Northern Europe, with its colder and more nutrient rich water; and at three sites in the warmer and less nutrient rich waters of the Mediterranean.

DOMMRS - Ireland

Research organisation Dahiti O' Murchu Marine Research Station and production company Murphy's Irish Seafood collaborated to introduce the production of seaweed grown on longlines, alongside Murphy's organic Atlantic salmon facility on the west coast of Ireland. Through the project longlines of seaweed were grown over 2013 and 2014, typically comprising 200m long surface lines deployed 50m from fish cages, to grow the brown seaweeds *Alaria esculenta*.

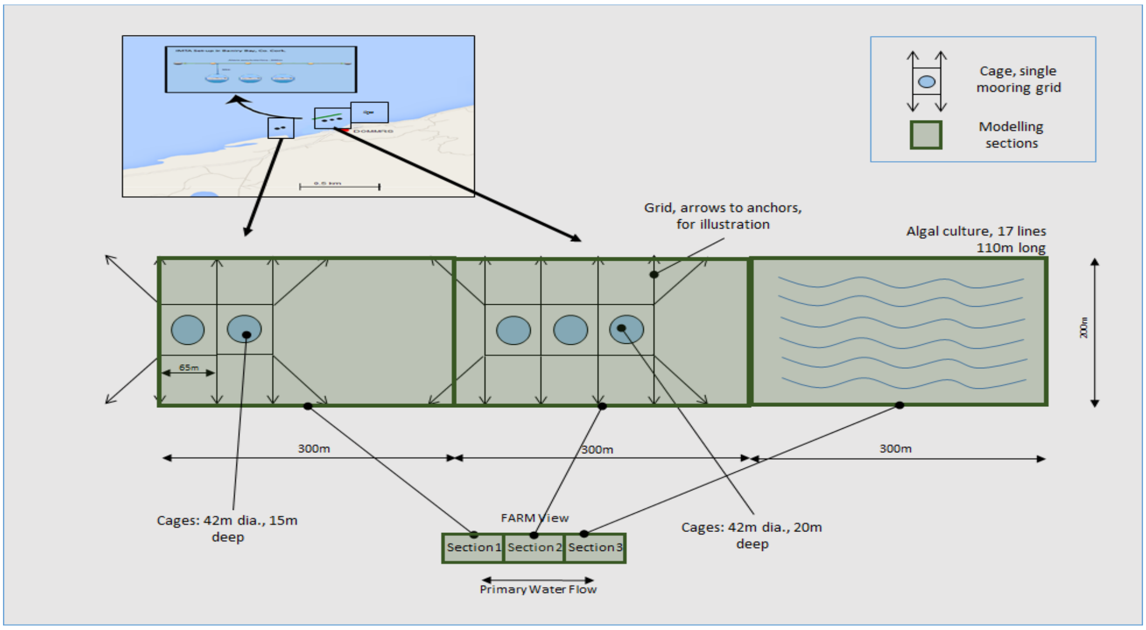


Figure 3 The layout of the IMTA operation at the DOMMRS site.

In June 2013, the final harvest resulted in an average biomass of between 17.2 and 18.1 kg wet weight per metre of line. This represented better growth than the average achieved at other locations in Ireland (approximately 10kg/m), although there was little difference between the control site. In 2015, the trials were increased slightly in size, consisting of a 300m IMTA line adjacent to the cages, and a 100m control line approximately 1km downstream of the cages. The distance between fish farm and seaweed longline was increased to 150m to facilitate the implementation of new anchorage lines at the salmon farm and for the longlines themselves, required for reinforcement following winter storm damage. The production of seaweeds in the IMTA system has been used in commercial and research applications. In 2013 and 2015 seaweed harvested was sent to an Irish horse feed company as a health supplement and used within the Marine Station's own facility to feed sea urchins. In 2015, the sugar kelp harvested was sent to the Environmental Research Institute of University College Cork for use in biogas research. DOMMRS and Murphy's have learnt a lot about the development, benefits, and potential of IMTA through the IDREEM project. There are now current plans for expansion when in July 2016, after a four-year wait, DOMMRS was awarded their requested seaweed licence, which will allow deployment of seaweed longlines over an area of 6 hectares approximately 200-300m from the salmon site. This is the largest consented seaweed production site in Ireland, and the company has identified a market in Japan for their seaweed and are now developing the required processing infrastructure required to service this demand.

Figure 4 IMTA produced seaweed harvest at DOMMRS

Scottish Salmon Company Scotland

SSC grow Atlantic salmon at their Ardcastle site, with production carried out as distinct cohorts (all in all out, prior to re-stocking) which has a permitted biomass of 1373T grown in 9 cages, stocked with smolts at approximately 80g WW and harvesting at an average WW of 4600g after a maximum production period of 600 days. Mortality is slightly higher than the industry standard at 10%. Fish are fed manufactured feed achieving an FCR of 1.13. SSC had the most advanced IMTA site, with the additional species located approximately 200m from the salmon culture site and consists of 12 longlines. growing mussels (*Mytilus edulis*) on "New Zealand" continuous rope, seaweed (*A. esculenta & S. latissima*) on seaweed strings, oysters (*Crassostrea gigas*) in SEAPA baskets, queen scallops (*Chlamys opercularis*) on collectors and pearl and lantern nets, and sea urchins (*Echinus esculenta*) in pots and oyster baskets.

Figure 6 The IMTA grid of 12 longlines pictured from the salmon feed barge at the SSC site

The company harvested a total of 2,500 kg wet weight (ww) *A. esculenta* (Dabberlocks) in May 2013 and 2015 and 1,000 kg ww of *S. latissima* (sugar kelp) in May 2015, and sold the product to a Scottish company, Mara Seaweeds, who dried, diced and milled the seaweed for use as a food condiment. 60,000 kg of mussels were also harvested as spat, that were then deployed at other locations around Scotland for on-growing. The site has also produced over 250,000 queen scallops, which are currently being harvested, individually quick frozen and are entering the market as a high value niche product. Other species were grown for a variety of reasons, including provision of broodstock, specimens for other research.

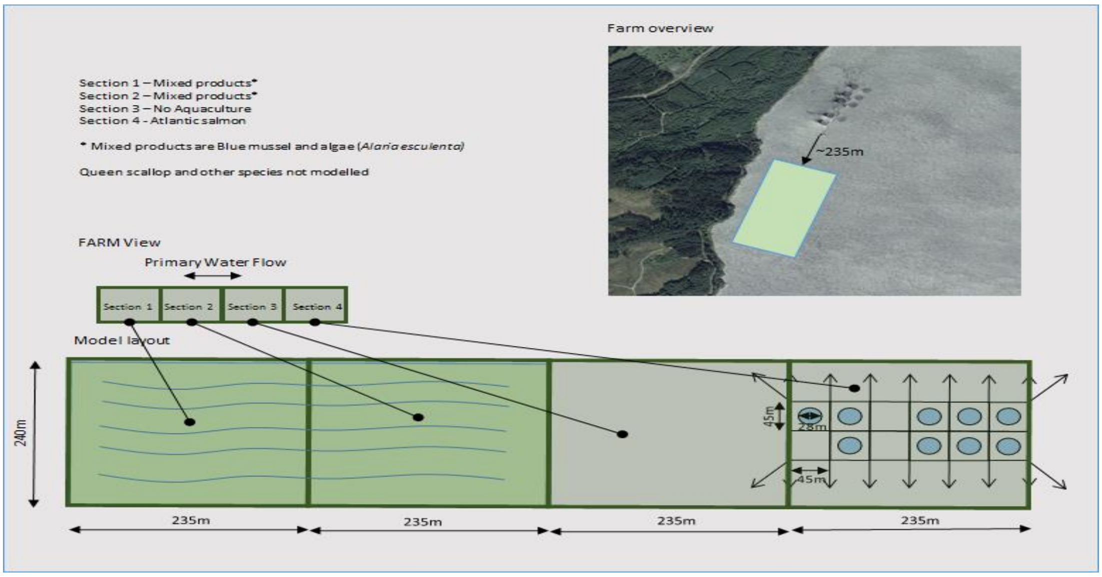


Figure 5 The conceptual layout of the SSC site

The company's IMTA system provided the opportunity to invest is other niche requirements, such as research and broodstock development, provision of much needed mussel spat that could be on-grown within the company, as well as harvestable stock for direct sale.

The company currently has plans to develop IMTA at a further 2 sites, before possible expansion throughout the company. This company produced both the first commercial seaweed product and the first commercial shellfish product from IMTA in Europe which represents a major step forward for the development of eco-efficient technology in European Aquaculture

Figure 7 The commercial IMTA products produced by SSC during the IDREEM project

GIFAS Norway

The Norwegian IMTA system developed by Gildeskål Aquaculture Research Station (GIFAS) at Oldervika, inside the Arctic Circle, was done with the collaboration of the Norsk institutt for bioøkonomi (NIBIO). GIFAS are a private research and development company and salmon producer, producing approximately 2500T of Atlantic salmon per cycle, against a maximum permissible biomass of 1550T in a site containing 13 cages in a 2 x 6/7 cage formation. Production is carried out in cohorts ("all in all out") with harvesting taking place periodically as stocks are graded. Growth period is approximately 500 days. Smolts are added to cages at approximately 60g to 120g depending on the time of year added and grown to a mean harvest weight of 5000g. Fed with manufactured feed pellets, an FCR of as low as 1.07 is achieved, with a very low mortality at not more than 6% achieved. Additional species focused on growth of *Alaria esculenta*, grown between the two rows of fish cages, on longlines of up to 12km in length.

Between May and July 2015, GIFAS harvested 2,200 kg wet weight of seaweed, which was subsequently air-dried on-site and sent to Ireland for use in fodder products. Some of the best quality material was used to test its suitability for human consumption, a collaboration with a local salt maker.

In late 2015 and early 2016 a larger scale seeding took place at the site, with 1.5 km of *A. esculenta* seeded string deployed in December 2015 and 1.5 km in February 2016. The company had a long-term commitment to the development of IMTA through a redesigning of their mooring grid to include the capacity to develop IMTA. The redeployment of a mooring grid is a significant investment, and one which will be in the water for the next 10 years.

GIFAS are confident of the potential marketability of their IMTA seaweed and identified a number of potential markets, including food for human consumption, feed ingredients, and the development of bioactive compounds. The IDREEM project was instrumental in securing the first IMTA licence in Norway.

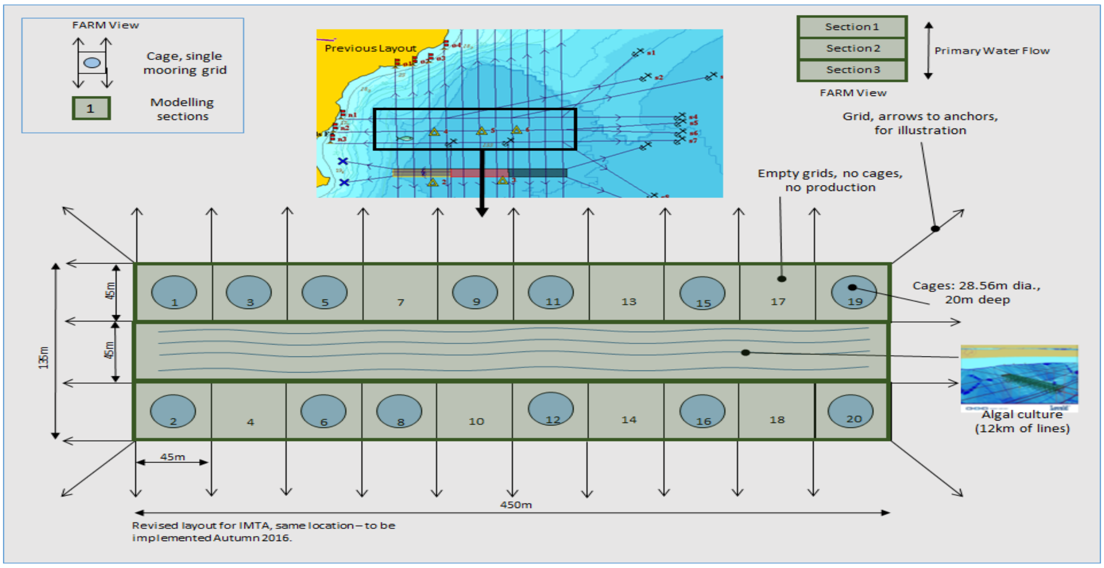


Figure 8 GIFAS IMTA layout

Aqua Italy

In Italy, development of IMTA was a collaboration between sea bream and sea bass producer AQUA s.r.l. at their fish farm in the Ligurian Sea, and the University of Genoa. Aqua's primary species are seabass and sea bream, which account for approximately 75% and 25% of fish production respectively, producing a total of 240T per annum in 12 cages in a 2 x 6 cage formation at their project site. Growth periods range from 18 to 20 months (540 – 600 days) depending on environmental factors such as sea temperature, with fingerlings added to cages when approximately 4g wet weight (WW) and grown to a harvest size of approximately 350 – 400g. Fed manufactured pellets, an FCR of approximately 2.4 is achieved. Mortality is relatively high against industry standards at 30%, mostly through escapes (e.g. storm damage). Fish are harvested at a rate of five cages per annum, with all cages re-stocked immediately, so the site contains mixed cohorts. Prior experiments on IMTA species had included growing turbot, but final demonstration activity and production will combine fish culture with submerged pacific oyster production grown in lanterns hanging near to the fish cages, attempting to achieve an annual oyster harvest of 6 – 8T per annum.

Despite low levels of microalgae and detritus in the water column on which the oyster feed, oyster growth performed sufficiently well, the pacific oyster performing better than the native European oyster. Based on the biomass achieved over the course of this project, it is estimated that potential production at the site could be in the range of 15 tonnes/annum, and taking 1 to 1.5 years to achieve harvest weight, before being transferred to another site for final growing, harvest and sale.

