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AQUASPACE

Ecosystem Approach to making Space for Aquaculture

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CASE STUDY FINAL REPORTS

Lead Beneficiary	**Institute of Marine Research**
Deliverable authors	**Øivind Strand and Øivind Bergh.** **Case study (CS) leaders: Roberto Pastres John Icely, Ibon Galparsoro, Kerepeczki Éva, Adele Boyd, Suzanne Bricker, Ana Martins Sequeira, Nafsika Papageorgiou, Aline Gagnery, Antje Gimpel, Jon Grant, Hui Liu, Suzi Billing, Jeffrey Ren** **Case study authors given under each case study.**
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Review log

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1.0	July 2017	Anne Marie O'Hagan & Ellen MacMahon (UCC)	
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2.0	August 2018	Paul Tett (SAMS)	Approved resubmission

CONTENTS

EXECUTIVE SUMMARY

The Aquaspace project is focusing on how to allocate space for aquaculture in a way that is socially and environmentally sustainable. Policy-management issues have been investigated, and tools for aquacultural area management and marine spatial planning have been applied, in 17 Case Studies in Europe, North America, China, and Australasia. This report describes these case studies, which embrace a variety of: species; cultivation methods; industry developments; sectoral clashes; and natural conditions. In this revision, a new section 17 provides some general conclusions from the case studies.

1. INTRODUCTION

One of the challenges of the 21st century is that of satisfying human demand for protein. Some of this will be met by increased marine farming of fin-fish, shellfish, and seaweed (Duarte et al., 2009). If it is to be sustainable, such expansion requires improved understanding of aquaculture-environment interactions. Furthermore, it requires increased use of public coastal space for aquaculture, which puts it into conflict with other societal demands for use of that space.

The Aquaspace project is focusing on how to allocate space for aquaculture in a way that is socially and environmentally sustainable. The project has described and analysed policy-management issues acting as constraints against utilisation of additional areas for aquaculture (O'Hagan et al. 2017). It has reviewed and developed tools for aquacultural area management and marine spatial planning (Gimpel et al. 2016). The context for this work has been a variety of case studies, representing the various stages of development and natural conditions that exist in Europe and the world. This report describes these case studies and their findings.

The Aquaspace project originally had 16 case studies in Europe, the USA, Canada, Australia, and China (Figure 1). Subsequently, a New Zealand study was added as the 17th case study.

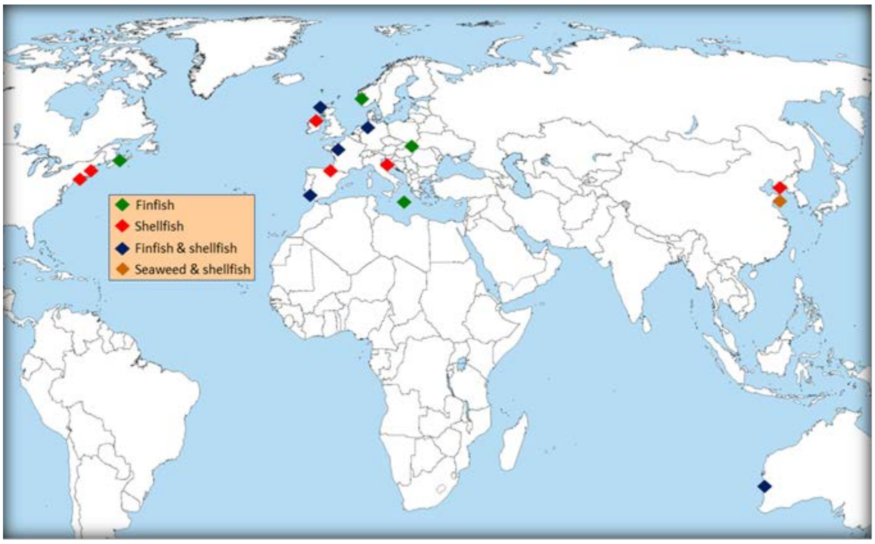


Figure 1. Case studies of the Aquaspace project, geographical location and type of study, divided into finfish, shellfish, seaweed and combinations. A New Zealand case study focusing on shellfish was recently added.

Each of the 17 cases summarised in Table 1 explored different concepts of aquaculture in different environments, ranging from tropical to temperate. One case is in freshwater in a landlocked state (Hungary) whereas the remaining 16 are highly diverse examples of marine cases, with finfish, shellfish, seaweed and different combinations of these.

In the majority of cases, aquaculture is operational and ranges from large scale industry to small scale local farming. Some cases describe plans for developing commercial aquaculture from an existing experimental scale.

Conflicts with other users of the coastal zone emerge as a major factor limiting aquaculture development. These uses include (amongst others) tourism, nature protection, fisheries, energy production, and transport. Although Maritime Coastal Planning within EU member states is beginning to take place within the framework of EU directives, the case studies reveal a great variety of legislation applying to aquaculture at member state and sub-state levels, or within the nations outside the EU that are collaborating in Aquaspace.

It has been hypothesized that co-use of coastal waters by aquaculture and other sectors, notably energy, could reduce the level of conflict, and thus allow more space for aquaculture. (Stelzenmüller et al. 2013). Some of the Spatial Planning tools applied or developed within Aquaspace are intended to aid co-use. These tools, and others, have been evaluated in selected Case Studies, as is reported here. A cross evaluation and synthesis of the cases will be reported separately, from Work Package 5 of the Aquaspace project.

Table 1. Case studies of the Aquaspace project, showing scale, environment type, species cultivated, culture system and key issue(s). Scale R= region, B = bay, C = country, S= regional Sea, Environment: C= coastal, I = inland, O = offshore

Case study	Scale	Environmen	Type	Culture system	Key issues
Adreatic Sea, Italy	R	C	shellfish	bottom, suspended	proximity to protected area conflicts with tourism, fisheries
Algarve Coast, Portugal	R	C, O	warm finfish, shellfish	cages, ponds, suspended bottom	co-use, optimising space allocation, disease connectivity
Basque County, Spain	R	C, O	shellfish	suspended	making space and changing culture for aquaculture
Békés County, Hungary	R	I	FW fish	ponds, tanks	proximity to bird reserves, clean water availability
Carlingford Lough, UK	B	C	shellfish	trestles, bottom	complex governance, co-use.
Great Bay Pisccataqua and Long Island Sound, USA	B, R	C	shellfish	trestles, bottom	legal constraints and use conflicts
Houtman Abrolhos Islands, Australia	R	C, O	shellfish finfish	suspended, cages	conservation area, co-use, potential for disease spread
Mediterranean Sea Multiple EEZ	S	C, O	warm finfish	cages	co-use with other industries, complex governance
Normandy and Cancale, France	R	C	shellfish	cages, bottom, suspended	multiple conflicting uses, complex governance

North Sea, Germany	R	C, O	shellfish, finfish	bottom cages	co-use with other industry, increase of production level, complex governance
Norwegian Coast, Norway	R, C	C, O	cold finfish	cages	sea lice connectivity, space availability, co-use
Nova Scotia Bays, Canada	B	C	cold finfish	cages	enhancing social licence user/fisheries conflicts
Zhangzidao Island and Sangou Bay China	R, C, B	C, O	seaweed, shellfish	suspended	competition for space with other industry; increased production
Argyll and Bute, Scotland, UK	R, C	C, O	cold finfish	cages, suspended	community opposition, space availability, landscape/seascape impacts, sea lice connectivity; increased production
Pelorus Sound, Marlborough, New Zealand	R	C	shellfish	suspended	Variable production/yield,

As far as possible, all Case Study descriptions follow the same format:

- Characteristics of the study region and its aquaculture
- Spatial planning and management issues
- Tools used
- Stakeholder engagement
- Case study results
- Relevance of the case study within Aquaspace
- Conclusions and prospects
- References cited in the account of the study
- Annexes with summarized information in tables.

References

Duarte, C. M. et al. (2009). Will the Oceans Help Feed Humanity? BioScience 59(11): 967-976.

Gimpel, A. et al. (2016). Aquaspace D3.1: Tools and methods supporting EAA: Finding the gap towards an environmental Cost Benefit Analysis.

O'Hagan, A. M. et al. (2017). Aquaspace D2.1: Regional review of Policy-Management Issues in Marine and Freshwater Aquaculture.

V. Stelzenmüller et al. (2013). Guidance on a better integration of aquaculture fisheries and other activities in the coastal zone. From tools to practical examples. Ireland. COEXIST project 2013, 76pp. Downloadable from www.coexistproject.eu

2. ADRIATIC SEA, ITALY

Roberto Pastres and Daniele Brigolin

2.1. General characteristics

Shellfish culture is an important activity along the whole Adriatic and Ionian Italian coasts. The two main products are: i) Manila clam *(Tapes philippinarum)*, which is farmed in the Northern Adriatic lagoons, such as the Lagoon of Marano, Venice, Goro and Scardovari, and ii) Mediterranean mussel (*Mytilus galloprovincialis*), which is farmed mainly offshore on long-lines from the Gulf of Trieste, in the North, to the Gulf of Taranto. In Aquaspace, we focused on investigating how the implementation of MSP could facilitate the expansion of offshore mussel culture in the region, with a focus on the Emilia-Romagna coastal area, which at present, produces about 22,000 tonnes per year, representing about one third of Italian production.

The study area, shown in Figure 2.1, is located between 3 and 12nm from the shore, ranging from a latitude of 44.84 north to 43.97 south and a longitude of 12.24 west to 12.93 east, covering a total surface of 1561 km^2. Compared to other areas in the Adriatic, primary production here is enhanced by the nutrients delivered by the Po river: both satellite and *in situ* data show a clear Chlorophyll a gradient from North to South, as the nutrient rich Po waters are transported southward by the Adriatic coastal current (see Figure 2.1). The area is therefore, in general, suitable for shellfish farming. The seabed is mainly sandy and muddy: therefore, it hosts soft bottom benthic communities, including wild shellfish, e.g. *Chamelea galina*, and demersal fish, e.g. *Solea solea*, which are of commercial (fisheries) interest.

From the economic point view, the main sector in this coastal area is tourism: the seaside towns of Rimini, Riccione, Cesenatico, Cattolica are all very well-known holiday venues. However, fishery and aquaculture are still important and part of the area's cultural heritage.

2.2. Spatial planning and management issues

Shellfish culture, mainly *Mytilus galloprovincialis* in the coastal area and *Ruditapes philippinarum* in coastal lagoons, are well established activities in Emilia-Romagna: the total annual production was about 40000 tonnes in 2013, with 21,552 tonnes of mussel and 18,994 tonnes of Manila clam. However, research and pilot studies have demonstrated that the area would be suitable for developing the culture of the European flat oyster *Ostrea edulis* and the Pacific oyster *Crassostrea gigas*. Shellfish production in Emilia Romagna Region is nationally significant: in 2014 mussel production in Emilia-Romagna accounted for about one third of national mussel production, and about 60% of clam production. Products are sold both locally and nationally. Suspended mussel culture is carried out offshore in long-lines using socks of plastic material.