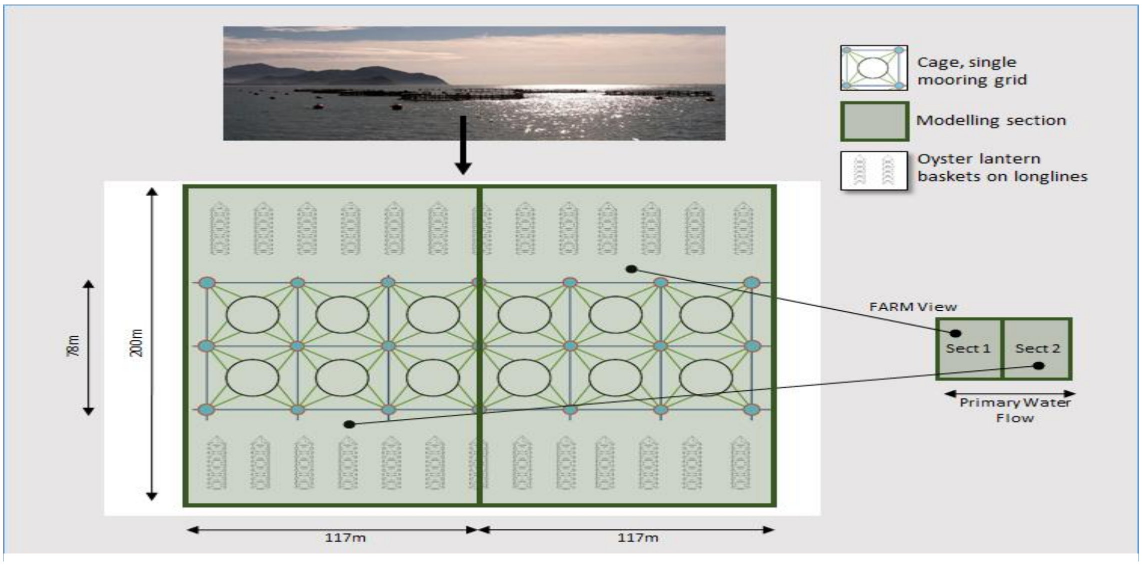


Figure 9 AQUA site layout, showing sections and species contained per section.

This transfer of product may change in future. The site was given outline permission as a research project, and at the time of writing did not have graded shellfish water status that would allow direct harvest and sale from site. The work conducted on feasibility of farming oyster alongside the fish, in terms of growth and survival of oysters in an oligotrophic environment, has been sufficient for the company to apply for this graded shellfish water status and work is on-going with the regulator to test the water and gain the necessary information and data to gain this essential approval, so that the site can in future be a fully integrated IMTA site. The company plans a scale-up commercial scale IMTA production facility, concentrating on pacific oyster along with their sea bass and sea bream, with planned deployment of oyster both north and south of the fish cages. Since there is a lack of oyster production locally the plan for market into the future will be local distribution to retailers and restaurants. The company is using IDREEM project results, to reinforce its position with local regulators and the government on the

Figure 10 Dissemination of the IDREEM products through public tastings in Italy

importance of enlarging the farm using IMTA.

SeaWave Cyprus

Off the southern coast of Cyprus, in the Vasiliko/Zygi region, Seawave Fisheries Limited has cages of gilt-head bream (*S. aurata*), sea bass (*D. labrax*), and meagre (*Argyrosomus regius*) and has been collaborating with a local research organisation, MER lab, to bring IMTA to this part of the eastern Mediterranean.

The local environmental conditions in this part of the Mediterranean have proved to be a major barrier to IMTA development at Seawave. The temperature of the water is above the tolerance level of many species and the water is highly oligotrophic, with low concentrations of Chlorophyll and other particulate matter so essential, for example, for bivalve growth. Trials will continue beyond the life of the IDREEM project but growth trials have been conducted using mussels (*Mytilus galloproncialis*), sea urchins (*Paracentrotus lividus*), oysters (*Ostrea edulis*), abalone (*Haliotis tuberculata*), and blue crabs (*Callinectes sapidus*). Despite repeated set backs, it was possible to identify a number of species groups that offer opportunities for the development of commercial scale IMTA in the oligotrophic conditions of the eastern Mediterranean . These include sponges for use in cosmetic or biotechnology industries, or the development of aquaculture based on local bivalve species such as *Pinna nobilis* (Pen shells).

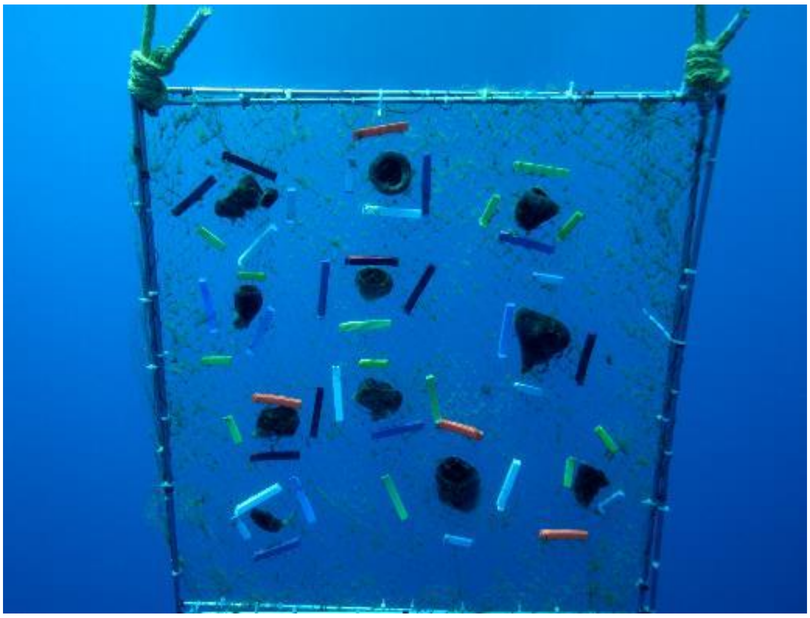


Figure 11 The development of sponge aquaculture may be crucial to development of IMTA in oligotrophic environments

In addition to the full open water sites, there were two companies where closed containment IMTA was developed. In one of these cases this was envisaged from the start of the project (VFF Scotland). In the other case the use of this approach evolved through the course of the project due to a combination of logistical and environmental constraints. In these cases it has been possible to directly measure the environmental impact of the implementation of IMTA. This has not been possible within the other production systems of the IDREEM project due to large background variation swamping any signal from the IMTA system.

FIA Aquaculture Scotland

FIA aquaculture is a marine hatchery based on the west coast of Scotland. Their IMTA system was based on taking the waste water from their hatchery broodstock tanks and running the water through a number of raceways that had been placed inside polytunnels. The waste water came from Turbot, (*Psetta maxima*), Cod (*Gadus morhua*) and Sea bass (*Dicentrarchus labrax*) broodstock and were first fed into settlement tanks, where the larger particles settled out. The waters then flowed into 4.8 m raceways. In the first section (approximately 20%) there was a sand bed which contained *Neris virens* (a rag worm with a high commercial value for recreational angling) and suspended above them were purple sea urchins

Figure 13 The Ulva production from the raceways was fed back to the sea urchins

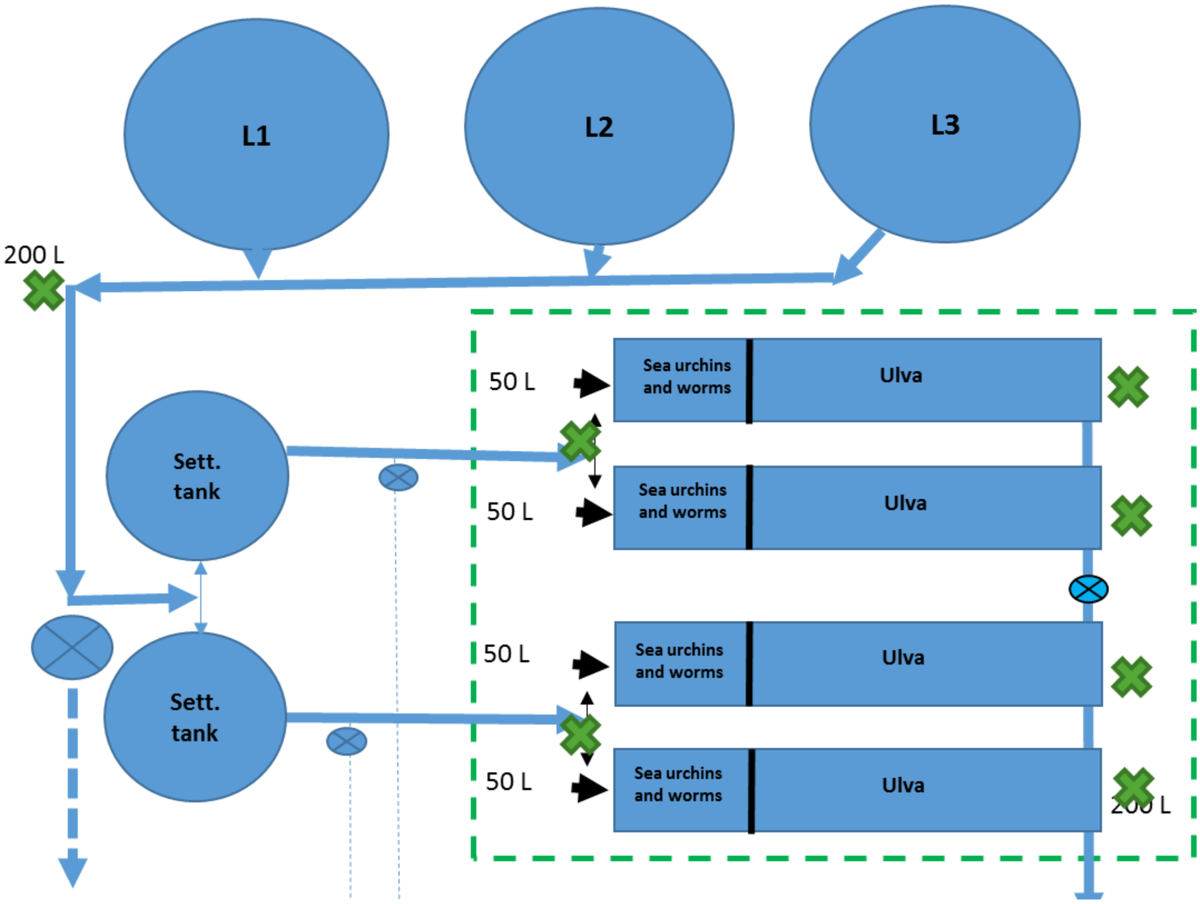


Figure 12 Figure 8The layout of the IMTA system at the pump ashore facility at FAI aquaculture

(*Paracentrotus lividus*). In the end section of the raceway was a tumble culture of sea weed (Ulva spp). This seaweed grew well on the nutrients from the broodstock and was fed back to the seaurchins. The faecal matter from the sea urchin was deposited on the sand bed beneath and was ingested by the worms. Water chemistry analysis showed that the system was effective in removing ammonium, phosphate and total nitrogen from the system. There was an observed increase in nitrate/nitrite and this was due to nitrification of ammonium within the settlement tanks.

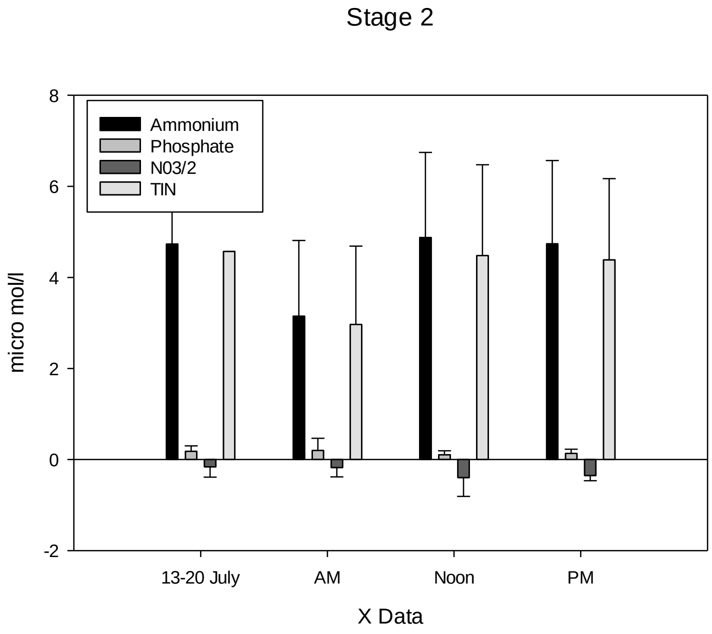


Figure 14The nutrient reduction of the final IMTA system at FAI. Positive values show reduction in nutrients from the broodstock to the outflow of the system.

The company was pleased with the environmental performance of the IMTA system and were discussing increasing the number of raceways as well as looking for a market for their worms.

Suf Fish Israel

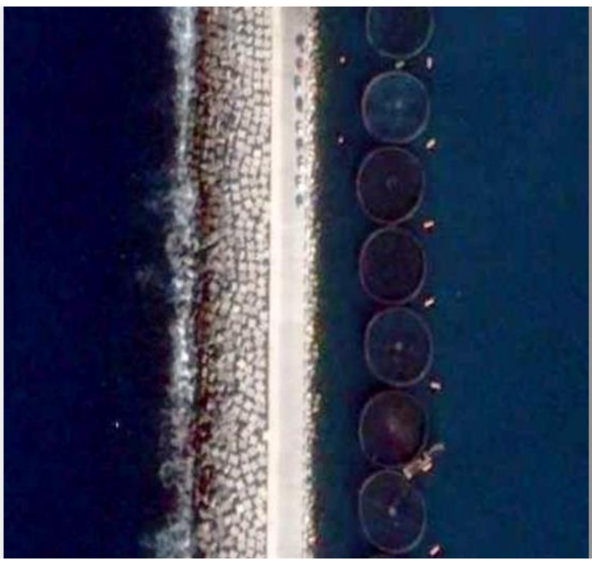


Figure 15 The position of the SeaWave farm within the breakwater of the port

Suf Fish grow Sea bream within the vicinity of the shipping port of Ashdod. A number of trials were set up at this facility including the use of grey mullet. Unfortunately due to an exceptional storm much of the infrastructure at the farm was destroyed, and this led to the farm being rebuilt within the breakwater of the port. This opened up an opportunity to develop an innovative form of IMTA where the water from under the sea cages was pumped ashore to tanks for the production of seaweed. The analysis done of this system showed that it had significant

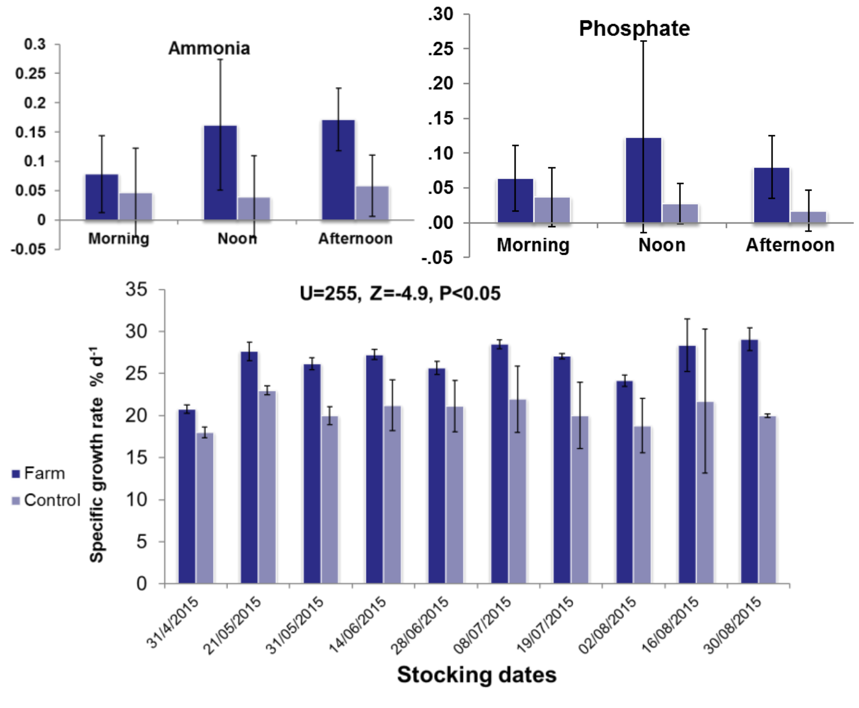


Figure 16 The impact of the seaweed on the nutrient concentrations in the effluent from the fish farms and the growth rates of the seaweed

potential to reduce the environmental impact of the caged fish through a reduction in dissolved nutrient such as ammonium and phosphate. It was also an effective system for the production of seaweeds. The company reported having discussions with a number of companies with a commercial interest in purchasing the seaweed, but the volumes produced were not sufficient at the present stage.

Environmental Assessment of IMTA development

Assessments were made through the collection of water column and sediment data from SME farm partners and analyses through appropriate indexes (TRIX for water column and M-AMBI for the benthic communities). IDREEM data shows that off-shore farms or those located in more dynamic environments in Europe, generate a low impact on water quality and the surrounding seabed. This contrasts with observations in some regionally enclosed coastal areas and indicates the possibility of pursuing a sustainable blue growth agenda, as pursued by the European Community, by fostering the development of off-shore farming activities.

There were no observed differences in water column and seabed impacts at sites that started as monoculture facilities and ended as IMTA sites, culturing a range of different species. This is perhaps not unexpected, given the relatively small scale of the IMTA experimental layouts that has not allowed for a more intensive assessment.

These results, showing performance of IMTA in off-shore conditions, reinforce the potential for decision-making in spatial planning and highlight the need to challenge the technical constraints related to operating in off-shore conditions in implementing IMTA as well as the legislative constraints related to licensing and permitting for IMTA operations.

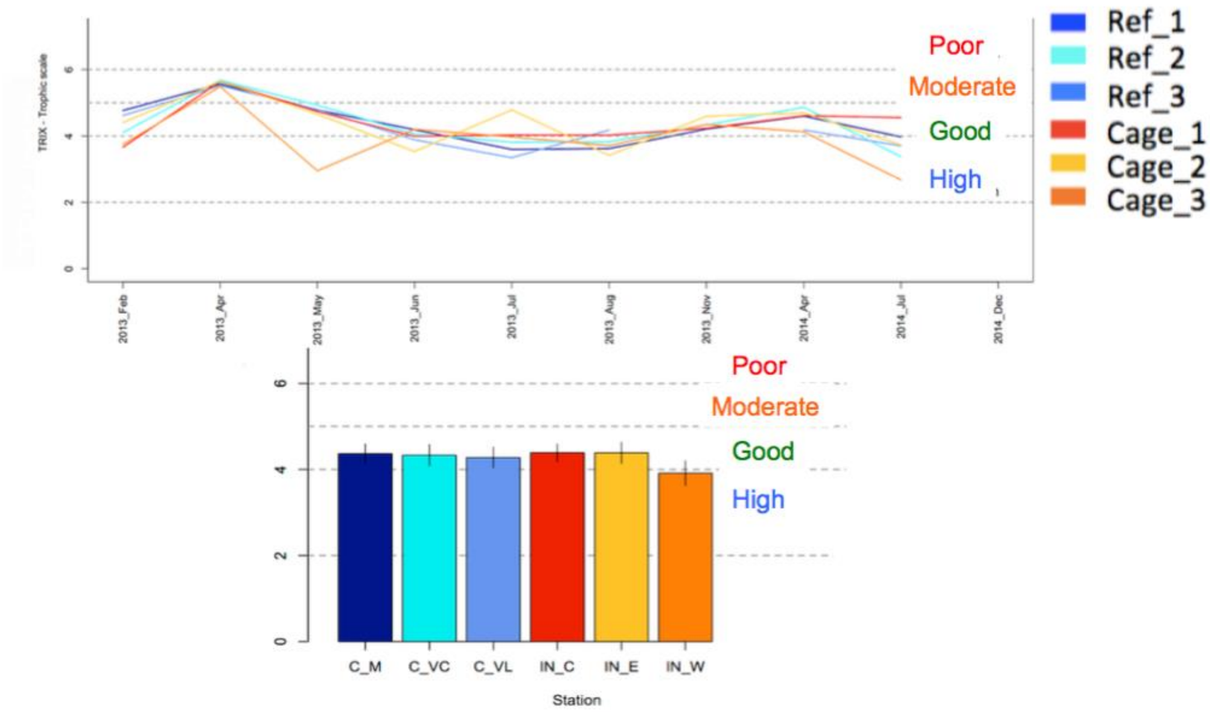


Figure 17 TRIX index trend evaluated at AQUA farm throughout the sampling period in control and farm sites and average values (bars).

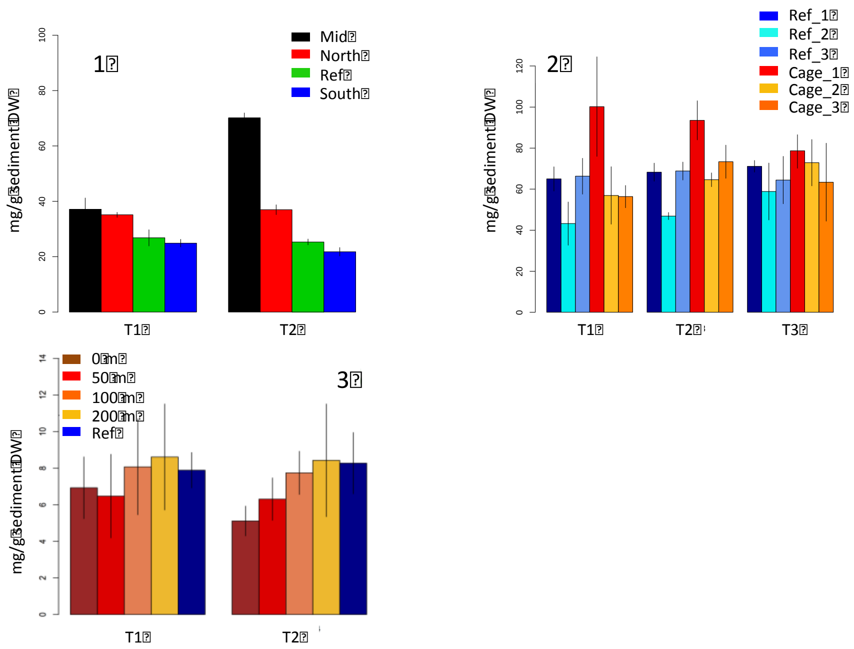


Figure 18 Organic matter concentration (mg/g sediment dry weight) at different times in sediments below three of the farms of the project, located in North-Eastern Atlantic Ocean and Mediterranean Sea. Error bars are 1 standard deviation.

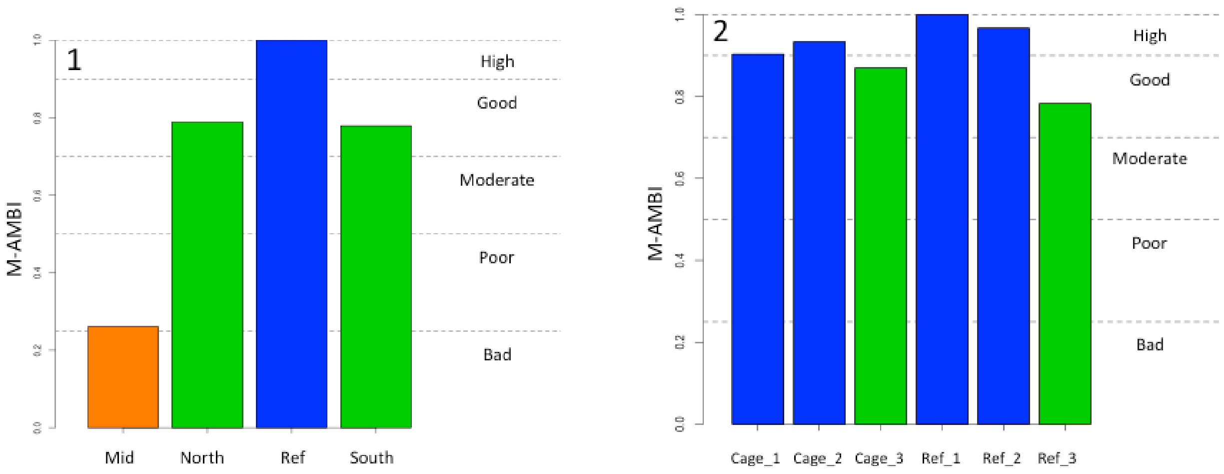


Figure 19 Environmental quality assessment by means of M-AMBI benthic index in sediments below three of the farms of the project, located in North-Eastern Atlantic Ocean and Mediterranean Sea.

As far as food safety issues, as a first step relevant legislation was collected and its present implementation in monoculture aquaculture in the different countries was assessed by collecting information from farm partners. A data collection spreadsheet was sent to all SME partners in October 2014. The aim of this spreadsheet was to gather information on the analyses currently preformed at each production site to assess food quality and animal health, the laws these analyses comply with, and compare this information among SMEs. A preliminary assessment, in the form of a summary table, was produced and sent back with comments to each SME partner on March 31st 2015. A table that crosschecks the laws that are implemented by each SME was also produced, to address that issue of whether different SMEs apply the same laws.

The analysis of these data confirmed the fundamental lack of specific regulation, not only in reference to IMTA but also to some “new” cultured organisms, also in monoculture condition, such as seaweeds. Following the regulatory framework and the species which were selected for being tested in the IMTA systems, UNIGE performed two sets of analyses:

1) Analyses on fish welfare on the basis of a set of biomarkers. Essays run at UNIGE.

2) Analyses on pollutant contents in both fish and co-cultured species (macroalgae, shellfish). Analyses run in a certified laboratory in Italy.

Samples for assessing food safety and animal health (of the main fish crop) were collected and analysed to evaluate relevant contaminants concentrations and relevant stress biomarkers.

The concentration of relevant contaminants in organisms farmed or cultivated under IMTA conditions were evaluated and compared to relevant National and European legislation. All contaminants evaluated in IDREEM samples were below the thresholds set by EU regulation. Only Cadmium and/or Arsenic concentration in Kelp samples, from different sites, resulted in slightly higher or close to the threshold for human consumption and/or as a feed material. These higher values do not seem to be related to the co-cultivation condition, as a consequence of IMTA implementation, but to a natural species specific bioaccumulation. These specificities should be taken into account when addressing species selection (also in monoculture conditions), considering background environmental concentrations and possible sources.

As a final remark, data collected do not support any criticality in terms of contaminants bioaccumulation (Metals, PAHs and PCBs) related to the implementation of IMTA.
As far as animal health, exposure biomarkers (Metallothioneins, heat shock proteins, catalase, superoxide-dismutase, cytochrome P4501A) were analysed from liver samples of farmed fish and compared to usual and alternative fish tissues, such as scales and caudal fin, in order to explore a less invasive approach for assessing fish welfare. All the biomarkers were expressed not only in the liver, as expected, but also in scales and fin. Scatter plot analyses showed no significant difference between scale and fin samples. Data on scales showed several differences in the gene expression between sea bass and salmon, as well as between sites for the same species, suggesting a good sensitivity of the innovative approach.

Economic impacts of IMTA development

Market Conditions

One of the key objectives of IDREEM was to provide information and decision-support, therefore our focus switched somewhat from the plans described in the DOW to the more central issue facing the SME's in IDREEM. This was the general lack of market awareness and expertise and the relatively low priority placed on developing related market strategies as part of the IMTA investment. As such a review of First Sale Price (FSP) of products produced or planned by the IDREEM SME partners was undertaken. The FSP is the price received by the producer prior to processing but generally including transport. It was selected over the other two options – wholesale and retail prices – because it most accurately reflects the price basis for sales within most of the IDREEM partners SME's. The data source was the European Monitoring Observatory for Fisheries and Aquaculture (EUMOFA) which is the most comprehensive source of data available. specifically that reliance on commodity markets leaves a producer exposed to a much higher degree of price volatility than is the case for products with value-added. Moreover, coupling the investment with IMTA production with a market strategy to promote products as more sustainable can reduce market risk exposure and increase the profit potential of the IMTA investment. To the best of our knowledge this report is the first to isolate country-product-target market groupings for the purpose of modelling trends and using the models for forecasting future prices. The methods used are documented and replicable

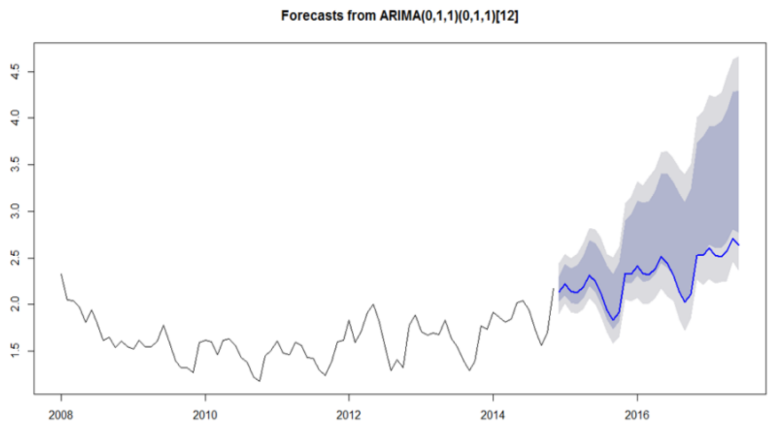


Figure 20 Training set and forecast (UK Queen Scallops sold in the UK)

and therefore can be used as a tool to support IMTA decisions currently and in the future. This analysis revealed that sophisticated markets for salmon led to a lower degree of price cyclicality where as the newer products of IMTA where the market is not so well developed exhibited high levels of cyclicality. This market volubility for IMTA products may act to disincentive investment in IMTA.