Overall, given the hydrodynamic features of the area and the predominantly sandy seabed, the environmental impact due to phytoplankton depletion and enrichment of organic sediment is not very relevant. The most severe impact is due to the accidental release of plastic socks, currently

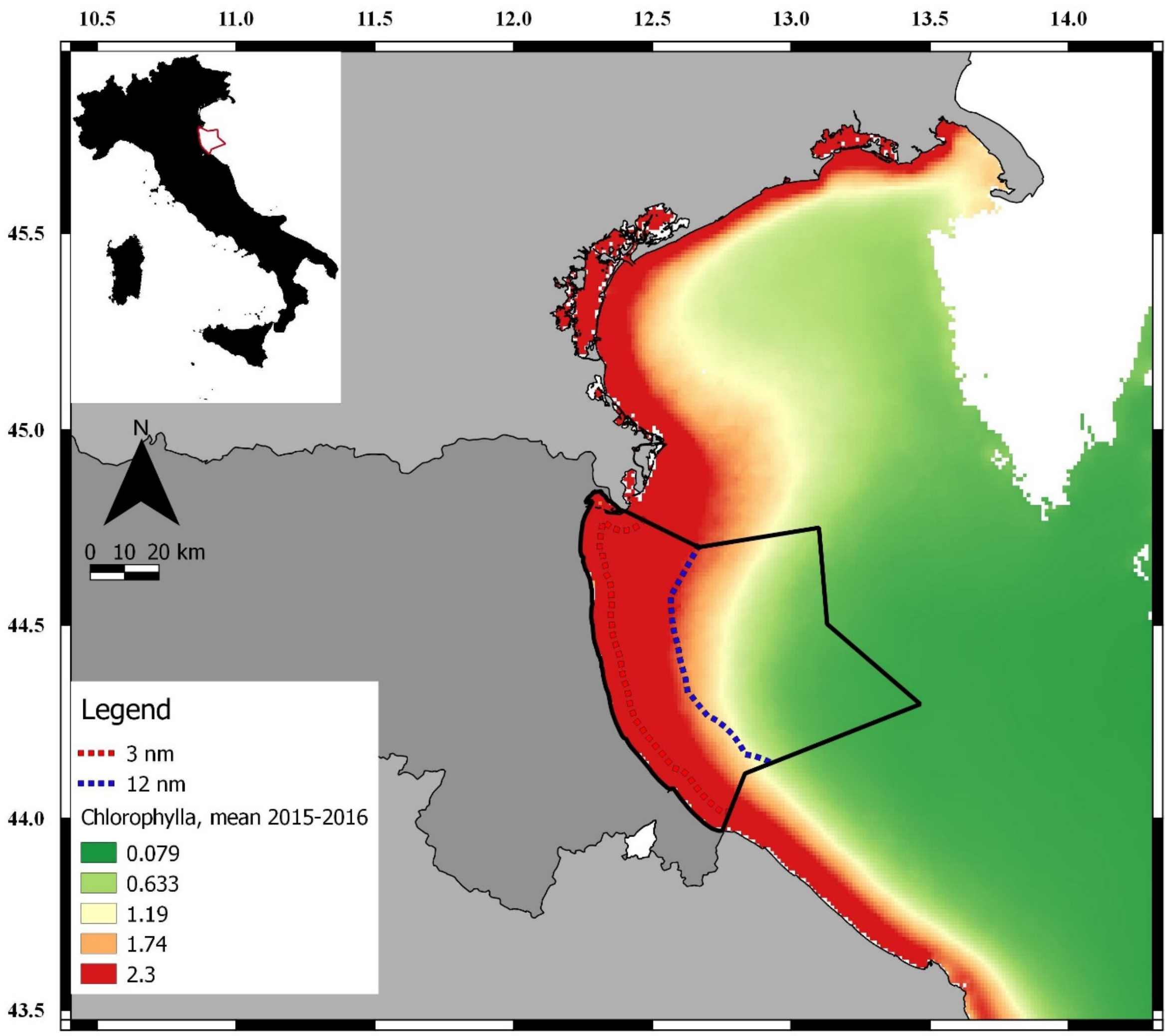


Figure. 2.1. Average Chlorophyll a concentration in the study area in the year 2015-2016: the map is based on daily data at 1km resolution from the Copernicus Marine Service.

made of polypropylene, during storm events as they contribute to plastic macro-litter, one of the EU Marine Strategy Framework Directive descriptors.

Conflicts with tourism activities are limited, as mussel culture is already perceived as a traditional and environmentally friendly activity. Mussel culture can, however, interfere with fisheries and navigation. There are Natura 2000 sites in the coastal area where shellfish culture is not allowed.

We made an inventory of sea uses in the area, in order to identify constraints to the expansion of mussel culture, in particular in the coastal zone between 3 and 12nm from the shore; which led us to identify the following:

- Presence of ports
- Presence of biological conservation zones and Natura 2000 areas
- Mooring areas
- Commercial and tourist marine traffic routes
- Presence of Italian Navy installations

- Sand deposits
- Seabed mining areas
- Underwater pipes

The results of this analysis were taken into account in the application of the "Bluefarm 2" tool and are summarised in the maps presented in section 3.

The shellfish farming sector is characterised by high fragmentation, as most companies are very small: in 2014, 29 companies were operating involving approximately 300 workers. Most of them take care of the harvesting and commercialisation of the product, which is almost exclusively sold fresh. As a result, operators have little influence on market prices and usually their low profitability margin makes it difficult for them to invest in innovation, as well as in insuring their capital against potential threats, i.e. storm events.

Offshore mussel production in Emilia-Romagna started in the early 1980s and boomed in the 1990s: from about 2,400 tonnes in 1987 (3 farms) to 14,000 tonnes in 1997 (14 farms). Since then, the production volume has steadily increased until 2012. In the last four years, it seems to have reached a roughly constant level, fluctuating around 21,500 tonnes. Recently farmers started looking for alternative species. Pacific oyster seems a good candidate for shellfish farming diversification, based on the results of pilot studies, but, at present, its production is not yet at a commercial scale.

The stagnation of mussel farming production is probably due, on one hand, to the decline in profitability of the activity, which is also now competing with non-EU imports, and, on the other hand, to complex administrative arrangements and environmental regulations, which limits the attraction of new investment. In this regard, plastic waste disposal is a financial burden which could be avoided by adopting new materials. Pilot studies involving the implementation in the region of the so-called Japanese long-lines are currently being undertaken. This technology, already being used successfully in New Zeeland, would require the relocation of some farms to deeper areas, moving farms further offshore. Diversification, i.e. oyster farming, is also being tested. In both cases, the suitability of the area to the introduction of these innovations should be investigated.

<u>The main goals of this case study, therefore, were</u>:

To identify the most suitable sites for offshore mussel culture in the coastal area between 3 and 12 nm from the shore;

To assess the potential for co-locating the production of mussels and Pacific oysters.

With respect to Italian policies to support the sector, in compliance with the Article 34 of EU CFP Regulation 1380/2013, in 2014 the Italian Ministry of Agriculture, Food and Forestry Policies (MiPAAF), published a Strategic Plan for the development of aquaculture covering the period 2014-2020. The Plan is designed to address four priorities, which were identified at EU level, namely: 1) simplification of administrative procedures; 2) reasonable certainty for aquaculture operators in relation to access to waters and space; 3) enhancing the competitiveness of the national aquaculture industry; and 4) ensuring fair competition and improving the supply chain. The implementation of the plan is supported by the European Maritime and Fisheries Fund (EMFF). In Italy, EMFF is allocated to the "Regioni", i.e. County Council, which should manage the funds at the local level. Allocation of funds through public calls is currently ongoing.

In Italy, MSP has not been fully implemented as yet. At present, the use and protection of marine space is presently managed by both national and local authorities, according to the type of use. For example, fishing, aquaculture, tourism and coastal protection are entrusted to the “Regioni” (counties), whereas energy uses are managed at national level. The Italian Parliament has only recently, in November 2016, approved a decree to transpose the EU MSP Directive.

The case study could be relevant for the implementation of the MSP Directive in Italy, given its recent transposition. Under that legislation, guidelines for defining management plans for the maritime space should be provided by an Inter-Ministerial Committee within 12 months. Subsequently, plans should be designed and approved by the Ministry of Transport and Infrastructure by the end of 2020. Plans should be designed on the basis of the EAA: aquaculture is explicitly mentioned as one of the sea uses to be taken into account. The planning process will involve stakeholders through public consultations. Therefore, Aquaspace could effectively contribute to the implementation of MSP, by providing science-based tools for identifying areas to be allocated to aquaculture. As AZAs have not been defined yet in the study area, the tools proposed by Aquaspace could be employed for that purpose and complement specific tools that have already been developed for supporting MSP, such as the Technical Chart of the Sea recently developed under the IPA SHAPE project (www.shape-ipaproject.eu) and the ADRIPLAN Portal, which is the main output of the DG MARE ADRIPLAN project (http://www.shape-ipaproject.eu/).

2.3. Stakeholder engagement and participation

Stakeholders were involved in the case study work since its inception, in collaboration with SIRAM – the Italian Society for Applied Research on Mollusc Farming (Società Italiana per la Ricerca Applicata alla Molluschicoltura, http://www.siram-molluschi.it) and AMA – the Mediterranean Aquaculture Association (Associazione Mediterranea Acquacultori, http://www.a-m-a.it/). In a preliminary survey, we identified three groups of stakeholders:

- F- Farmers and farm consultants;
- R - Regulators and public servants involved in environmental and food safety monitoring;
- S - Scientists involved in shellfish research.

On the basis of this, we designed the following stakeholder engagement strategy:

- 1) Organisation of an initial workshop (at the beginning of the Aquaspace project) in November 2015 to present the Aquaspace project and determine stakeholder opinions and requirements;
- 2) Make contact with regulators in the case study area and in the surrounding Italian Adriatic coastal zones, i.e. Veneto, Marche and Abbruzzo, as well as with the Italian Ministry of Agriculture, Food and Forestry Policies (MiPAAF), who is directly involved in the implementation of the MSP Directive at national level;
- 3) Presentation of the results of our spatial analysis to regulators using the purposely designed "Bluefarm 2" tool (see next section) during individual meetings, in order to get their feedback; and
- 4) Presentation of the final results to scientists, farmers and farm consultants at the SIRAM annual conference, to be held in November 2017.

As the third activity is still on-going and the fourth one will be carried out after the submission of the present deliverable, only the first and second steps are presented fully here, together with a summary of the feedback received thus far from regulators.