Ecosystem Services

Within IDREEM, ES are examined as part of the economic assessment of IMTA at pilot sites in six European countries. Monetary valuation of ES must be preceded by an accurate measurement of the ES of interest and changes in their provision. Moreover, this must be done in a manner that facilitates the translation of multiple metrics (e.g.: physical, ecological, demographic, health) into monetary ones. The assessments conducted in this report provide a set of methodologies and illustrative case studies to guide this first step. The first of these models viewsheds at each of IDREEM's six coastal sites and demonstrates the spatial gradient for potential visual disamenity related to the placement of a farm and relates this to demographic data showing where people most likely to be impacted are located. The final method is developed in the context of Good Environmental Status (GEnS) targets of the Marine Strategy Framework Directive (MSFD) and lays out the concept of using these targets as inputs into the planning of IMTA, specifically asking the question of what scale of conversion from monoculture to IMTA is needed to gain a given environmental quality target. This last approach is highly interdisciplinary incorporating mapping, sensing, LCA and modelling tools. Economic values have been emphasized because they are widely accepted, they enable decision–makers to assess trade-offs using a common unit of measure and because valuation methodologies are rather well developed for many situations. Other metrics exists (e.g.: ecological, demographic, health) and the scope for using these needs to be explored, especially in cases where economic measures are difficult to estimate.

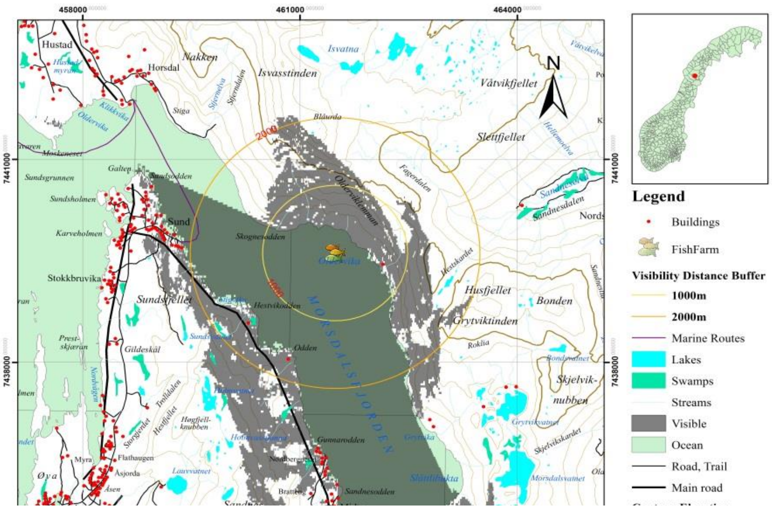


Figure 21 Viewshed GIFAS site, Norway

Risk Management

IDREEM project stakeholders assessed the risks and uncertainties based on two year of experience with six IMTA pilot projects. The following categories of uncertainty associated with IMTA were identified:

- **Structural** - related to the optimal configuration of cages and structures for extractive species culture (eg: lines, rafts, benthic enclosures, etc.) to maximize biomass and ensure the ability of structures to withstand severe weather events.

- **Low oxygen** – particularly in warm climates and seasons, the risk of hypoxia events with increased biomass and different in-sea structures accompanying IMTA is unknown.
- **Pathogen harbouring and transfer** - within the farm when more than one species are cultivated in proximity there is uncertainty to risks related to crop loss due to mortality or food safety regulation.
- **Other issues related to food safety** - Chemical residue uptake by filter feeders, availability of local infrastructures such as those needed for bivalve depuration
- **Social acceptability** – seaweed culture, because of its need for larger areas and the chance of seaweed waste nuisance (egg: waste washing up on shore) was raised by several farms operating in relative proximity to populated areas.
- **Brood stock and non-indigenous species (NIS)** - Local availability of bloodstock and potential for introduction of NIS if foreign bloodstock is imported.
- **Comparative advantage** for production of any/all IMTA co-products compared to monoculture of the same.
- **Regulation** – concerns were raised about current and future regulation that could make it more difficult or impossible to obtain a commercial license; create a precedent for imposing more restrictive environmental regulation.
- **Financial uncertainty** –while most of the above risks translate directly or indirectly into financial consequences, there is an additional set of issues related to uncertainty related to the cost of building and operating an IMTA farm and the marketability of IMTA products, including certification and the development of niche markets for IMTA products.

However as the project evolved it became clear that two other risks were also faced by the IDREEM SME participants are biomass losses stemming from natural disasters and disease and price risk. These were selected for indepth analysis in this second risk report because:

1. they appear to be major inhibiting factors to investment; and
2. developing solutions, in the form of decision-support tools appears feasible.

Damage caused by severe weather appears to have plunged uninsured aquaculture firms into a cycle of damage and recovery that inhibits innovation. Aquaculture, and in particular the SME and non-salmon producing sub-segments appear to be very under insured meaning that European aquaculture as a whole is in this damage-recovery cycle. Our analysis provides an overview of the supply and demand sides of biomass insurance and indicate that better outreach and education as well as decision-support tools are needed for purchasers. More expertise among suppliers and possibly targeted government support is needed to solve supply-side issues.

Most SME fish farmers produce a very basic product that is subject to volatile prices. Based on evidence from within IDREEM, the potential for investment in marketing capacity has been analysed. The purpose is to discern the extent to which improved marketing may lead to better access to supply and value chains since such access will increase the chances of improving revenues. Our analysis used a combination of theoretical Real Options (ROA) modelling and empirical evidence from market research conducted within IDREEM.

Social interaction of IMTA development

Determining Stakeholder attitudes towards IMTA

The social acceptance of new aquaculture developments are crucial if the technology is going to be applied and developed. IMTA success will depend on satisfying key stakeholders and IDREEM undertook stakeholder analyses from six European countries involved in the project. Levels of stakeholder engagement within the aquaculture industry fluctuate between countries, and where more stakeholder engagement takes place this is often because the regulatory process requires it. Businesses likely have neither the time nor the money to undertake work which is not required by regulation or believed to be necessary. Very few stakeholders were identified as advocates with the majority of stakeholders, across all countries, identified as neutral or indifferent. Across all countries, the majority of stakeholders sat within the ‘subjects’ (those with high interest but low power) group. This is a group who should be engaged in the process and the aim should be to move them into the ‘players’ group. This is a dynamic process and will change in response to the policy and market drivers and the shifting of IMTA from experimental to mainstream practice. It is in this context that we recommend the following areas of further action:

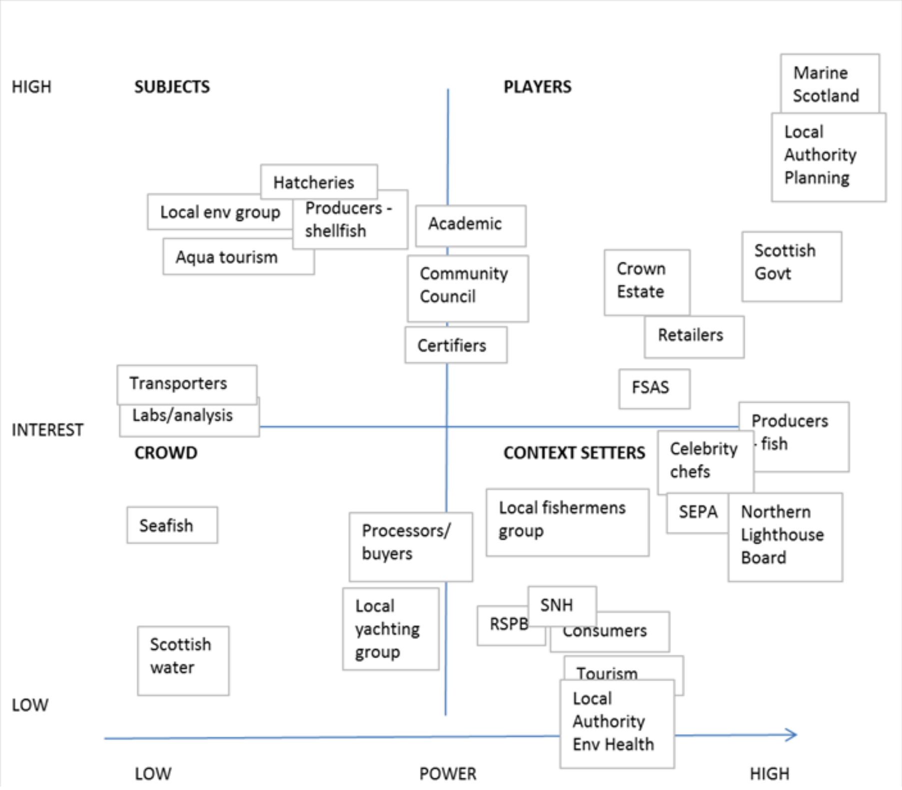


Figure 22 Power versus interest grid for Scottish integrated multi-trophic aquaculture stakeholders.

- IMTA operators should continue to monitor and engage with key stakeholders, particularly those identified as ‘players’ in the analysis.

- Building a constituency or ‘base of support’ will be critical for moving IMTA forward through all phases of the supply chain and to the consumer. Resources should be focused on maintaining the interest of ‘subjects’ and increasing their engagement (ie. moving them towards becoming ‘players’).

The regulatory Environment for IMTA

For the development of IMTA it was crucial to understand the structures, processes and decision makers with whom it will be necessary to engage in order to expand the IMTA industry. Each national case study has a complex mix of legislation. This is generally focused on traditional single-species monocultures and IMTA-specific regulation is virtually non-existent. Reforms that support IMTA in the future will need to address seafood safety, introduced species, pollution, and disease control. It will also need to address the broader economic and social concerns over IMTA including commercial use of secondary species and products and social acceptance of IMTA products. While it is very early days for IMTA operations, the current legislative framework in nations with established large-scale aquaculture industries appears fit for purpose. Engagement between industry and regulators in each country is necessary to develop the legal framework for IMTA beyond the experimental or pilot phase. With current legislation focusing on monocultures it remains to be seen if it can be simply 'amended' to incorporate bi-culture and poly-culture. Countries such as Scotland are in the midst of policy debates and reform over IMTA (in relation to kelp production) and monitoring these reforms, and communicating the outcomes to industry will be essential to advance IMTA as a sustainable production strategy. Retailer and consumer awareness of IMTA products is currently peripheral to the IMTA debate yet critical for the development of the industry. This will need to be addressed in any regulatory reform particularly around the debates relating to food safety and disease prevention.

We recommend that IMTA developers maintain close contact with regulators and input into the reforms for establishing multi-species sites beyond the pilot stage – establishing a continual science into policy process is key.

Public attitudes towards IMTA

Green consumerism is becoming an increasingly important aspect of understanding markets and it may be that the IMTA concept can remedy some of the environmental concerns held by consumers. Whilst some limited work has been done to elicit information about the public's perceptions of IMTA, no large scale study has yet been conducted prior to the IDREEM project. Due to the need to conduct interviews with the public in a number of European countries in a short period of time and the likelihood that the internet was available for a large percentage of the population in (particularly western) Europe, a web-based survey method was chosen. A survey questionnaire was developed to explore the social and economic dimensions of public perceptions of IMTA and was split into four sections: (1) Understanding of aquaculture benefits and impacts and IMTA; (ii) Choice experiment asking participants to choose between products (iii) Perceptions of fish products and buying behaviour; and (iv) demographic information. The results of this study suggest that perceptions of aquaculture in general may not be as negative as previously believed. In fact, consumers often rank the benefits as higher than the impacts. The results of this study also show that although the majority of consumers have never heard of the term 'integrated aquaculture', the majority of consumers do believe that this particular aquaculture system may be able to improve a number of environmental and economic features. This knowledge may lead to a more positive outlook for the sustainable development of the aquaculture industry. Respondents had largely not heard of the term 'integrated aquaculture' previously, but after having the basic concept explained believed that it could help to improve the sustainability of aquaculture overall. Understanding the profile of these favourable consumers may provide useful information to design promotional and communication messages, target the appropriate audience and develop persuasive messages which are understandable by a majority of consumers. It may be that consumer levels of knowledge relating not just to IMTA, but to aquaculture in general, may be low and dominated by negative publicity. This may mean that the general public associate a negative image with other forms of aquaculture and products, regardless of their relative risks and benefits. For this reason, promoting positive information in order to educate the general public (using information from scientific, government institutions as well as through the media) would likely lead to mainstream acceptance of IMTA thus ensuring that the general public are willing to buy the end product.

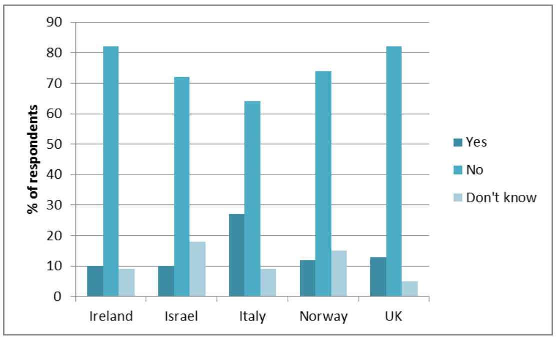


Figure 23 Respondents' answers to the question: Have you ever heard of the term integrated aquaculture

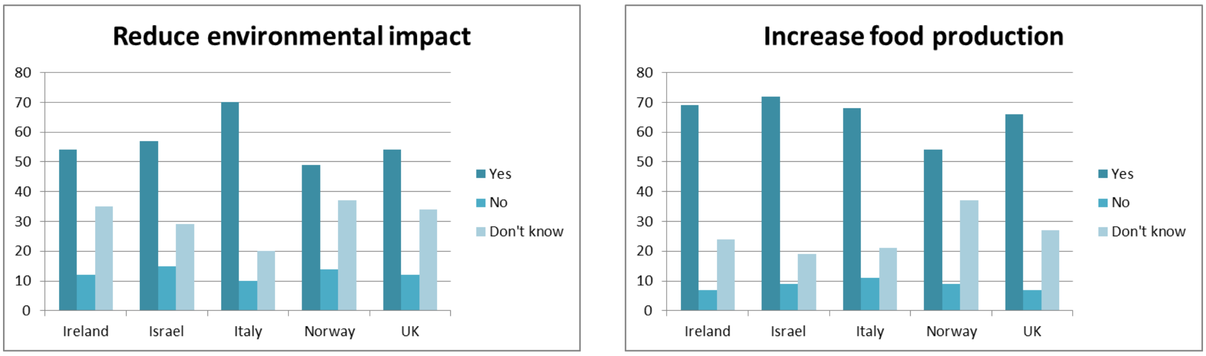


Figure 24 Percent of respondents' answers to the question: Do you think integrated aquaculture has the potential to...?

Life Cycle Assessment of IMTA operations

Work package six (WP6) has provided the Life Cycle Assessment (LCA) of the Integrated Multi-Trophic Aquaculture (IMTA) systems for each fin-fish producer within the IDREEM project. Therefore, WP6 started its participation in IDREEM with LCA training for the different partners and followed with a process for qualitative data collection and monoculture systems' description as these systems will provide the baseline for future comparison. LU developed-up a 2-stage intensively supported working procedure to get all the information needed from the SME/RTD pairings to perform the monoculture LCA studies. Firstly, flow diagrams were asked from the pairings. By discussing directly with the pairings draft flow diagrams of the currently running monoculture systems were drafted by LU and submitted for review to the pairings. Once the flow diagrams were agreed upon and marked as 'final', the second stage of the LCI work, the actual data collection, was started up. For this, LU developed a MS-Excel spreadsheet (including a separate excel based tool for fuel, electricity and lubricant oil allocation to different processes based on the use of different equipment for different purposed on-site in collaboration with one of the SMEs, and a separate excel based tool to convert offshore infrastructure in materials use).

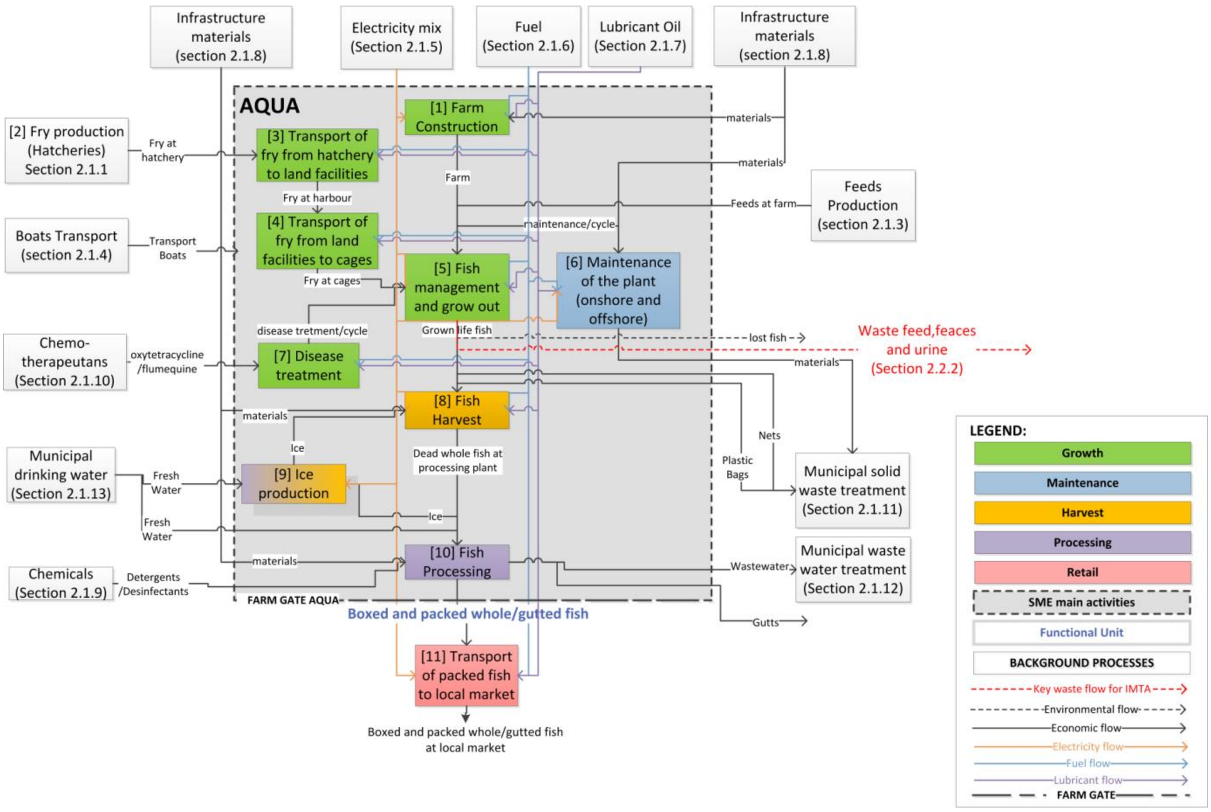


Figure 25 Flow diagram with system boundaries for the monoculture production of AQUA (cradle-to gate) including main economic flows and with an emphasis on the foreground processes

LU further supported this data collection work by Skype, e-mail and face to face discussions whenever needed. This support was ongoing from month 12 until month 43 of the project. The LCAs performed in the IDREEM project provide a first estimation of the comparison of the life cycle environmental impacts of fish produced in monoculture versus fish produced in IMTA systems for SMEs. Results in this study are highly uncertain as inventories correspond to "presumed", projected (not validated) scenarios for the IMTA components and are dependent on methodological choices, specifically the choice of allocation method to make the two systems comparable. Further research should include methods like the one developed under the project to deal with uncertainty and creating statistically based LCA results with even more robust conclusions. It is important that future studies deal with variability and uncertainty of production data (from cycle to cycle) as well as uncertainty introduced due to methodological choices, particularly the allocation choice. For this, however, additional production data is required that were not yet available during the IDREEM project.

Table 1Sensitivity analysis for allocation of the growth process in the IMTA system of DOMMRS. Numbers in red indicate categories where the IMTA system performs better than monoculture

		DOMMRS (physical allocation)		DOMMRS (economic allocation)	
Unit or equivalency		IMTA – Mono	%Change vs. Mono	IMTA – Mono	%Change vs. Mono
Abiotic depletion (elements,)	kg antimony.	1.1E-07	3.6%	2.2E-07	7.3%
Abiotic depletion (fossil fuels)	MJ	-3.9E-01	-1.1%	7.8E-01	2.3%
Global warming GWP100	kg CO2	-5.4E-02	-2.0%	3.8E-02	1.4%
Ozone layer depletion	kg CFC-11.	-7.2E-09	-3.6%	-4.2E-10	-0.2%
Human toxicity	kg 1,4-$C_6H_4Cl_2$.	9.5E-03	1.2%	3.8E-02	4.7%
Freshwater aquatic ecotoxicity	kg 1,4-$C_6H_4Cl_2$	-8.3E-02	-3.6%	-5.4E-03	-0.2%
Terrestrial ecotoxicity	kg 1,4-$C_6H_4Cl_2$	-3.6E-02	-4.0%	-5.2E-03	-0.6%
Human toxicity	cases	-4.6E-08	-3.3%	2.0E-09	0.1%
Fresh water Ecotoxicity	PAF m3.day*	-1.7E-01	-2.0%	1.2E-01	1.4%
Photochemical oxidation	kg ethylene	-3.9E-05	-3.1%	3.2E-06	0.3%
Acidification	kg SO2.	-7.0E-04	-3.3%	2.6E-05	0.1%
Eutrophication	kg PO4---.	-5.2E-03	-4.6%	-1.4E-03	-1.3%
Freshwater use	m3	-9.1E-04	-3.1%	1.0E-04	0.3%
Land use	m2a	-5.0E-02	-1.3%	8.3E-02	2.2%

In general, results for all SMEs suggest that at the scales and with the setups considered in the IDREEM project, IMTA systems perform very similar to monoculture systems in terms of environmental impacts per unit of fish. The specific impact categories increasing or decreasing depend on the actual setup of the IMTA species and the material requirements and wastes generated to construct, operate and maintain it. Additional impacts also depend on the integration of activities for managing the IMTA species into the current activities of the farm for fish grow-out. To maximize the benefits of IMTA, larger production scales of IMTA species could be explored. Likewise highly economically valued species can lead to larger allocation factors for IMTA species thus fewer impacts per unit of fish.

Modelling Tools for IMTA

The IDREEM project developed a range of dynamic models which provide a screening technique to evaluate growth of species and impacts from culture through both monoculture and IMTA. In IDREEM, one of the major means of assessing IMTA's potential to improve re-use of materials and develop additional production, was through modelling. Models developed incorporated individual growth models for the target species, integration of individual models into a population model that evaluates the growth and environmental consequences of farm-scale production, and integrating species into a unified model approach to evaluate growth and environmental consequences of multiple species at the same time. This provided tools for the fin-fish producer to optimise and evaluate their IMTA installations.

Individual models

Modelling was undertaken through individual production models developed through a visual platform for fish, shellfish, macroalgae and deposit-feeders, referred to as AquaFish, AquaShell, AquaFrond, and AquaDep respectively. These models are net energy balance (NEB) models, developed with appropriate parameterization describe energy intake from feeding (fish and shellfish), or photosynthetic action in algae, and energy use in basal and other metabolic processes, and swimming (in fish only), and catabolic processes that result in the generation of wastes that are added to the environment in either dissolved or particulate form. Overall there is a mass balance produced to ensure appropriate allocation of energy which subsequently gets converted to biomass gain, and quantities of physical wastes. Parameterization of the models was done through literature search for required terms, development of components of the model and assessment of growth at individual farms to calibrate and validate the model results. The additional species for which individual growth models were developed, calibrated and validated are: Atlantic salmon and sea bass, the algae *Alaria esculenta* and *Ulva lactuca*, and a deposit feeding sea cucumber. Pre-existing models for mussel and oyster were updated.

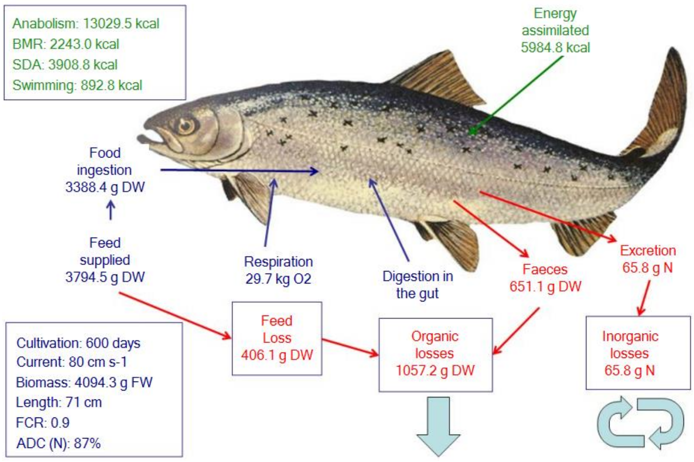


Figure 26 WinFish model mass balance, showing example for Atlantic salmon (*Salmo salar*).

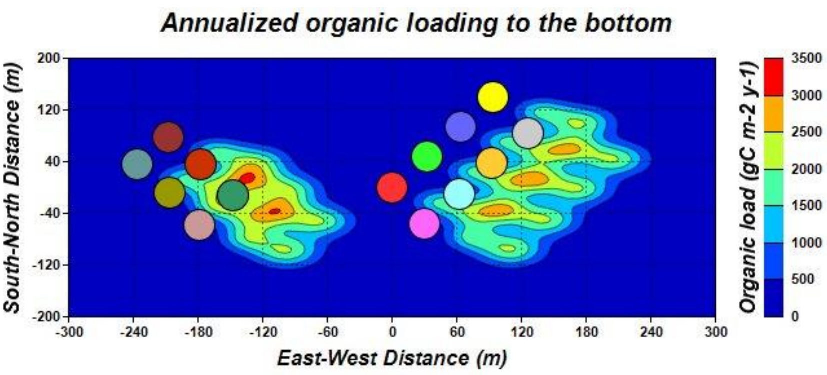


Figure 27 Screenshot of ORGANIX model structure, to define spread and settlement of particulate organic waste

Each species growth in the model had to reflect the growth at all partner sites where a particular species was grown, differences in results based on local culture practices, including culture period. Individual models for finfish were complemented by development of a new model, ORGANIX, for particulate waste deposition and distribution on the seabed, for depositing material emanating from fish cages.

Integrated Models

The dynamic link libraries for individual growth models were incorporated, after testing, into the Farm Aquaculture Resource Management (FARM) model. The FARM model integrates the growth/production models with environmental driver data and culture practice information to provide a broader assessment of aquaculture potential for species.

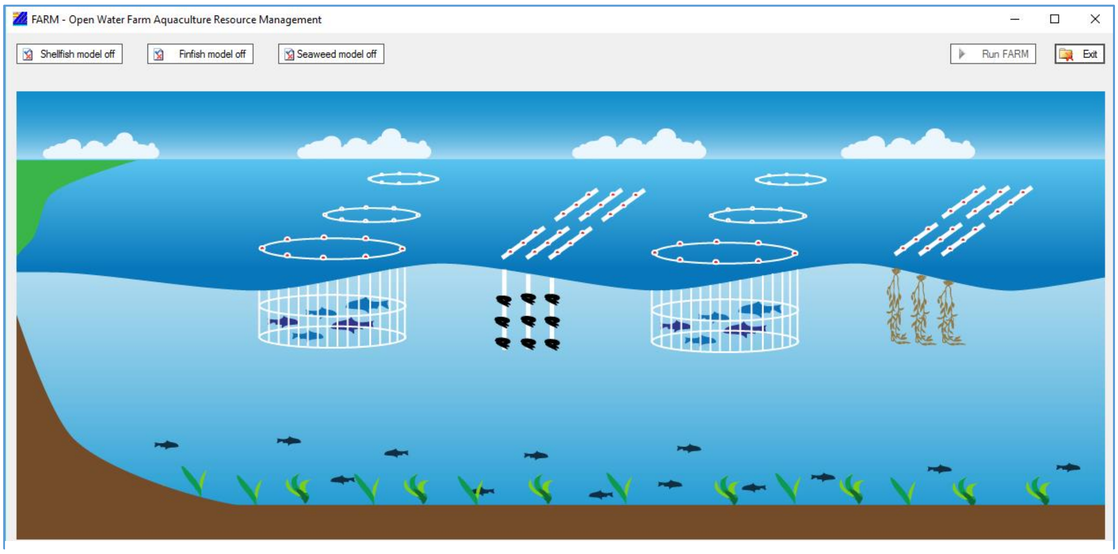


Figure 28 FARM model front screen for version delivered to IDREEM project partners, set to allow model runs for shellfish, fish and seaweeds in monoculture, or any combination in IMTA mode.

Individual growth models for all species were successfully integrated into the FARM framework, and Figure 1 shows the model front screen as seen by the user. The user selects the appropriate species group on the front screen (shellfish, finfish, seaweed and deposit feeder [not shown in Figure 2 version]) which takes the user to the set-up page which includes species selection, culture practice, cultivation density and other set-up information. As well as enabling the modelling of individual species under monoculture the FARM model underwent re-coding to enable selection of multiple species, with up to one species per species group (finfish, shellfish, algae, deposit feeder) able to be selected. An IMTA system of up to 4 species can therefore be simulated. The FARM modelling approach enabled an evaluation of the outputs from the partner IMTA sites and differences in environmental sinks and sources that occurred because of multiple species being grown at each site. The full list of environmental outputs covering carbon, nitrogen and phosphorus from each site were defined in Monoculture (fish only) and IMTA report cards delivered to Leiden University to support Life Cycle Analysis undertaken in WP6; and also to the University of Haifa as a small part of their economic assessment undertaken in WP3.