2.3.1. *Stakeholder workshop*

The workshop was held in Chioggia, near Venice, on November 7th 2015, back-to-back with the annual SIRAM conference. In total, there were 47 registered participants: 19 representing Farms/consultants, 18 Regulators and 10 Scientists. The main objectives of the workshop were:

- To present the state of implementation of MSP in the Adriatic Sea,
- To identify the main issues limiting the development and profitability of shellfish farming in the area, and
- To provide an overview of the Aquaspace project and present a preliminary version of the "Bluefarm2" tool to be developed during the project and applied to the case study.

The workshop was divided into two sections: 1) presentations by experts and 2) round table. Presentations were well received and encourage lively debate. All stakeholder groups agreed that MSP represents an opportunity for more efficient management of shellfish culture and for the allocation of areas where this industry could expand. Farmers, researchers and representatives of environmental agencies agreed that excess bureaucracy is the main factor inhibiting the further development of shellfish culture in the area. The implementation of MSP and definition of AZA were regarded as highly beneficial, as both could speed up concession of leased areas: at present, it can take a new investor up to two years to get a licence. Farmers pointed out that in many instances they are not involved in the decision making process at an early stage. They also remarked that there are cultural barriers, such as language, terminology, format of scientific reports, which inhibit their full exploitation of the results of scientific projects, such as Aquaspace. As regards the Aquaspace case study analysis and the preliminary results from "Bluefarm 2" tool, used to identify new areas suitable for development, farmers pointed out that criteria concerning risks (*i.e.* storm, occurrence of HABs, breakout of disease) should be introduced in the framework, as well as socio-economic indicators.

2.3.2. *Feedback and recommendations from the stakeholder workshop*

The workshop outcomes are summarised according to the requirements, recommendations and suggested actions below:

- Establishing a unique contact point, at national level, to help farmers with the licensing process and to comply with current legislation: at present, farmers are finding it very difficult to deal with these aspects.
- Investing in research projects, aimed at supporting diversification to other farmed species.

- Continued Professional Development training is needed, in order to address gaps in capacity relating to planning and management of aquaculture.
- Economic support from authorities may be needed to address adverse events, which may be exacerbated by climate change.
- Transparent and efficient licensing process.
- Identification and classification of areas suitable for shellfish farming based on a set of criteria, including biomass productivity and access/proximity to markets.
- Establishing a stakeholder platform, guaranteeing the involvement of all relevant stakeholders, including farmers, in decision making.
- Data concerning environmental variables and food security, should be made available by public authorities.

Figure 2.2. Presentation of the Aquaspace project at the Italian case study stakeholder workshop, Chioggia (Italy), Nov. 7th 2015

2.4. Tools used in the case study

In this case study, thus far, we have applied the "Bluefarm 2" tool, for identification of AZA and individual site selection, which was developed by Bluefarm within Aquaspace. We are also planning to apply the Ecosystem Cost Benefit Analysis tool, being developed by the Thünen Institute, before the end of the project. In this section we describe the first tool, as the second one is already described in Aquaspace Deliverable D3.1 and its application to other case studies is described elsewhere in this deliverable.

The "Bluefarm 2" tool is based on a Spatial Multi Criteria Evaluation (SMCE) methodology, which allows one to combine different spatially explicit information layers, covering both constraints to the further development of shellfish culture and also suitability criteria (e.g. productivity, environmental impacts and socio-economic factors). The latter are subsequently aggregated in a spatially explicit suitability index, using an appropriate weighting algorithm. Constraints include conflict of uses, such as those listed in the previous section, i.e. presence of ports, Marine protected areas, navigation routes etc. The results of the application of "Bluefarm 2" can therefore be easily visualised in 2D maps, such as the ones shown in the next section. The tool, and its preliminary results, are described in detail in the open access paper (Brigolin et al. 2017).

"Bluefarm 2" can be applied to different spatial scales, in accordance with the spatial resolution of the input data. In Aquaspace we applied it to the scale of a coastal area, but in future it could be applied to the whole Adriatic region. It was applied using the open source GIS programming environment Q-GIS: a Q-GIS plug-in for easily transferring the tool to another area is currently being designed and tested and will be delivered before the end of the project. At the end of the project, Bluefarm will distribute the plug-in for free to registered non-profit organisations and public authorities

2.5. Case study results

In accordance with the two goals of the case study given in Section 2, we applied "Bluefarm 2" to assess:

the suitability of the coastal area between 3 and 12nm from shore for mussel and pacific oyster farming.

The flow of information which characterises the application of the "Bluefarm 2" tool is shown in Figure 2.3, from left to right. Spatial information layers relating to constraints and criteria were produced on the basis of freely available data sources, such as field surveys and remote sensing, operational oceanography and environmental modelling, which can be downloaded from the EU Copernicus Marine Service, as well as from other data portals, such EMIS and EMODnet. This feature of "Bluefarm 2" should appeal to public administrations and enhances its capacity for transferability. Whenever necessary, these data were used as input to modelling tools owned by Bluefarm or purposely developed in the framework of Aquaspace.

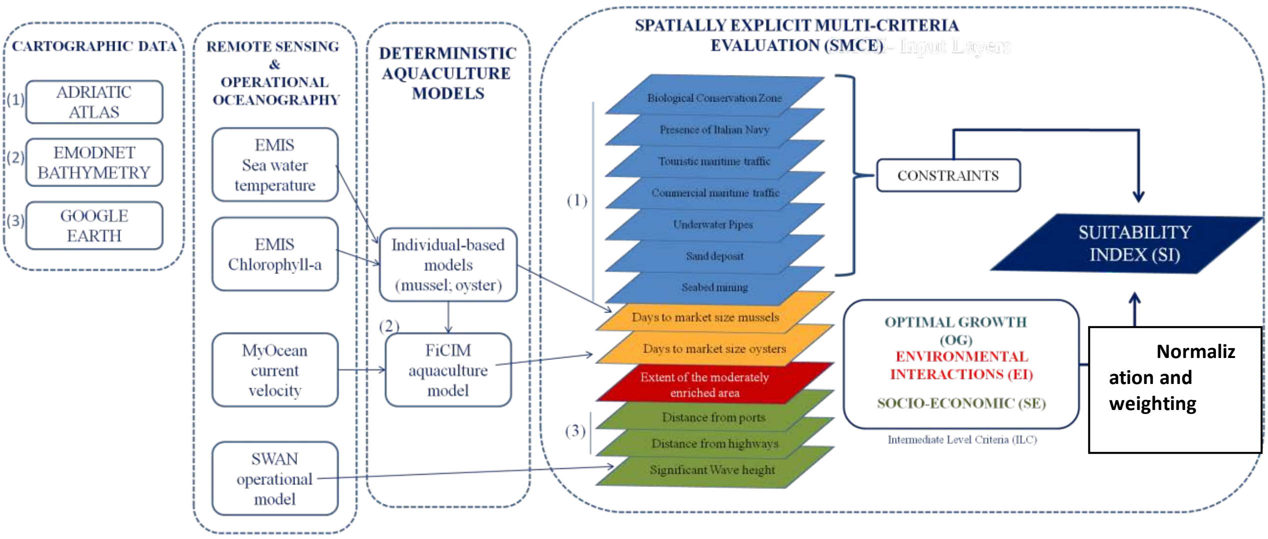
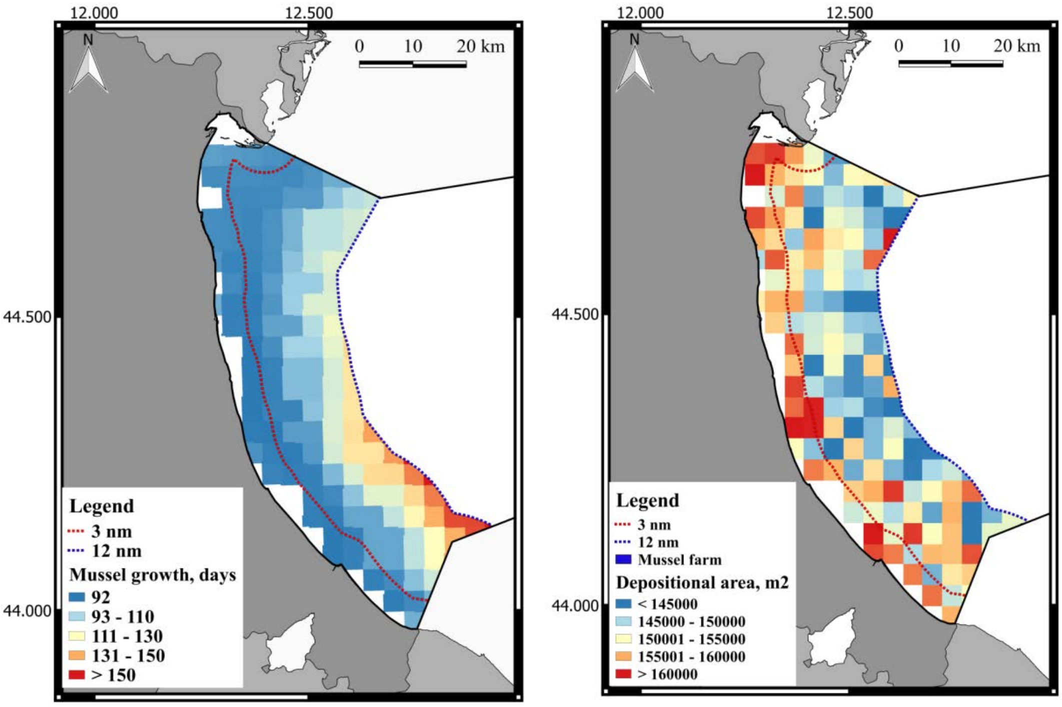


Figure 2.3 Visual representation of the application of the Bluefarm 2 tool to the Italian Aquaspace case study.

In particular, productivity criteria, collectively labeled "Optimal Growth" in Figure 2.3, are based on an indicator of potential biomass yield, i.e. days to reach market size, which was computed using bioenergetic models for the two shellfish species. Bluefarm made these models freely available as R codes: the package (RAC) can be downloaded from: https://cran.r-project.org/package=RAC. The Environmental impact criterion was assessed using the model FiCIM (Fish Cage Integrated Model) (Brigolin et al. 2014, Brigolin et al. 2015) which was customised to simulate the organic deposition of mussel pseudo-faeces on the seabed. Significant wave height was taken as a proxy of the risk of harvest losses due to storm events: data, based on the SWAN model, were provided for free by ARPAE, the Environmental Protection Agency of Regione Emilia Romagna. Constraints were downloaded from the ADRIPLAN (http://data.adriplan.eu/) and SHAPE (http://www.shape-ipaproject.eu/) data portals.