Crucially the model was able to deal with both the spatial and temporal configuration of IMTA. This temporal component has been crucial in understanding the dynamics of the

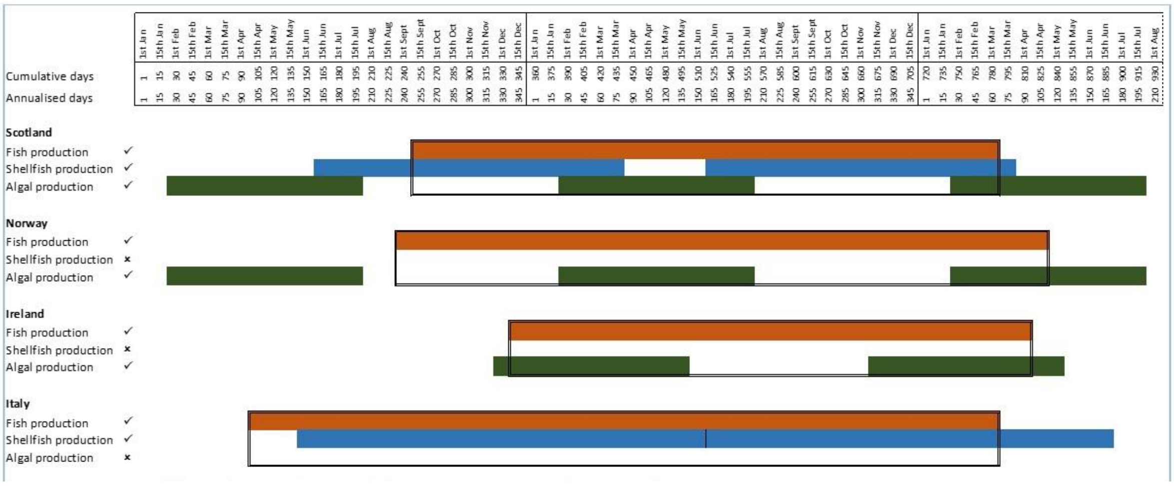


Figure 29Representation of the temporal overlap in production between species at the four IMTA sites used in this study.

IMTA system. For IMTA to occur, species need to be in the water and growing at the same time. Given that aquaculture, in the main, follows natural seasonal patterns for growth of each species, this overlap cannot always be achieved for a most effective IMTA system.

Model roll out

The calibrated and validated production version of the FARM model software was delivered to all partners through a link to a webpage maintained by LLE - http://www.longline.co.uk/IDREEM/deliver/. During the project the work associated with the model, the model, and accompanying results were presented, as oral presentations, during the 2014 and 2016 European Aquaculture Society conferences in San Sebastian (Spain) and Edinburgh (Scotland) respectively, in the well-attended IMTA sessions. In September 2016, at the final project meeting held in Edinburgh, LLE staff undertook a training exercise for all project partners. This consisted of tuition in how to download the model from the server; how to open the model; details about completing model set-up including descriptions of and discussion on each of the environmental and culture practice model parameters (what to change, how, what the consequences were for specific changes made and so on); running the model; and evaluating the model outcomes. After the project has been concluded the model will be made more generally available, along with results from the modelling activity, through the LLE web portal, available for other farms, regulators and policy makers to access the information.

Overall the modelling activity successfully integrated the ability to model the growth and effects of individual species under monoculture and multiple species in an IMTA system. The FARM model provides a realistic methodology to evaluate monoculture of individual species and co-produced species in an IMTA system, in terms of growth and environmental interactions.

More broadly the modelling activity showed:

1) That the level of production of shellfish and algae needed to fully re-use materials emanating from fish cages, to create environmentally benign aquaculture requires a significant increase in production and use of physical space.
2) An IMTA system that incorporates mussels could offset some the particulates added by fish culture (the suspended part), albeit no direct coupling of uptake of fish particulate waste could be verified.
3) The results indicate that there is probably not a direct coupling between the particulate and dissolved wastes present in the water column from fish (and shellfish) culture, and growth of shellfish and algae respectively. It is likely that some of the particulate and dissolved load from fish culture is being consumed by shellfish and algae (respectively), but this does not translate into significantly increased growth in either extractive group.
4) None of the farms used in this study implemented an IMTA that included deposit-feeding species that might offset the larger proportion of the waste feed and faecal material sinking to the seabed from the fish cages.
5) At the four sites where IMTA was simulated the predicted increase in overall production was 4.8%, which represents an improvement on the stagnation that is observed in EU aquaculture.
6) Modelling shows that the temporal overlap in production is critical when a directly coupled system (i.e. IMTA farm) is considered.
7) Increasingly the cumulative effects of aquaculture development are considered at a larger bay scale, so separate companies might grow each of the species used in this study under monoculture, and the cumulative production of all species within a larger bay scale can be evaluated as a complete IMTA system.

The future development of IMTA in Europe: a synthesis of the IDREEM project

The IDREEM project has clearly identified that IMTA can work in Europe. It has shown that there are a number of IMTA systems which are appropriate for both the Mediterranean and the north east Atlantic. We have also demonstrated that there is a market for IMTA products and a good consumer acceptance of these products. We have also shown that IMTA is not easy, especially for SMEs to undertake, and it requires a significant investment. We have also demonstrated that it can deliver on the potential of increased productivity and reduced environmental impact. However this potential is closely connected to the scale of development, and that for small producers the scale required for measurable environmental benefit may be beyond what SME producers can invest in. As such there is currently a mis-match between who bares the cost and risk of IMTA development and who receives the benefits of IMTA. Most of the costs of adopting IMTA (and not just financial ones) are borne by the industry and yet their benefits are not being accrued by the industry. As such there is relatively little incentive for the industry to invest in its development.

However the IDREEM project has identified a number of tools that would allow this mismatch to be realigned:

1. Firstly there needs to be a **definition of IMTA that the industry can adopt**, a definition that can be understood by consumers and industry alike. Following on from this definition there needs to be a certification for IMTA, so that industries who invest

in IMTA can protect their investment from cheaper copies who have the potential to devalue the IMTA ‘brand’.

2. Secondly, industry needs to be given the **flexibility to deal with the spatial mismatch in scales** described earlier between the extractive components of IMTA and the fin-fish production. The only way to do this for the dissolved component of the farm wastes is to pursue a water body approach to IMTA and to the management of aquaculture. There are clear drivers as to why the management of aquaculture at the loch/fiord/bay level would be attractive to fin-fish companies. Using IMTA as a way to ‘balance’ aquaculture within a wider ecosystem and to manage the social and environmental impacts will require a change in policy and regulation but offers the best chance for wider scale adoption of IMTA.
3. Thirdly the **technical and biological constraints of benthic IMTA need to be overcome**. Aquaculture in Europe is mainly managed on its benthic impact and at the same time this is the most concentrated source of nutrients that leave fin-fish production sites. Therefore this is the most obvious target for the IMTA win/win, but conversely because it is the most technically challenging it is the least developed. Although there were trials within the IDREEM project, it was not possible to find a workable solution for benthic IMTA. There is a clear need for further research spanning the disciplines of engineering and biology in order to come up with a workable solution for benthic IMTA.
4. The fourth condition that needs to be in place is the development of a **market for aquacultured seaweed in Europe**. Globally the seaweed industry is worth approximately $7bn and Europe imports approximately 90,000 tonnes of seaweed annually but only produces a tiny amount of seaweed domestically through aquaculture. Seaweed is a crucial component of most IMTA systems and we know that for it to make a significant contribution to nutrient reduction it needs to be grown in large volumes. These volumes of seaweed, though they have a high intrinsic value as a raw product, have a very limited market in Europe. The development of processing plants and bio-refineries for seaweed would allow for the expansion of this important component of IMTA and for it to reach its true economic value.

The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results.

One of the main socio-economic impacts of the IDREEM project was the development of IMTA at 7 sites across Europe and the very obvious impact this had for the businesses concerned. This process has been recorded in some detail in the previous section of the final report but it is worth reiterating that at the final project meeting all the producers had expressed a commitment to continue the development of their IMTA site after the project. It is also reiterating that the IDREEM project recorded a number of major achievements for the development of IMTA across Europe. These have included:

- The first IMTA licence for Norway
- The largest seaweed licence in Ireland
- The first commercially produced and marketed open water IMTA seaweed product in the UK
- The first IMTA shellfish to be sold in the UK
- The application for the first offshore oyster licence in the *Ligurian Sea*

This list of major achievements all represent major milestones in the development of IMTA across Europe, but they underpin the socio-economic impact that the project has had on the fin-fish producers, For these producers the development of IMTA has enabled them to enter new markets with commercial products within the lifetime of the project. These commercial products have included:

- Individually quick frozen queen scallops from Scotland
- Specialist dried seaweed and salt condiment from Norway
- Seaweed for inclusion in animal fodder from Norway and Ireland
- Seaweed as a condiment from Scotland
- Mussel spat from Scotland

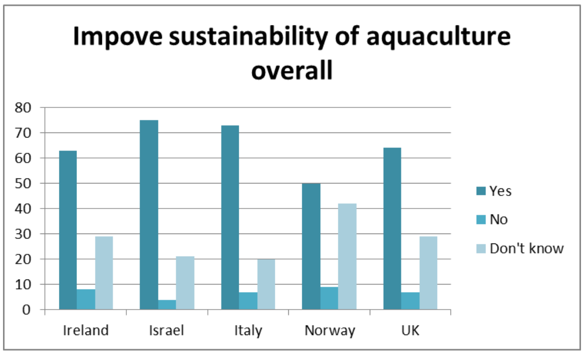
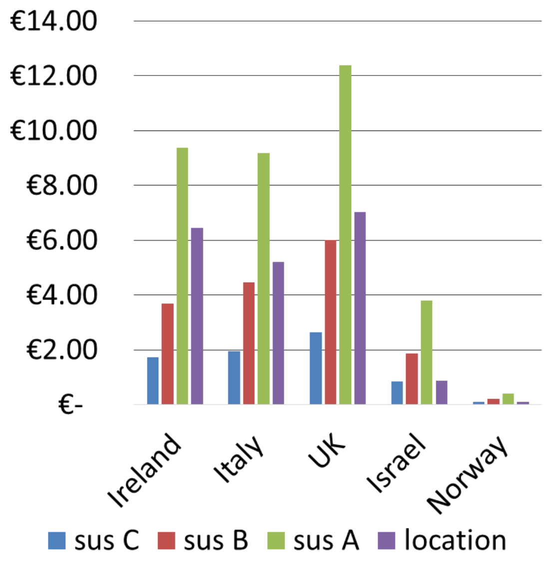


Figure 30IMTA can alter public perceptions of IMTA across Europe

In addition to these products there are a number of close to market products being developed as a consequence of this project and these include oysters from Italy, seaweed as a component of fish-feed (Israel) and the development of a new seaweed product from Ireland for export to Japan.

All these products represents a diversification for the European aquaculture industry from fed fin-fish aquaculture to a more sustainable and diverse portfolio of high value products. This development has huge potential to foster innovation within rural and sometimes remote communities, supporting crucial jobs and services. These also have the ability to change the perceptions of the European Aquaculture industry, Work undertaken within the IDREEM project has shown that the development and implementation of IMTA has the ability to increase positive public perceptions of aquaculture. This has the potential to have a massive impact on the industry as a whole. Currently the European aquaculture industry has grown at about 1% per annum over the last decade. This is significantly below the global average. One of the reasons for this low growth has been the significant regulatory burden the industry faces especially when it comes to licencing new sites. This burden partly stems from the regulators' perception of the public opinion over aquaculture. Research undertaken as a part of the IDREEM project has shown that there is a perception gap between regulators and the general public, and this perception gap may be slowing some of the aquaculture development in Europe. Addressing this issue through the development of innovative aquaculture solution with which the public can identify could serve as a tool to reduce the perception gap and increase the social licence to operate for aquaculture in Europe. The modelling approach allowed evaluation of IMTA set-ups for 4 of the 7 SME partner sites, each of which was shown to increase overall production, which has the potential to increase farm revenues. The modelled outputs replicated reasonably well the actual activity undertaken at each farm. In all cases, at least some of the additional production that occurred at the sites did find markets and those companies were able to increase revenues. The modelled outputs overall showed an increase in production (tonnes), at these pilot scales, of 4.8%; which is significantly better that the generally stagnating position of aquaculture development in Europe. This shows other companies and the aquaculture industry that there is potential in implementing IMTA, if licensing and regulations allow; to improve production and revenues overall.



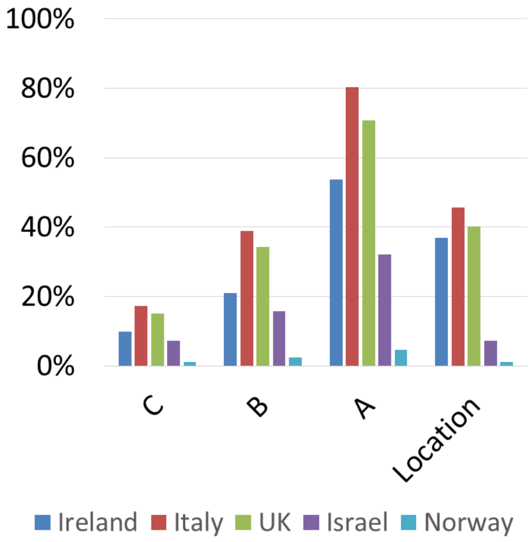


Figure 31 The willingness to pay of European consumers for IMTA aquaculture products

Another very quantifiable socio-economic impact of the IDREEM project relates to the work done under the economic work package on willingness to pay by consumers for fin-fish produced using IMTA production methods. This survey showed that across all partner countries there was a willingness to pay more for environmentally produced aquaculture fish. Our research also showed that amongst SME fin-fish producers especially in the

Mediterranean there is a lack of product differentiation within the market. These two findings have major implications for the development of the European aquaculture industry. As European aquaculture products increasingly face competition from products outside of Europe, and as the market share for European produced aquaculture products decreases, it is becoming increasingly important that the high quality produce from Europe is able to differentiate itself in the global market and attract a premium for its quality and safety. The development of a market and standards for IMTA would be one way to ensure that the European aquaculture industry can expand through market differential and innovation. Related to this is the issue of food safety, one of the risks identified at the start of the project was that of whether IMTA production was associated with any decrease in product quality and safety. Work undertaken in the IDREEM project has showed that there is no scientific basis for this risk, and in doing so has removed another perceived bottleneck in the development of IMTA. The modelling that was also undertaken within the project also has significant socio-economic impact. In terms of the LCA modelling it has shown that even for monoculture, operations such as packaging and boat transport can have a significant effect on the environmental impact of the production and that my targeting these identified 'hot spots' it is possible to create a greener industry . In terms of the IMTA system it has also given the fin-fish producers the tools to identify how better to integrate their operations to create more sustainable business models. In addition the development of the FARM model offers to include IMTA offers new potential markets. LLE's the FARM model was a pre-existing product that has supported several organisations, including NOAA in the US and AFBI in Ireland, both of whom use the FARM model to evaluate shellfish culture within their defined areas as a regulatory undertaking. Through the IDREEM project the FARM model has undergone a transformation, with new species added that can be evaluated as monoculture, and full development of the capability to model multiple species under IMTA scenarios. For Longline Environment Ltd this opportunity allows the company to increase its modelling offering to the aquaculture industry, and in added markets, including the north Atlantic region for salmon and algae, and sea bass and oysters in the Mediterranean. The model capability has advanced significantly and in the longer term will enable LLE to offer new services and advisory capacity to the aquaculture industry.