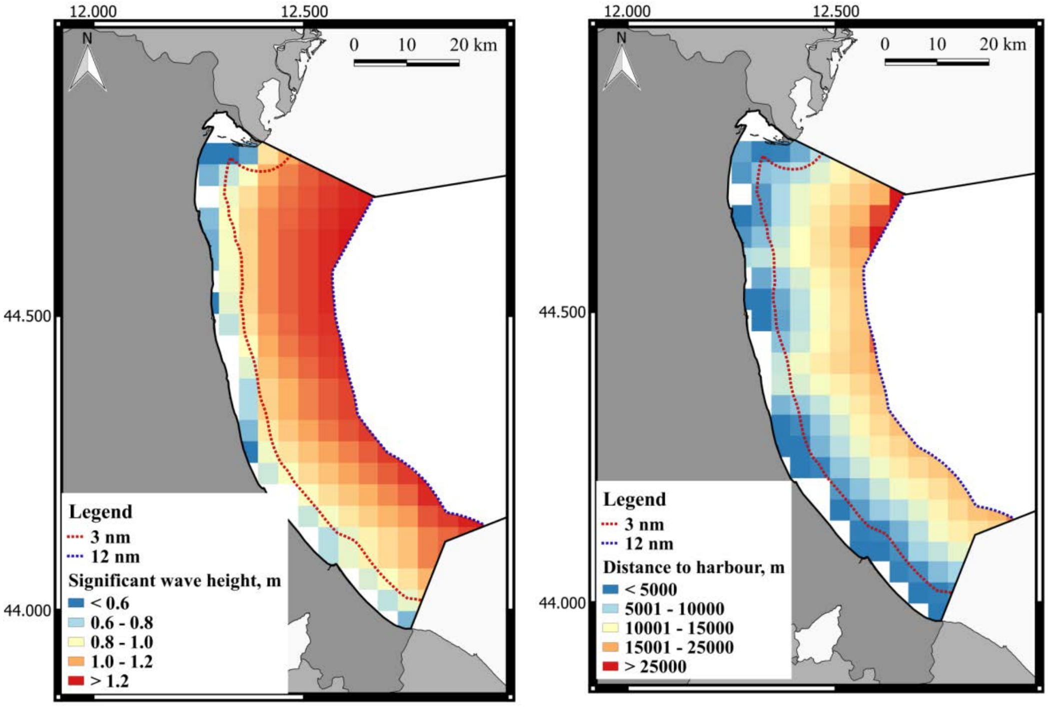


Figure 2.4. Maps of relevant criteria used for assessing mussel farming suitability: 1) Days to reach market size (top-left), 2) Impact of bio-deposition on the seabed (top-right); 3) Risk of harvest loss due to storm events (bottom-left); 4) Distance to landing ports (bottom-right).

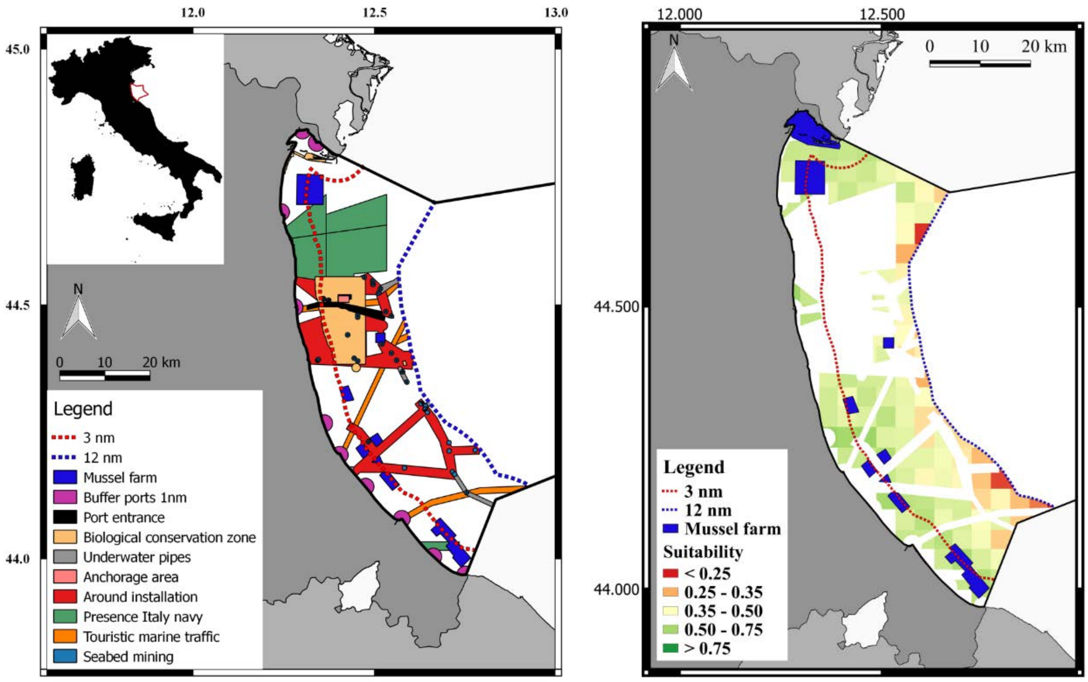


Figure 2.5. Results of the application of "Bluefarm 2" to the case study: 1) spatial constraints to the expansion of mussel farming due to use conflicts (left), 2) suitability map for mussel farming: blue areas are already leased to mussel farmers.

The results are summarised in Figure 2.4, which presents, as an example, the most relevant information layers concerning the mussel farming suitability criteria, and Figure 2.5, which shows the constraints and the final suitability maps, obtained by aggregating the criteria and overlapping the constraints. As one can see, the indicator of mussel productivity suggests that up to about 6 nm from the shore the potential biomass yield is similar along the whole coastal area, where, on average, a specimen would take approximately 4 months to reach a market size of 5cm. Furthermore, the impact on the seabed decreases with the distance from the shore. However, moving away from the shore would increase both the risk of harvest loss due to storm events and the distance from landing ports, which, in turn, leads to increased energy costs and CO_2 emissions (Lourguoi et al. 2017). As a result, the final suitability map, on one hand, shows that there is still significant potential to expand mussel culture between 3 and approximately 6 nm, with potential production similar to that of the mussel farms currently operating on the edge of the 3 nm, as shown in Figure 2.5. This finding could support the implementation of Japanese long-lines in the region, which would lead to both a reduction of cost for farmers and of macro-plastic waste released accidentally to the environment.

2.6. Application of tools

The results shown in the previous section suggest that it is feasible and cost-efficient to use publicly available geo-referenced data and information for supporting the inclusion of aquaculture activities in the implementation process of the EU’s MSP Directive (2014/89/EU).

The tool applied to this case study, namely "Bluefarm 2", is based on a transparent procedure, through which the above information, is post processed whenever necessary using simulation models and converted into maps. In this specific application, there were no particular difficulties with input data. Emilia Romagna authorities and agencies fully cooperated, for example, in providing free comprehensive data sets concerning significant wave height, which was used to estimate a proxy of harvest loss risk. Furthermore, most data were available from EU services, such as the Copernicus Marine Service, and data portal produced under other EU funded projects, such as SHAPE and ADRIPLAN. We, as Bluefarm, added to that the capacity of converting the initial spatial layers into indicators useful for a suitability assessment of shellfish farming. However, spatial information layers, though valuable "per se", can be regarded as input to the "Bluefarm 2" tool: in order to produce the output, i.e. the suitability of these layers have to be normalised and "weighted", i.e. ranked in relation to their relevance, which could be different for each stakeholder category. As this last step can greatly affect the output, weights should be assigned through a participatory process, in which different "suitability scenarios" could be discussed and evaluated by farmers, investors, regulators, representatives from other sectors involved in use conflicts. In Aquaspace we did not go that far: the weights used for producing the suitability maps are, in fact, based on our "educated guess". However, once the information layers have been collected and archived in a GIS environment, such a process is technically feasible and its computational cost is very limited, thus allowing real-time creation and discussion of suitability scenarios. In this regard, the Q-GIS plug-in, which Bluefarm will make available free of charge, could support public authorities in carrying out this type of exercise.

2.7. *Relevance of the case study within Aquaspace*

Europe imports a large amount of seafood, including shellfish, which means that there is scope for growth of shellfish farming, provided such an increase in EU production is accompanied with adequate marketing strategies. Reducing the time required for getting licenses and selecting appropriate sites using science-based site selection tools represent desirable mandatory steps towards the further development of this non-fed and environmentally-friendly type of aquaculture: we therefore feel that our case study provides convincing evidence that supporting a science-based process of shellfish AZA identification is presently feasible and cost-effective, through the harvesting of publicly available data and the conversion of such data into spatial layers concerning relevant indicators and criteria for suitability assessment. The Multi Criteria approach, which is at the core of the "Bluefarm 2" tool, allows one to structure the flow of information in a transparent manner and to involve stakeholders in the analysis of suitability scenarios: this feature is very relevant for the implementation of the MSP Directive, which explicitly requires a participatory approach. Of course, the results can be improved both by using site-specific data concerning, for example, hydrodynamic circulation and including more socio-economic information layers, which could better address the requirements of farmers and investors.

2.8. *Conclusions and future prospects*

In accordance with the stakeholder engagement strategy outlined in Section 3, we are still currently presenting the results outlined in section 5 to regulators. A first meeting was held in March 2017 in Bologna, at the Regione Emilia Romagna premises. The meeting was organised under the national flagship project "RITMARE", (http://www.ritmare.it/), coordinated by the Italian National Research Council (CNR). We were invited by CNR colleagues to present our main findings to public officers involved in MSP. The outcome of the meeting was very positive and, as a follow up, we are now undertaking a joint effort with CNR-ISMAR (Istituto di Scienze Marine - Institute of Marine Sciences) colleagues, aimed at improving the results, in terms of spatial resolution, use of site specific hydrodynamic data and inclusion of layers concerning potential synergies with other activities, i.e. seabed mining and conflicts with fisheries. This is a first, concrete step towards the exploitation of the Aquaspace results in the Italian context. Bluefarm associates have also been invited by ISPRA, (Istituto Superiore per la Ricerca e la Protezione Ambientale - Higher Institute for Research and Protection of the Environment) to join a platform, called "ITAQUA", for supporting the Italian authorities involved in the implementation of MSP as well as farmers and investors who may wish to start new businesses in the shellfish industry in the area by providing science-based tools for allocating new leased areas along the Adriatic coast line or re-allocating existing farms with different farming technologies.

It can be a tool for decision makers: Results can support science-based design of Allocated Zones for Aquaculture (AZAs) in order to avoid conflicts, and promote sustainable aquaculture in the Mediterranean Sea, where the space for these activities is becoming increasingly limited.

We are planning to have a stakeholder meeting in the autumn 2017, in order to present the results of the application of the Aquaspace tools i.e. Bluefarm 2 and, if possible, ECBA,, with a focus on the Italian case study. This should provide: 1) feedback to refine the tools developed and tested in our case study; 2) an assessment of the tools by potential end users.

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3. ALGARVE COAST, PORTUGAL

John Icely and Bruno Fragoso

3.1. General characteristics

The Algarve is an administrative region located along the southern coast of Portugal (Figure 3.1), with an extensive coastline adjacent to the Atlantic (Turismo de Portugal 2014). This region has traditionally been the most productive region for aquaculture, with fish and shellfish cultured in extensive and semi-intensive systems in sheltered lagoons and estuaries. However, to contribute to the better use of the Portuguese Exclusive Economic Zone, the government has declared aquaculture as a priority sector for development, with particular emphasis on concessions, where investors can obtain licenses to set up offshore aquaculture for fish and/or shellfish. With this effort to promote aquaculture, the objective is that total production doubles to 20,000 tonnes by 2020. As there is only limited space for expansion in the inland waters, this Case Study will focus on the recent expansion of offshore aquaculture along the Algarve coast.

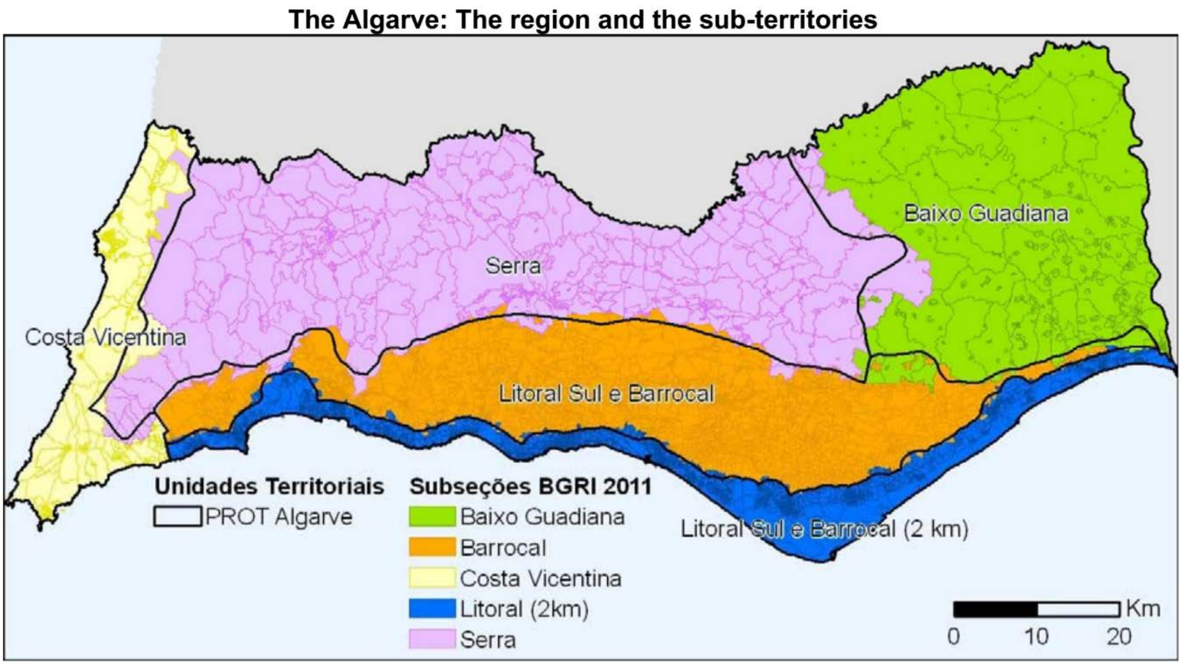


Figure 3.1. Algarve region and sub-territories (source: http://s3platform.jrc.ec.europa.eu/documents/ 20182/92074/ALGARVE+REGIONv2.pdf/8cf33c4e-a4b0-41ff-87d5-39274e3c59d6)

Portugal developed a National Strategy for the Sea between 2013 and 2020 (Governo Portugal, 2013 http://www.dgpm.mam.gov.pt/Documents/ENM.pdf) that takes into account Maritime Spatial

Planning (MSP) (http://www.msp-platform.eu/countries/portugal) to address the following maritime activities:

- Natural Living Resources:
  - Fisheries
  - Aquaculture
- Natural Non-Living Resources
  - Mineral extraction
  - Offshore renewable energy production
- Infrastructure uses and activities:
  - Ports
  - Tourism
  - Shipping
- Other current uses: marine biotechnology, coastal defence

Initially, the MSP plan for Portugal (http://www.msp-platform.eu) was only a pilot plan, but on the 10 April 2014, Decree-law No. 17/2014 was approved to define the political basis for a new and simplified approach to "marine spatial planning and management' for all the Portuguese maritime space, including the continental shelf beyond 200 nautical miles.

On 12 March 2015 a supplementary law, Decree-law No. 38/2015), was implemented to define the legal mechanisms for maritime spatial planning instrument and to define how private citizens may utilise maritime space. With regard to the implementation of this law, a framework for the Planning and Management of the National Maritime Space was developed based on a study for Planning and Organising Maritime Space (POEM, 2012). Thus in 2015, Order No. 11494/2015 was the start of Portuguese MSP, where the competent authorities were identified for preparing and supporting the process. This date is not long after the EU adopted the Maritime Spatial Planning Directive (2014/89/EU). The European Commission (2014) stated that "for the implementation of Maritime Spatial Planning it is imperative to consider the economic, social and environmental aspects to support sustainable development and growth in the maritime sector, applying an ecosystem based approach, and to promote the coexistence of relevant activities and uses''

3.1.1. *A description of the geographical and biological context*

The Algarve occupies 5.4% of the total area of the national territory, and from its exposure to the Atlantic Ocean on its western and southern border, it borders the Alentejo region to the north and the Guadiana River to the east, separating the Algarve from the Spanish Community of Andalusia (Turismo de Portugal, 2014). It has 160 km of coast, with fishing as one of the main economic resources; indeed, historically it was probably one of the first human activities in this region. The Algarve has important advantages for the fishing sector, with a wide range of available resources, an important fleet and a population with a substantial appetite for seafood. With this extensive experience in fisheries and the productive coastal waters, it is suggested that the conditions for mollusc and finfish aquaculture are good (CCDRAlg 2005).

In terms of the EU Water Framework Directive, the Algarve coast is classified as a mesotidal, moderately exposed Atlantic coastal type (Bettencourt et al. 2004). The Algarve coast is affected by seasonal upwelling induced by northerly winds, the cold upwelled waters of the west coast apparently turn around Cape São Vicente and then flow eastward along the shelf break, although the same pattern could be generated by shelf edge upwelling (see references in Goela et al. 2016). During particularly strong northwest wind events, upwelled waters are observed to cover the whole Algarve shelf and then proceed offshore from near the mouth of the Guadiana River at the Spanish-Portuguese border, again following the shelf edge of the Gulf of Cadiz. During the down-welling, a coastal counter-current transports warm surface waters to the west, eventually reaching Cape São Vicente, and even proceeding northward along the west coast when winds reverse to the south (Fiúza 1983) from May to September. In summary, upwelling events can supply nutrient rich water resulting in high primary productivity, contributing to a commercially valuable fishery as well as bivalve aquaculture.

3.1.2. *Socio economic context*

The Algarve has a resident population of 451,006 people, representing only 4.3% of the national population (INE, 2012). During the summer months, due to tourism the population triples to near 1.5 million people. There is an increasing effort in the Algarve to provide services for tourism, which continues to increase with a significant impact on the national economy. The services represent 80.3% of the total employment in the Algarve, industry 6.3%, construction 9.8% and agriculture 3.3%. In 2010, it is estimated that the Algarve contributed €7.2 million to the national GDP, a value near 4.2% of the national total (Turismo de Portugal, 2014).

Relating specifically to aquaculture, employment in 2011, represented 2,316 direct jobs where 18% were women, and with only five companies employing more than 10 people. Most of the workers have low qualifications and work within a family business, but there are also a considerable number of people with higher education (university level). The national production of aquaculture in 2012 only contributed 5.4% (10,317t) to the total seafood landings, and therefore cannot yet be considered an alternative to the traditional fisheries sector (DGRM, 2015).

3.2. Spatial planning and management issues

3.2.1. *What aquaculture species, types and systems exist in the area*

Traditional Portuguese aquaculture is land-based, characterised mainly by marine extensive and semi-intensive systems located in lagoons, estuaries and intertidal areas along the coast (Ramalho and Dinis 2011). The main species produced are shellfish - clams, oysters, mussels, and fish - turbot, seabream and seabass. Bivalve aquaculture is still the most important form of aquaculture in the Algarve; fish produced in ponds represent only 9.2%. Most of the bivalve aquaculture sites are located within the Ria Formosa lagoon, where extensive aquaculture represents 88% of the total production. The cross-cut carpet clam, or the “good clam” in Portuguese, (*Ruditapes decussatus*) is the main species produced (Figure 3.2, left window), but mussel production has doubled from 2012 to 2013 with a total 1,547 tonnes, mostly due to recent offshore installations (INE, 2016). The Ria de Alvor also contributes to the production of bivalve clams and oysters, and finfish, seabass and seabream (APA, 2014). Along the Algarve coast, there are an increasing number of offshore concessions, with the first offshore longlines installed in Sagres in the late 1980s (Figure 3.2, right window) with the main purpose of growing scallops followed by Pacific oysters (*Crassostrea gigas*).

Aquaculture activities related to mollusc culture in inland waters are mainly for clams and oysters (e.g. *Ruditapes decussatus, Venerupis decussata, Venerupis pullastra*). A small proportion is retained for domestic consumption with the majority exported. Longlines for mussel culture (*Mytilus spp*.) is a more recent activity and production is mostly for export, as there is low domestic demand for this species. Finfish culture (e.g. *Sparus aurata, Dicentrarchus labrax, Solea senegalensis, Diplodus sargus, Anguilla anguilla*) using extensive rearing systems still occurs in inland waters, but it is mainly a subsistence activity with cultured fish destined for domestic consumption. Fish culture in ponds using semi-intensive rearing systems is still small scale, with some firms recently terminating their business (Bolman et al. 2011).

Although the Ria Formosa lagoon is a National Park, it is also the largest aquaculture site in southern Portugal, hosting more than 50% of the total bivalve culture production in Portugal. Most of the intertidal zone within the Ria Formosa is licensed to individuals and small firms for clam culture by clam farms, producing a yield of about 8000 tonnes of total fresh weight per year (Bolman and Bogaardt 2011). Apart from aquaculture, the Ria is also used for tourism, extraction of salt and sand, and fisheries.

For the purposes of the Algarve Case Study, there is a focus on offshore aquaculture as there is only limited space for expansion in inland waters. Furthermore, the Portuguese government has defined aquaculture as a priority sector for development (Governo Portugal 2013). Recently, there has been an effort to pre-establish areas for offshore aquaculture, and reduce the licensing time for new investments (Figures 3.3 and 3.4).