Main dissemination activities and exploitation of the results

IDREEM employed a number of very successful techniques to ensure that there was good dissemination and exploitation of the IDREEM project and its results. The IDREEM project has become recognised as the most significant IMTA development project in Europe.

Project Website The website was an effective tool to disseminate the results and the achievements of the project and to raise the awareness on IMTA and was visited by more than 8,000 users. The content of the website was disseminated mainly via the newsletters to the mailing list of subscribers and aquaculture stakeholders. The website showed an

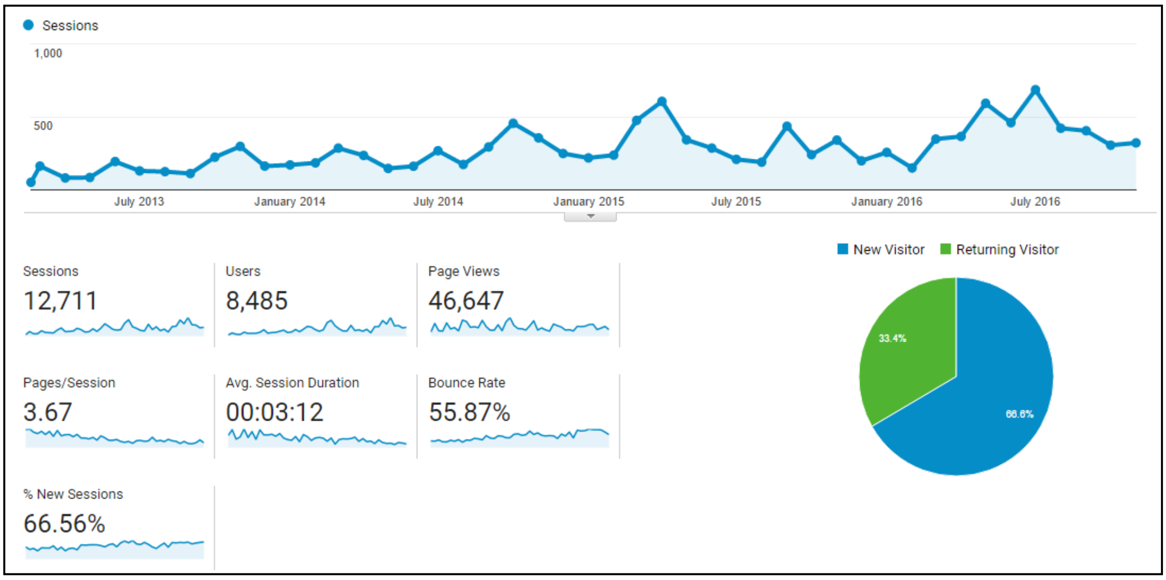


Figure 32 The website traffic and other statistics from 2012-2016

increasing trend in traffic over the course of the project demonstrating a growing awareness in and the wider community of the IDREEM project and its results. There was a major update to the project website half way through the project that allowed for a more blog style news content which allowed for the rapid addition of new results and outputs.

Conferences and meeting

As well as taking part in the normal academic conferences the IDREEM project organised its own workshop/conference in conjunction with 7 other European projects and also organised project specific sessions at two European Aquaculture Society conference.

The European Seaweed Production and Marketability Workshop

This was a world first, bringing together five EU projects - AT~SEA, EnAlgae, IDREEM, SeaBioPlas and Atlantic BlueTech, in conjunction with the GlobalSeaweed network, and the Biomarine International Clusters Association (BICA). The event resulted in interesting and challenging discussion of best practices in seaweed cultivation, harvesting, analysis and product extraction. It aimed to:

- Establish the transnational value of the European seaweed resource, towards the marketability of its products, considering the conservation and genetics of the resource basis, the regulatory framework and social acceptability issues.

- Create an informative reference framework for industry, as well as for regulators, research and service providers.

Figure 33 The European Seaweed Production and Marketability meeting brought together 7 projects and other 100 representatives from industry government and academia.

Highlights included the chairman of the recently formed Scottish Seaweed Industry Association (SSIA) discussing how businesses must work with government and regulatory bodies early on if the potentially lucrative sector is to thrive. Walter Speirs, former chairman of the Association of Scottish Shellfish Growers, issued his counsel as he opened a conference on European Seaweed Production and Marketability. The event, hosted by the Scottish Association for Marine Science (SAMS), near Oban, attracted an international guest list of over 100 delegates, including seven of the most influential projects in seaweed cultivation. The conference, which was supported by Highlands and Islands Enterprise, also heard presentations from industry experts. Professor Juliet Brodie, research phycologist at the Natural History Museum in London, told delegates:

This meeting was illustrative of an on-going relationship, communication and collaboration between the IDREEM project and other EU projects such as AT~SEA, and EnAlgae. The IDREEM project engaged with these projects to ensure that their research has been placed in a larger European and global context and to fully explore any synergies between the projects.

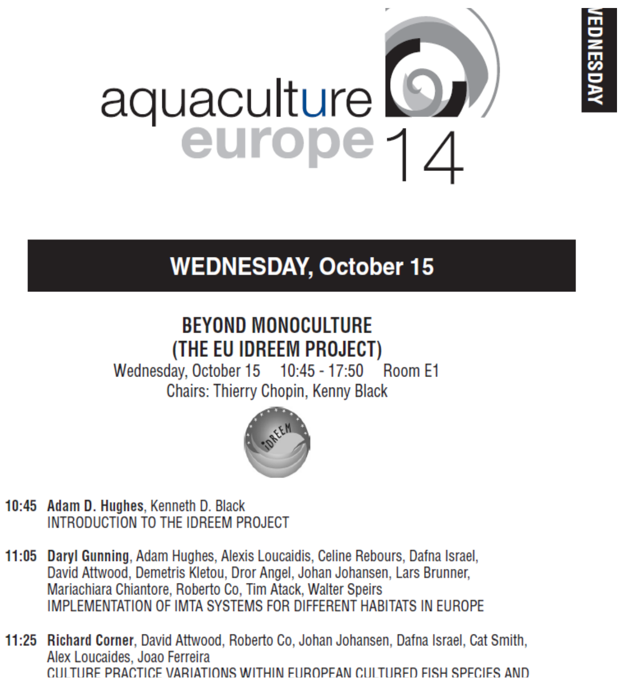


Figure 34 The first page of the program from the EAS 2014 showing the IDREEM session

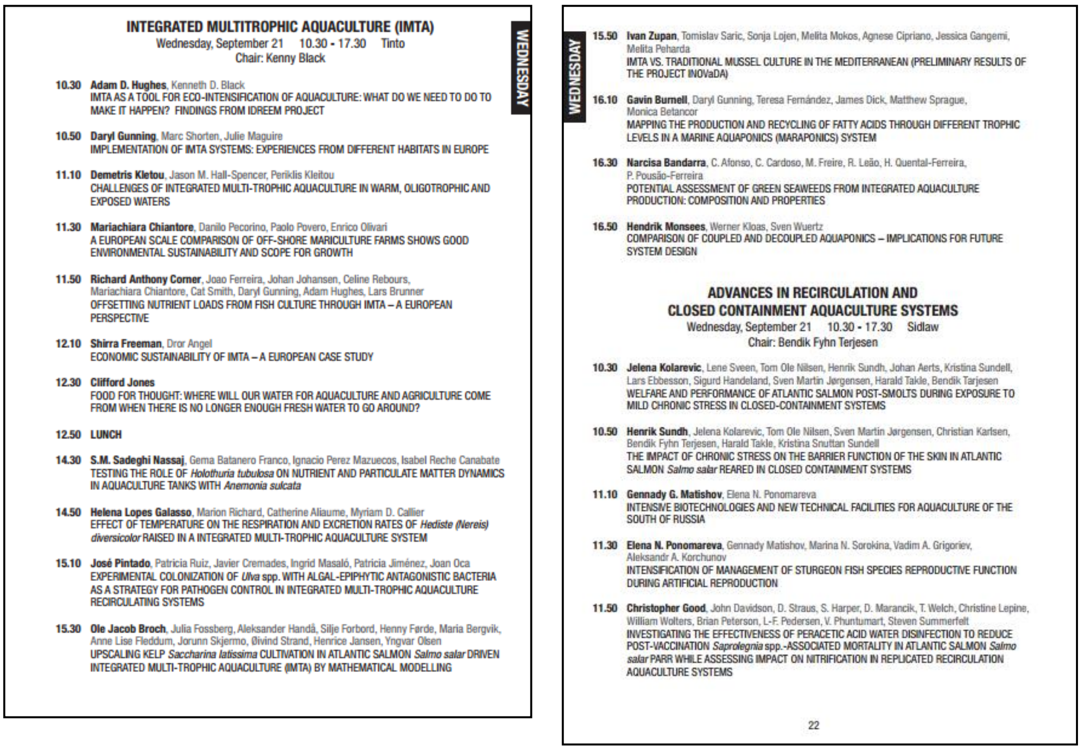
Aquaculture Europe 2014

The first IDREEM conference was held on 15 October 2014 in San Sebastian, Spain. The event was structured as a one day parallel session within the larger Aquaculture Europe 2014 Conference, organized by the European Aquaculture Society in collaboration with AZTI Tecnalia. Over 1,000 attendees from 54 countries participated in this conference from 14 to 17 October 2014, representing a wide and diverse audience of researchers, companies and industrial organizations, institutions, media and policy makers. The final agenda included 8 speakers from the IDREEM consortium, six in the morning session and two in the afternoon session. The remaining speaking slots (9) were attributed by EAS to speakers outside of the consortium whose abstracts were relevant to IMTA research and debate. In addition to the oral presentations, 4 poster presentations were accepted. The hall (around 80 seats) remained crowded with people standing, confirming wide interest in the topic; at least 120 participants attended the morning session, chaired by Dr Kenny Black (SAMS). The IMTA networking lunch was organized during the lunch break between the morning and the afternoon sessions. The idea was to provide a space for free networking and interaction among stakeholders, speakers and participants to the IDREEM day. A dedicated IDREEM area was arranged by the organizers at the conference premises, with free seats and tables. Over 45 people attended the networking lunch which provided a useful platform to liaise and interact with stakeholders in a pleasant and informal way.

Figure 35 The IDREEM networking lunch at EAS2014 was a huge success for IMTA networking

Aquaculture Europe 2016

The second IDREEM conference was held on 21 September 2016 in Edinburgh in the framework of the Aquaculture Europe 2016 conference, organized by the European Aquaculture Society, EAS, in cooperation with the Marine Alliance for Science and Technology for Scotland (MASTS). AES 2016 was held at the Edinburgh International Conference Centre and attracted a total participation of 1700 from 65 countries. The session chaired by Prof. Kenny Black and Dr Adam Hughes (SAMS), attracted at least 120 participants and presented the result of the project with six presentations in the morning session by IDREEM partners, namely: Adam Hughes, Daryl Gunning, Demetris Kletou, Mariachiara Chiantore, Richard Corner and Shirra Freeman. ETA supported the organization of the conference with the preparation and distribution of the print copies of the IDREEM book (100 copies distributed by hand to participants).



INTEGRATED MULTITROPHIC AQUACULTURE (IMTA)
Wednesday, September 21 10.30 - 17.30 Tinto
Chair: Kenny Black

WEDNESDAY

10.30 **Adam D. Hughes**, Kenneth D. Black
IMTA AS A TOOL FOR ECO-INTENSIFICATION OF AQUACULTURE: WHAT DO WE NEED TO DO TO MAKE IT HAPPEN? FINDINGS FROM IDREEM PROJECT

10.50 **Daryl Gunning**, Marc Shorten, Julie Maguire
IMPLEMENTATION OF IMTA SYSTEMS: EXPERIENCES FROM DIFFERENT HABITATS IN EUROPE

11.10 **Demetris Kletou**, Jason M. Hall-Spencer, Periklis Kleitou
CHALLENGES OF INTEGRATED MULTI-TROPHIC AQUACULTURE IN WARM, OLIGOTROPHIC AND EXPOSED WATERS

11.30 **Mariachiara Chiantore**, Danilo Pecorino, Paolo Povero, Enrico Olivari
A EUROPEAN SCALE COMPARISON OF OFF-SHORE MARICULTURE FARMS SHOWS GOOD ENVIRONMENTAL SUSTAINABILITY AND SCOPE FOR GROWTH

11.50 **Richard Anthony Corner**, Joao Ferreira, Johan Johansen, Celine Rebours, Mariachiara Chiantore, Cat Smith, Daryl Gunning, Adam Hughes, Lars Brunner
OFFSETTING NUTRIENT LOADS FROM FISH CULTURE THROUGH IMTA – A EUROPEAN PERSPECTIVE

12.10 **Shirra Freeman**, Dror Angel
ECONOMIC SUSTAINABILITY OF IMTA – A EUROPEAN CASE STUDY

12.30 **Clifford Jones**
FOOD FOR THOUGHT: WHERE WILL OUR WATER FOR AQUACULTURE AND AGRICULTURE COME FROM WHEN THERE IS NO LONGER ENOUGH FRESH WATER TO GO AROUND?