Figure 3.2. Aquaculture systems in the Algarve, removing seaweed in traditional clam aquaculture in Ria Formosa (left), offshore aquaculture for oysters at Sagres (SW Portugal) (right).

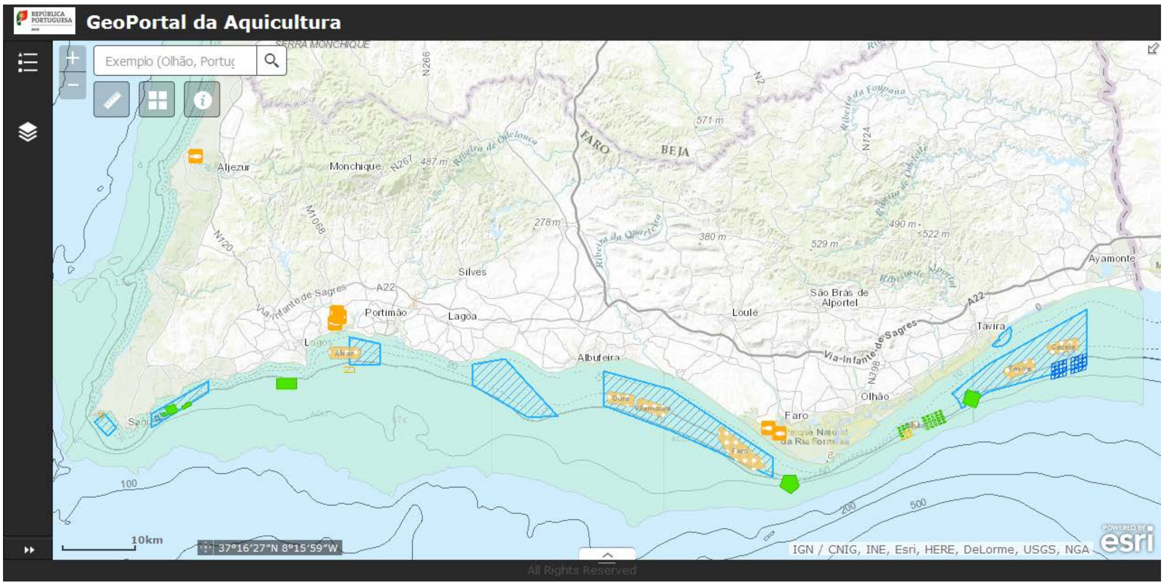


Figure 3.3. Map of the Algarve region showing the current aquaculture sites (green and orange) and the potential future areas (blue boxes) (source: http://eaquicultura.pt/navegue-pelo-mapa-da-aquicultura-em-portugal/)

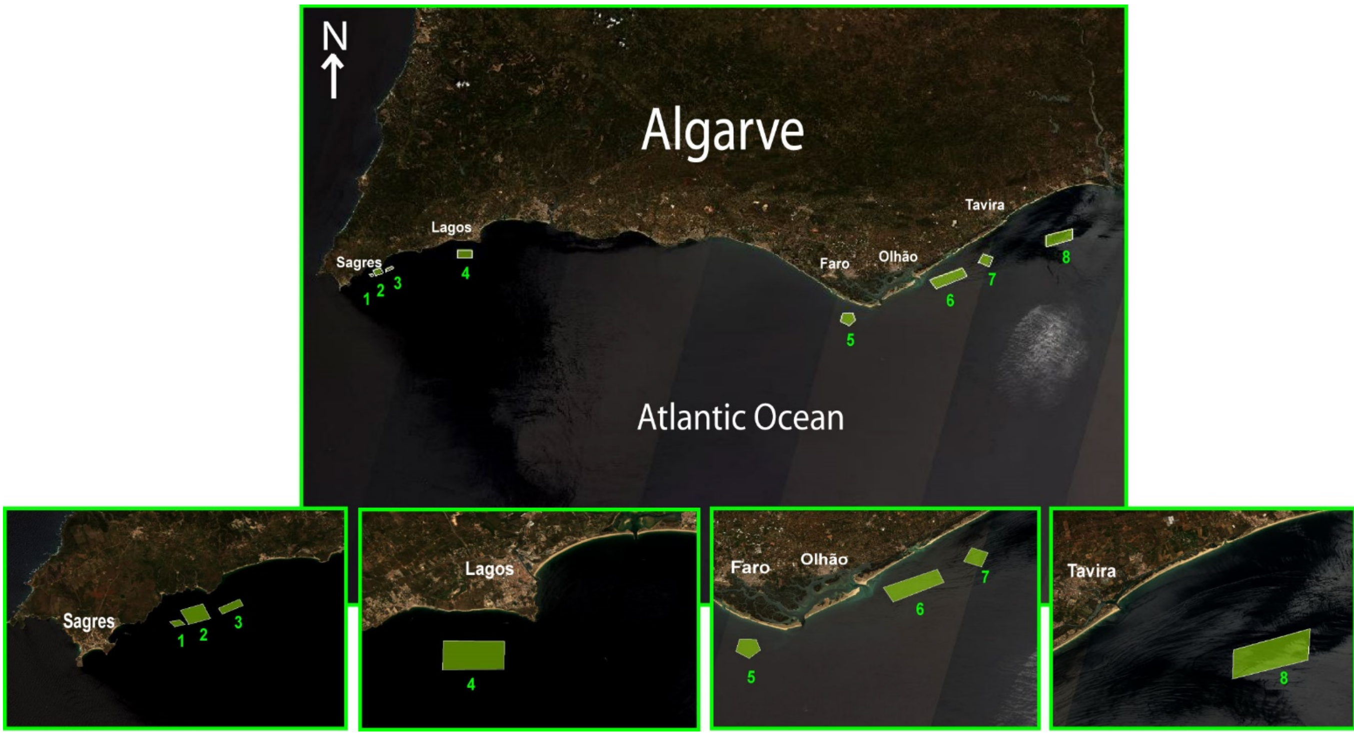


Figure 3.4. Sentinel-2 satellite images with the locations of the current operational offshore aquaculture concessions along the South coast of Portugal. The numbers correspond to specific concessions: 1 and 3, Aquasacrum; 2; Finisterra; 4, Testa & Cunha; 5, IPMA fish farm pilot station off Olhão; 6, APA Armona; 7, Companhia das Pescarias do Algarve; 8, APA Tavira. (adapted from http://eaquicultura.pt/navegue-pelo-mapa-da-aquicultura-em-portugal/)

3.2.2. *Spatial structure and management issues*

Along the Algarve coast, there is potential for conflict between the aquaculture industry and other activities. Some of these potential conflicts for the Algarve and, in particular for the Ria Formosa lagoon, were described in the COEXIST project (www.coexistproject.eu***).***

- Co-location of aquaculture with designated conservation and tourism areas.
- Offshore aquaculture and fisheries in the same areas (the presence of the aquaculture plots excludes some types of fishing).
- Recreational boating and ships can change sediment properties and have detrimental consequences for aquaculture activities and species.
- Bivalve fishing/gathering closures due to the detection of seasonal toxins and consequent preventative measures taken to avoid health risks are not well accepted by some producers.

The interactions between Fisheries and Aquaculture and other relevant activities within the Ria Formosa lagoon coastal area, as identified in the COEXIST project, are shown in Figure 3.5. In this area, there is conflict between sand extraction and bottom fishing. Where sand extraction occurs, clam dredging and bottom trawling are forbidden. There is also a conflict between cable laying and bottom fishing. Where there are cables, clam dredging and bottom fishing gear (e.g. bottom trawling and bottom purse seining) is forbidden. Shellfish gatherers that have clam and oyster beds are sometimes inconvenienced with dredging and cabling/piping works, because they may disturb the sediment beds where molluscs are produced. Fish aquaculture operators also claim that shell and sand extraction impoverishes water quality, due to turbidity and the suspension of solids. Tourism, namely ordinary tourists using coastal waters for swimming or bathing, may also complain if there are dredgers nearby, which can occur, albeit rarely. The same applies for land-based anglers that use beaches where people go swimming or bathing. Land based anglers also claim they have the right to fish in ponds and rivers used for other activities. Diving operators that take their clientele for tourist SCUBA diving purposes may also complain if certain marine features appear destroyed or damaged due to irregular diving, fishing, or other human activities (Bolman et al. 2011). Tourism brings some disturbance especially during the summer season due to a significant increase in numbers of people using coastal areas (Jongbloed et al. 2011). These examples of conflict reflect those occurring along the rest of the Algarve coast.

Recent developments in management issues related to MSP and aquaculture in the Algarve are highlighted in the following sections of the Algarve Case Study based on tools used for the case study, the outcomes of stakeholder engagement and participation and how this information has provided knowledge for the section on case study results.

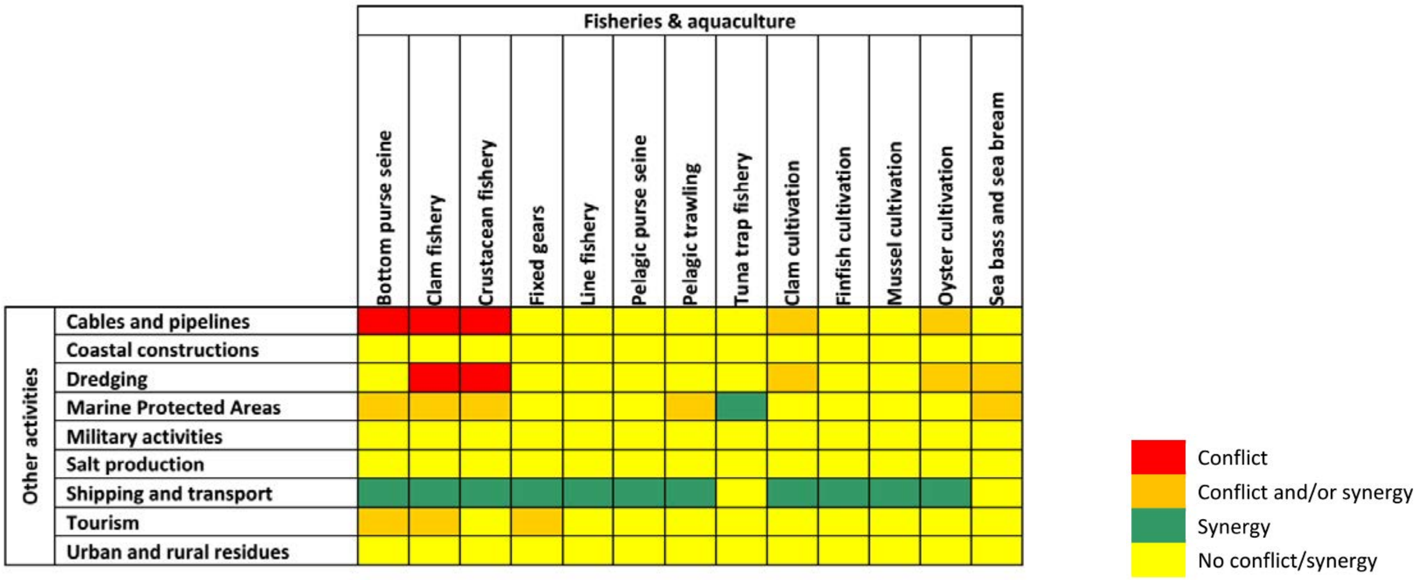


Figure 3.5. Interaction between Fisheries & Aquaculture and other activities (Bolman et al, 2011).