12.50 **LUNCH**

14.30 **S.M. Sadeghi Nassaj**, Gema Batanero Franco, Ignacio Perez Mazuecos, Isabel Reche Canabate
TESTING THE ROLE OF *Holothuria tubulosa* ON NUTRIENT AND PARTICULATE MATTER DYNAMICS IN AQUACULTURE TANKS WITH *Anemonia sulcata*

14.50 **Helena Lopes Galasso**, Marion Richard, Catherine Aliaume, Myriam D. Callier
EFFECT OF TEMPERATURE ON THE RESPIRATION AND EXCRETION RATES OF *Hediste (Nereis) diversicolor* RAISED IN A INTEGRATED MULTI-TROPHIC AQUACULTURE SYSTEM

15.10 **José Pintado**, Patricia Ruiz, Javier Cremades, Ingrid Masaló, Patricia Jiménez, Joan Oca
EXPERIMENTAL COLONIZATION OF *Ulva* spp. WITH ALGAL-EPIPHYTIC ANTAGONISTIC BACTERIA AS A STRATEGY FOR PATHOGEN CONTROL IN INTEGRATED MULTI-TROPHIC AQUACULTURE RECIRCULATING SYSTEMS

15.30 **Ole Jacob Broch**, Julia Fossberg, Aleksander Handå, Silje Forbord, Henny Førde, Maria Bergvik, Anne Lise Fleddum, Jorunn Skjermo, Øivind Strand, Henrice Jansen, Yngvar Olsen
UPSCALING KELP *Saccharina latissima* CULTIVATION IN ATLANTIC SALMON *Salmo salar* DRIVEN INTEGRATED MULTI-TROPHIC AQUACULTURE (IMTA) BY MATHEMATICAL MODELLING

WEDNESDAY

15.50 **Ivan Zupan**, Tomislav Saric, Sonja Lojen, Melita Mokos, Agnese Cipriano, Jessica Gangemi, Melita Peharda
IMTA VS. TRADITIONAL MUSSEL CULTURE IN THE MEDITERRANEAN (PRELIMINARY RESULTS OF THE PROJECT INOVaDA)

16.10 **Gavin Burnell**, Daryl Gunning, Teresa Fernández, James Dick, Matthew Sprague, Monica Betancor
MAPPING THE PRODUCTION AND RECYCLING OF FATTY ACIDS THROUGH DIFFERENT TROPHIC LEVELS IN A MARINE AQUAPONICS (MARAPONICS) SYSTEM

16.30 **Narcisa Bandarra**, C. Afonso, C. Cardoso, M. Freire, R. Leão, H. Quental-Ferreira, P. Pousão-Ferreira
POTENTIAL ASSESSMENT OF GREEN SEAWEEDS FROM INTEGRATED AQUACULTURE PRODUCTION: COMPOSITION AND PROPERTIES

16.50 **Hendrik Monsees**, Werner Kloas, Sven Wuertz
COMPARISON OF COUPLED AND DECOUPLED AQUAPONICS – IMPLICATIONS FOR FUTURE SYSTEM DESIGN

ADVANCES IN RECIRCULATION AND CLOSED CONTAINMENT AQUACULTURE SYSTEMS
Wednesday, September 21 10.30 - 17.30 Sidlaw
Chair: Bendik Fyhn Terjesen

10.30 **Jelena Kolarevic**, Lene Sveen, Tom Ole Nilsen, Henrik Sundh, Johan Aerts, Kristina Sundell, Lars Ebbesson, Sigurd Handeland, Sven Martin Jørgensen, Harald Takle, Bendik Tarjesen
WELFARE AND PERFORMANCE OF ATLANTIC SALMON POST-SMOLTS DURING EXPOSURE TO MILD CHRONIC STRESS IN CLOSED-CONTAINMENT SYSTEMS

10.50 **Henrik Sundh**, Jelena Kolarevic, Tom Ole Nilsen, Sven Martin Jørgensen, Christian Karlsen, Bendik Fyhn Terjesen, Harald Takle, Kristina Snuttan Sundell
THE IMPACT OF CHRONIC STRESS ON THE BARRIER FUNCTION OF THE SKIN IN ATLANTIC SALMON *Salmo salar* REARED IN CLOSED CONTAINMENT SYSTEMS

11.10 **Gennady G. Matishov**, Elena N. Ponomareva
INTENSIVE BIOTECHNOLOGIES AND NEW TECHNICAL FACILITIES FOR AQUACULTURE OF THE SOUTH OF RUSSIA

11.30 **Elena N. Ponomareva**, Gennady Matishov, Marina N. Sorokina, Vadim A. Grigoriev, Aleksandr A. Korchunov
INTENSIFICATION OF MANAGEMENT OF STURGEON FISH SPECIES REPRODUCTIVE FUNCTION DURING ARTIFICIAL REPRODUCTION

11.50 **Christopher Good**, John Davidson, D. Straus, S. Harper, D. Marancik, T. Welch, Christine Lepine, William Wolters, Brian Peterson, L-F. Pedersen, V. Phuntumart, Steven Summerfelt
INVESTIGATING THE EFFECTIVENESS OF PERACETIC ACID WATER DISINFECTION TO REDUCE POST-VACCINATION *Saprolegnia* spp.-ASSOCIATED MORTALITY IN ATLANTIC SALMON *Salmo salar* PARR WHILE ASSESSING IMPACT ON NITRIFICATION IN REPLICATED RECIRCULATION AQUACULTURE SYSTEMS

22

Figure 36 The agenda of the IMTA session at Aquaculture Europe 2016. The first six morning presentations were given by IDREEM partners.

Other Scientific Conferences
In addition to these conference and sessions organised by the IDREEM project researchers from the IDREEM consortium presented at a large number of other conference. The table below gives an example of those conferences:

21-23 Sept 2015 Cherbourg France Seagriculture
21-22 March 2016 Moskito Island, British Virgin Islands
22-24 March 2016Environ 2016 - University of Limerick
16th June 2015 EXPO Milan, oral presentation
13-17 June 2016XLVII Congress of the Italian Society for Marine Biology, Turin (Italy)
25-27 May 2016 Industrial Ecology and Green Transformations" Bogota, Colombia

Scientific Publications
The research undertaken within the IDREEM project has led to a number of publications in the peer reviewed scientific literature. This offers a direct mechanism for the dissemination and exploitation of the foreground. Those papers include:

Goods and services of extensive aquaculture: shellfish culture and nutrient trading (2016) Ferreira, J. G. & Bricker, S. B. Aquaculture. International. 24, 803-825, doi:10.1007/s10499-015-9949-9
http://link.springer.com/article/10.1007/s10499-015-9949-9

Improving sustainability of aquaculture in Europe: Stakeholder dialogues on Integrated Multi-trophic Aquaculture (IMTA) (2016), Environmental Science & Policy, Volume 55, Part 1, January 2016, Pages 96-106, ISSN 1462-9011, http://dx.doi.org/10.1016/j.envsci.2015.09.006. http://www.sciencedirect.com/science/article/pii/S1462901115300757

A pseudo-statistical approach to treat choice uncertainty: the example of partitioning allocation methods. (2016), Beltran A., Heijungs R., Guineé J, Tukker A., The International Journal of Life Cycle Assessment, Vol 21-2016, issue 2, http://link.springer.com/article/10.1007/s11367-015-0994-4

Going beyond the search for solutions: understanding trade-offs in European integrated multi-trophic aquaculture development. (2016) Hughes, A.D., Black, K.D, Inter research Aquaculture Environment Interaction8: ,191-199 ,doi:10.3354/aei00174 http://www.int-res.com/abstracts/aei/v8/p191-199

Navigating Uncertain Waters: European Public Perceptions of Integrated Multi-Trophic Aquaculture. (2016). Alexander K.A., Freeman S., Potts T, Environmental Science and Policy Journal vol.61 http://www.sciencedirect.com/science/article/pii/S1462901116301125

Role of deposit feeders in integrated multi-trophic aquaculture – A Model analysis (2016). Cubillo A.M., J.G. Ferreira, S.M.C. Robinson, C.M. Pearce, R.A. Corner and J. Johansen, Aquaculture, 453: 54-66, doi:10.1016/j.aquaculture.2015.11.031.

The implications of aquaculture policy and regulation for the development of integrated multi-trophic aquaculture in Europe. (2015) Alexander K.A., Potts T, Freeman S., Aquaculture , Vol 443, http://www.sciencedirect.com/science/article/pii/S0044848615001295

Project Videos and Broadcast Television

The IDREEM project made extensive use of both project generated content and also featured on externally broadcast television programs.

To facilitate the use of project generated video content IDREEM set up its own You-Tube channel where it hosted seven videos that were produced within the project.

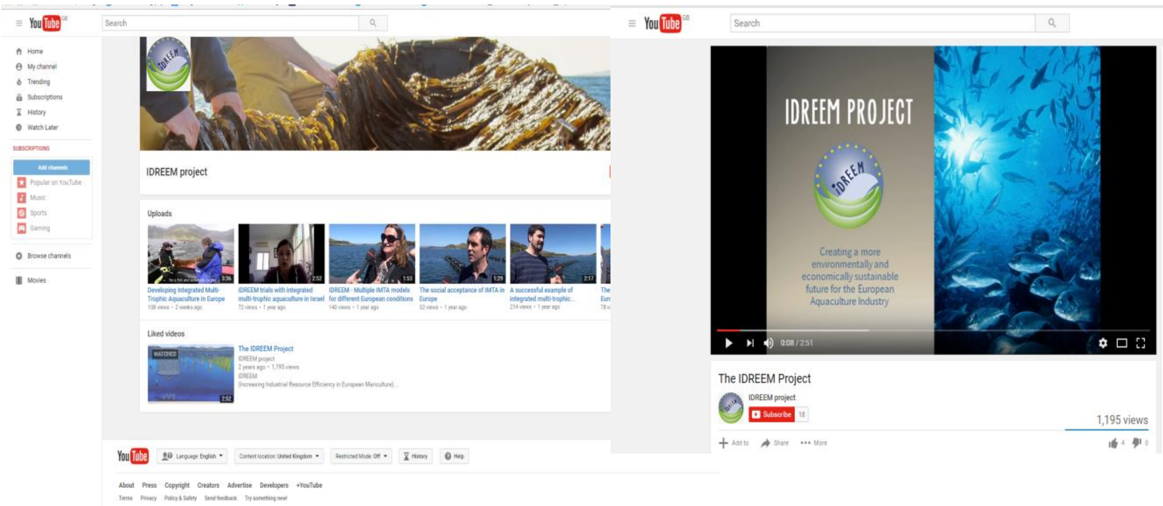


Figure 37 A screen shot of the IDREEM You Tube channel and one of our videos we used to disseminate the projects results

As well as project videos the IDREEM project also featured on two external produced television programmes. First was with Euronews TV. In the month of July 2016 the crew of Euronews visited SAMS and Scottish Salmon Company and collected interviews, clips of the IMTA pilot site in Loch Fyne and of the laboratories at SAMS. This resulted in **a 5 minutes documentary** titled "**A Fresh Splash for Aquaculture**" which Euronews TV broadcasted to 430 million households in 130 countries in thirteen broadcasting languages (English,German, Spanish, French, Italian, Portuguese, Russian, Arabic, Turkish, Persian, Ukranian, Greek and Hungarian). The documentary was then published on the Euronews website and is still at this url: http://www.euronews.com/2016/08/01/a-fresh-splash-for-aquaculture .

Figure 38 A screenshot of the Futuris documentary "A Fresh Splash for Aquaculture" on Euronews TV

Following the Euronews piece the project contacted the BBC Scotland rural affairs programme Landward who were also interested in doing a 5 minute section for their programme. BBC Landward program feature the IMTA site from the IDREEM project that was broadcast on 10th October 2016.

Figure 39 BBC reporter talking about the IDREEM project in Scotland

Beyond Monoculture

Another major accomplishment in this reporting period was the publication of the IDREEM summary book "**Beyond Monoculture-developing IMTA across Europe**". This consists of a 43 page book with nine chapters dedicated to describing the activities, the achievements and the lessons learnt in all the different work packages of the project. In addition, some final remarks about the key steps necessary for moving forward with commercial IMTA are presented. All work package leaders co-authored the book, by providing the text for their respective works packages. The editorial review was conducted by Maurizio Cocchi (ETA), Adam Hughes (SAMS) and Richard Corner (Longline Environment Ltd.). The entire text was then submitted to all the partners for final review and approval prior to publication. All the remarks received were considered in the final version of the book, therefore this publication represents the common position of the whole consortium. A free online pdf version was also published on the project's website (available in the home page www.idreem.eu).

Figure 40 The front cover of the IDREEM book (left); print copies of the book distributed at Aquaculture Europe 2016 in Edinburgh (right).

List of Exploitable Foreground

Exploitable Foreground (description):
The development of technology and knowhow for the co-cultivation of queen scallops, mussels and oysters with Atlantic salmon
Confidential: No
Foreseen embargo date:
Exploitable product(s) or measure(s): The production of the shellfish and the methodology for this production
Sector(s) of application: Aquaculture
Timetable for commercial use or any other use: Current and ongoing
Patents or other IPR exploitation (licenses):
Owner & Other Beneficiary(s) involved: Scottish Salmon Company, Scottish Association for Marine Science, whole IDREEM consortium

Exploitable Foreground (description):
The development of technology and knowhow for the co-cultivation of seaweeds with Atlantic salmon
Confidential: No
Foreseen embargo date:
Exploitable product(s) or measure(s): The production of the seaweed and the methodology for this production
Sector(s) of application: Aquaculture
Timetable for commercial use or any other use: Current and ongoing
Patents or other IPR exploitation (licenses):
Owner & Other Beneficiary(s) involved: DOMMRS, GIFAS, NIMBIO, Scottish Salmon Company, Scottish Association for Marine Science, whole IDREEM consortium

Exploitable Foreground (description):
The development of technology and knowhow for the co-cultivation of oysters with Sea bass and Sea bream
Confidential: No
Foreseen embargo date:
Exploitable product(s) or measure(s): The production of the oysters and the methodology for this production
Sector(s) of application: Aquaculture
Timetable for commercial use or any other use: Current and ongoing
Patents or other IPR exploitation (licenses):
Owner & Other Beneficiary(s) involved: Aqua, UNIGE, and whole IDREEM consortium

Exploitable Foreground (description):
The development of technology and knowhow for the co-cultivation of sponges with Sea bass and Sea bream
Confidential: No
Foreseen embargo date:
Exploitable product(s) or measure(s): The production of the sponges and the methodology for this production
Sector(s) of application: Aquaculture

Timetable for commercial use or any other use: 12-24 months
Patents or other IPR exploitation (licenses):
Owner & Other Beneficiary(s) involved: Seawave, and whole IDREEM consortium

Exploitable Foreground (description):
The development of technology and knowhow for designing fin-fish cage mooring grids to include macroalgae cultivation infrastructure
Confidential: No
Foreseen embargo date:
Exploitable product(s) or measure(s): Consultancy for other fin-fish farmers, application to other sites
Sector(s) of application: Aquaculture
Timetable for commercial use or any other use: Current and ongoing
Patents or other IPR exploitation (licenses):
Owner & Other Beneficiary(s) involved: GIFAS

Exploitable Foreground (description):
The development of FARM model to include new species and IMTA operations
Confidential: No
Foreseen embargo date:
Exploitable product(s) or measure(s): The model, it application and training to use the model
Sector(s) of application: Aquaculture
Timetable for commercial use or any other use: Current and ongoing
Patents or other IPR exploitation (licenses): Licencing for use
Owner & Other Beneficiary(s) involved: LLE