3.3. Tools used in the case study

As is clear from the previous sections, the Portuguese government has embraced the concept of MSP and has started to implement tools such Geographical Information Systems (GIS) to define areas that would be suitable for aquaculture (see Figs, 3,4). Based on the programme before 2014, the Portuguese Government carried out a SWOT analysis to assess the strengths weaknesses, opportunities and threats for their new 2014-2020 programme to support aquaculture, particularly, offshore aquaculture (Governo Portugal, 2014). This analysis is presented in Table 3.1.

3.4. Application of tools

Sagremarisco is collaborating with the company Bluefarm, an AquaSpace partner from Italy, Venice, to try out their approach to space allocation for offshore aquaculture combining remote sensing images with modelling. Sagremarisco is open to applying other tools that are relevant to the Case Study where the space for offshore aquaculture has already been predefined by government (e.g. Figure 3.4).

The most important and effective tool in this Case Study has been the direct interaction with stakeholders; information obtained from them, either formally through a questionnaire or informally through personal contact, and their attendance at meetings with representatives responsible for governance of aquaculture in Portugal and representatives of the Algarve aquaculture industry (see section below).

Table 3.1. SWOT Analysis adapted from 'Plano Estratégico Nacional para Pesca 2007 – 2013' (MADRP – DGPA, 2007).

"Internal" to Portugal	
Strengths	**Weaknesses**
• Existence of favourable conditions for aquaculture development • Skills relating to the cultivation of species are well adapted to the natural conditions • Potential to increase production of high quality and valued species. • Availability of qualified workforce • Can differentiate between the quality of products through different production methods and certification • Existence of scientific knowledge and technologies to support innovative and productive sectors.	• Level of planning for implementation of aquaculture and other activities offshore is limited • Licence duration is too short • Long and difficult licensing process • Activity perceived as high risk with a limited insurance cover • Insufficient self-funding capacity by the companies • Low levels of cooperation between farmers and the processing industry • Lack of consumer information on aquaculture products • Insufficient nurseries for the reproduction of marine species
"External" to Portugal	
Opportunities	**Threats**
• Existence of a National and European market with a deficit in seafood production and a growing level of consumption • Possibility of installing offshore concessions which can be combined with other activities. • Interest of consumers in certified products • EU commitment to developing the aquaculture sector • Portugal has the technology and human resources with the potential for innovation and adding valuing through its human resources • Collaboration with the industry to improve public acceptance of aquaculture products	• High competition from third countries • Conflicts of interest in areas with aquaculture potential • Increasing costs in production items, like energy and feed. • Probability of occurrence of pollution events or sporadic reduction of water quality due to climatic events • Difficulties in obtaining funding due to the highly precautionary evaluations from funding institutions

3.5. *Stakeholder engagement and participation*

Tables 3.2 and 3.3 show the contacts that have been made with aquaculture stakeholders by Sagremarisco, with Table 2 listing the people[1] that were spoken to at the 10th Aquaculture Seminar organised by APA (the Portuguese Association for Aquaculture Producers) in Setubal on 29th April 2016 reflecting producers, government ministers, government officials, scientists, and company representatives (audience approx. 100). A questionnaire was distributed to 40 people; although only nine were completed, a substantial amount of informal information was obtained via discussions with the 40 people given the questionnaires. The results from the questionnaire are presented in Deliverable 4.1 of the Aquaspace project, Annex 1 (Bergh et al, 2016). The questionnaire is divided into four different sections with a total of 16 questions. Part I relates to policy, norms, regulations and institutional issues; Part II to aquaculture and the environment; Part III to aquaculture and other uses/sectors; and Part IV relates to aquaculture and socio-economical aspects.

Since the APA meeting in April 2016, further stakeholder engagement has occurred and are described below and summarised in Table 3.3.

29th June 2016

- Meeting at DRAP Algarve (Regional Directorate for Agriculture and Fisheries), Patacão, Algarve, Portugal
- Stakeholders: Representatives of the DGRM (General Directorate of Natural Resources and Maritime Security), APA (Portuguese Environmental Agency), DGAV (General Directorate for Veterinary and Food Security) and IPMA (Portuguese Institute for Sea and Atmosphere) and Producers (40 attendees).
- This workshop aimed at providing information from the governmental entities to the industry, both the inshore and offshore producers of bivalves, about the exceptional mortality of oysters, clams and cockles that occurred, particularly, in the Ria Alvor along the Algarve Coast during the Autumn 2015. Important information on the responsibilities of these legal entities, demonstrated limitations to understanding and solving serious issues such as this exceptional mortality of bivalves at the Ria Alvor and adjacent offshore areas in 2015.
-

29th July 2016

- Meeting at DRAP Algarve (Regional Directorate for Agriculture and Fisheries), Patacão, Algarve, Portugal
- Stakeholders: Representatives of DGAV (General Directorate for Veterinary and Food Security)
- Interview with the DGAV provided detailed information about the licensing process and governance of aquaculture activities in Portugal. This interview provided the factual information supported by copies of the legal documents (*Decretos- lei*) of how aquaculture is licensed and subsequently managed (governed) in Portugal. There was also clarification about the governance hierarchy between the different institutions involved in the licensing process. This could change depending on what licenses a producer requires; but to give an idea of the number of licenses that a producer could need, Finisterra Lda, who have an offshore concession and an onshore processing facility for bivalves, hold 42 licenses at present and still require one or two more!

Table 3.2. Stakeholders contacted in the APA meeting at Setúbal, April 2016

Name	Institution	Stakeholder
[redacted]	CIIMAR	Scientist
[redacted]	Xylem	Equipment support
[redacted]	U. of Aveiro	Scientist
[redacted]	Bivalvia	Shellfish producer (Algarve)
[redacted]	Ostraselect Algarve Lda	Shellfish producer (Algarve)
[redacted]	CIIMAR	Scientist
[redacted]	U. of Aveiro	Scientist
[redacted]	Leya	
[redacted]	Materaqua	Producer
[redacted]	FCT/UNL	Scientist
[redacted]	IMAR (MARE)	Scientist
[redacted]	IMAR (MARE)	Scientist
[redacted]	Safiestela	Fish producer
[redacted]	Quinta do Salmão lda	Fish producer (trout)
[redacted]		Aquaculture manager
[redacted]	Vale de Lama	Fish producer (Algarve)
[redacted]	Canal do Peixe	Fish producer (Ria Aveiro)
[redacted]	Aquasacrum	Shellfish producer (Algarve)
[redacted]	Mirabilis lda	Scientist
[redacted]	Sec. Estado Pescas	Government
[redacted]	Puromar	Shellfish producer (Algarve)
[redacted]	Mousquetaires	Intermarché / Programa Origens
[redacted]	HIPRA	Veterinary
[redacted]	Aquasacrum	Shellfish producer (Algarve)
[redacted]	Jornal Economia do Mar	Journalist
[redacted]	DGAV	Government veterinary services
[redacted]	DGAV	Government veterinary services
[redacted]	U. of Aveiro	Scientist (labelling origins)
[redacted]	Docapesca	Administrator
[redacted]	Stolt Sea Farm	Trout producer
[redacted]	IMAR (MARE)	Scientist
[redacted]	IPMA	Scientist
[redacted]	IPMA	Scientist
[redacted]	FF Aveiro	Farmer
[redacted]	FF Setubal	Farmer
[redacted]	F de Medicina Veterinaria	Scientist
[redacted]	Secretary of State for the Sea	Government
[redacted]	Associação Portuguesa de Aquacultores (APA)	General Secretary of APA
[redacted]	Coopformosa	Coop viveiristas Ria Formosa

Individual names cannot be listed due to data protection and privacy restrictions.

22nd July 2016

- Meeting at Alvor, Algarve, Portugal
- Stakeholders: Bivalve producer in the Ria de Alvor
- Interview concerning his specific problems with bivalve culture at this location. Apart from the mortality which has fortunately been somewhat limited for him, he has several issues with licensing and subsequent monitoring activities with the governing institutions.

4th August 2016

- Meeting at Lagos, Algarve, Portugal
- Stakeholders: Offshore Aquaculture manager/consultant (Aquasacrum)
- Personal interview with the consultant /manager of Aquasacrum, one of the biggest investors in bivalve aquaculture in the Algarve. His comments are similar to those of the producer interviewed from the Ria Alvor. Aquasacrum was one of the companies who experienced substantial oyster mortality in Autumn 2015. It is notable that they sent samples to a laboratory that specialised in bivalve diseases: they received identification of what caused the mortality, but this was not acknowledged by the official Portuguese institutions.

Stakeholders: Finisterra SA

- Sagres, Algarve, Portugal

  Regular contact with the owners of Finisterra S.A. has provided detailed information of the day to day issues affecting the use and management of a 60 hectare, offshore concession area for mussel culture. One of the overarching issues is the slow response time of the State institution responsible for monitoring toxic algae (HABs), which has substantial economic consequences for the company

Table 3.3. Stakeholders contacted since the APA meeting in April 2016

Date	Name	Institution	Stakeholder
29th June 2016	[redacted]	DGRM	Regional Directorate for Agriculture and Fisheries
	[redacted]	APA	Portuguese Environmental Agency
	[redacted]	IPMA	Portuguese Institute for Sea and Atmosphere
	[redacted]	DGAV	General Directorate for Veterinary and Food Security
29th July 2016	[redacted]	DGRM	Regional Directorate for Agriculture and Fisheries
	[redacted]	DGAV	General Directorate for Veterinary and Food Security
22nd July 2016	[redacted]	Private individual	Investor/Producer in Ria de Alvor
4th August 2016	[redacted]	Aquasacrum	Aquaculture manager
Ongoing contact	[redacted]	Finisterra SA	Producer

Based on the feedback from stakeholders, the concerns were mainly:

- Licensing procedures;
- Closures of economic activity due to toxins from HABs;
- Severe economic losses due to disease;
- Difficulties in coping with sanitary and environmental monitoring as the rules keep changing;
- Low return on investment;
- Lack of financial instruments and insurance.

The concerns about licensing procedures, closures of commercial activities due to toxins from Harmful Algal Blooms (HABs), and problems related to disease are discussed further in the section below on case study results.

3.6. Case study results

The information provided for this section includes background data obtained from government and media sources, followed by information obtained via stakeholder engagement and participation.

3.6.1. *Statistics for production*

Bivalves represent 45% of total production where the principle species is 2,251 tonnes of the clams (*Ruditapes decussata*), the secondary species is 1,547 tonnes of mussels and the tertiary species is 1,085 tonnes of oysters. In 2014, there was a total of 1,521 licensed production establishments with only 2.1% corresponding to the floating structures that are normally associated with the production of bivalves (INE, 2016). The statistics for aquaculture production need to be improved in Portugal. This aspect was identified by the Secretary for State from the Ministry of the Sea, at the 12th APA symposium in Setubal in May 2017 and appealed to aquaculture producers to try to provide accurate and timely statistics on their production.

3.6.2. *Aquaculture development trends*

In 2005, the contribution of aquaculture products to the total production of the fishing sector in Portugal was limited with only 7000 tonnes (MADRP– DGPA, 2007). Portuguese production levels have stagnated during the last decade, with figures ranging between 7,000-8,000 tonnes, which constitutes a meagre 0.51% of European aquaculture (Ramalho and Dinis 2011). The production from aquaculture in Portugal in 2014 reached 10,791 tonnes with a total value of €50.3 million. Compared to 2013, there has been an increase of 7.2% in production but there was a decrease of 8.2% in total value. In the Algarve, there is not much potential to increase production on the intertidal areas of Ria Formosa and Ria de Alvor, due to space limitations, and environmental constraints, so it is expected that the recent offshore concessions can contribute significantly to an increase of production especially for mussels (*Mytilus galloprovinciallis*), oysters (*Crassostrea gigas, Crassostrea angulata, Ostrea edulis*) and possibly scallops (*Chlamis sp* and *Pecten sp*).

The diversification of species for farming and innovation are also key aspects to boost aquaculture. Aquaculture-related research done at University of Algarve and at IPMA is now available for farmers with complete production cycles for sole, meagre, and other finfish. Applied research has been carried out for aquaculture of molluscs, like cuttlefish and octopus, as well as for sea cucumbers, and it is expected that there will soon be caviar from sturgeon produced in the Algarve, resulting from a spin-off company (Caviar Portugal) from the University of Algarve.

3.6.3. ***Industry investment analysis***

As a contribution to the national strategy, the PROMAR programme (Operational Programme for Sea 2007-2013) has paid €10,319,396 million for a total investment of €17,198,993 million in 34 aquaculture projects in the Algarve up to 2014. The next funding programme is designated the MAR2020 programme (Operational Programme for Sea 2014-2020, funded from the EU) and it will have €78.6 million available for projects for the fishing sector including aquaculture. Additionally, there will be €27 million available for measures relating to sustainable aquaculture development. Along the Algarve coast several investments have been completed, primarily targeted at bivalve production in offshore systems. Approximately €11,900,000 have been granted to 13 enterprises with an investment over €50,000 per enterprise between 2007-2013 (Table 3.4). Some examples of the largest areas are shown in Figure 3.2 and 3.3.

Compared to clams and oysters, mussels (*Mytilus galloprovincialis*) have only recently been considered for aquaculture in Portugal, probably due to their low market value. However, the move to offshore areas has encouraged expansion in the production of this species (Kaas et al, 2015). Table 3.4 shows the investment in offshore aquaculture co-funded by PROMAR in the Algarve region up to January, 2014; covering investments in five different municipalities along the Algarve coast The production areas are mostly focused on bivalves, mussels and oysters, with an expected production of 7,240 tonnes and 2,405 tons, respectively. Other investment includes capture and fattening of wild tuna, with an expected production of 4,760 tonnes. The Algarve has a long and historical tradition of capturing tuna that enters and leaves the Mediterranean Sea for spawning, with fixed nets, and where they are kept and feed to achieve a high fat content to supply the market demand for sushi. The animals are slaughtered when necessary and when the quota is reached they have to release the remaining surplus animals into the wild.

Table 3.4. Portuguese companies or individuals that received a 60% subsidy from the EU between 2007-2013 for aquaculture projects.

LOCATION	No of entities	Subsidy paid out	Total investment
Continental	57	12 779 685€	21 299 475€
Algarve	34	10 319 396€	17 198 993€
Bivalves >50000 €	13	7 119 752€	11 866 253€
Fish > 50000€	6	2 976 432€	4 960 720€

Table 3.5. Offshore aquaculture investments co-funded by PROMAR in the Algarve region (until January 2014) (source: Guedes Soares & Santos 2014)

			PRODUCTION							
Municipality (place of investment)	Total investment (euros)	Execution (current status)	Area (m²)	Mussels (tons)	Oysters (tons)	Other species of bivalve molluscs (tons)	Bluefin tuna (tons)	Gilthead seabream (tons)	European seabass (tons)	Other species of fish (tons)
Faro	2031636	Concluded	4009				2380			
Olhão	909430	Concluded	480000	450	300	10				
Olhão	1048935	Concluded	480000	550	200	10				
Olhão	2237286	On going	376200	1990						
Olhão	1546285	Concluded	480000	1500	50	5				
Olhão	1869070	On going	480000	800						
Olhão	487085	On going	480000	300	130					
Olhão	191077	On going	250000					22	10	57
Portimão	1430866	On going	160000	1200						
Tavira	2031636	Concluded	4009				2380			
Vila do Bispo	1865046	Concluded	328000	450	225	25				
Vila do Bispo	2533500	On going	640072		1500					
TOTAL	18181851		4162290	7240	2405	50	4760	22	10	57

3.6.4. *Societal resistance to concessions for offshore aquaculture from media reports*

The recently established concessions for offshore aquaculture shown in Figure 3.2 and 3.3 have already been criticised by representatives from other activities, such as fisheries and tourism. The association (AlgFuturo) claims that these areas will produce losses in the eastern Algarve, for nearly 300 boats from the artisanal fisheries and thousands of direct and indirect jobs.

Additionally, they complain about not being consulted in the establishment of the existing APAA (Armona Aquaculture Production Area) and that it is the cause of a "plague" of mussels in the area (Feb 2016, http://barlavento.pt/economia/aquacultura-em-mar-aberto-ameaca-pesca-tradicional-no-sotavento).

A regional newspaper in the Algarve, on the 25-08-2016 (Figure 3.6) reported that Albufeira municipality was against the newly established aquaculture area, located 7.3km SW from the harbour entrance, as it would conflict with local artisanal fisheries, touristic boat operators, and restrict access to the Albufeira marina.

diáriOnline algarve

Director: José Mateus Moreno Director: José Moreno
Chefe de Redacção: Edgar Pires

Informação em constante actualização

Região Sul > Actualidade > Notícia

Câmara de Albufeira manifesta-se contra exploração de bivalves

Autarquia defende interesses dos pescadores e das empresas marítimo-turísticas

O presidente da Câmara Municipal de Albufeira veio a público vincar a sua posição contra a instalação de uma unidade privada de aquicultura de bivalves em águas costeiras, a 7,3 quilómetros do porto de abrigo, que considera "beneficiar interesses particulares", prejudicando os pescadores, as empresas marítimo-turísticas e a acessibilidade ao porto de abrigo e à marina de Albufeira. Carlos Silva e Sousa comunicou à Administração Central uma moção aprovada por unanimidade em reunião de Câmara para travar a produção de ostras e vieiras em mar aberto.

A Câmara Municipal de Albufeira deliberou, por unanimidade em reunião camarária do passado dia 23 de agosto, manifestar "clara oposição" à instalação de uma aquicultura com dois hectares para produção de ostras e vieiras, a 7,3 quilómetros a sudoeste do porto de abrigo de Albufeira.

A Autarquia manifestou a sua posição através de uma deliberação que já endereçou ao Governo, à CCDR Algarve e ao comandante do Porto de Portimão, onde se refere que a exploração "contraria manifestamente o interesse público, beneficiando, em exclusivo, interesses particulares". No documento pode ler-se que "o interesse público nesta zona está estabelecido de forma milenar a favor dos pescadores que operam a partir do porto de Albufeira e dos portos vizinhos, na sua maioria com pesca artesanal, o que representa o sustento de muitas famílias, além de que os pescados são de grande qualidade e representam enorme importância nos valores da nossa gastronomia com impacto nas nossas tradições e atividade turística".

O presidente da Câmara acredita que a exploração vem interferir com o livre usufruto do mar por pescadores e por empresas marítimo-turísticas, as quais já representam "um volume de negócios considerável e são geradoras de emprego". Carlos Silva e Sousa salienta ainda que "esta é uma zona de intenso tráfego marítimo, também com muitas embarcações particulares", pelo que a instalação da aquicultura viria "condicionar o acesso ao porto de abrigo e à marina de Albufeira", afetando a circulação de embarcações.

..diariOnline
19:23 quinta-feira, 25 agosto 2016

Figure 3.6. Newspaper reporting the position from Albufeira municipality against the newly established area for bivalve aquaculture

On the 14-09-2016 (Figure 3.7) a newspaper article, reported the position of the Municipality and the fisherman of Olhão, against the established areas for aquaculture in front of the fishing communities.

ECONOMIA PLANO DE ORDENAMENTO

Áreas para aquicultura revoltam pescadores

CONFLITO Zonas demarcadas para produção aquícola ficam em frente a comunidades piscatórias
LUTA Olhãopesca garante que, "perante tal afronta", setor da pesca "não ficará plácido e sereno"

JOÃO MIRA GODINHO

Os pescadores prometem lutar contra as áreas para aquicultura previstas no Plano de Ordenamento do Espaço Marítimo (POEM). Garantem que "o que está delineado provocará graves consequências e constrangimentos para a pesca profissional e para as suas comunidades".

"As zonas demarcadas com potencial para a produção aquícola situam-se frente a comunidades piscatórias relevantes e

PLANO É SEMELHANTE PARA QUASE TODA A COSTA CONTINENTAL

em importantes zonas de pesca, algumas delas milenares", refere Miguel Cardoso, da associação Olhãopesca.

A juntar a este problema, o dirigente destaca que "80% da frota de pesca portuguesa está associada ao segmento de pequena pesca, com embarcações de reduzida autonomia e que operam, de uma maneira geral, dentro das 3 milhas (4800 km) da costa". As áreas previstas para aquicultura situam-se até às 6 milhas (9600 km), englobando, assim, as zonas onde atualmente trabalham os pescadores. Miguel Cardoso destaca que o POEM é semelhante em quase toda a costa continental.

"Isto leva-nos a crer que quem projetou este quadro ou não conhece o setor da pesca profissional, só conhece a aquicultura, e mal, o que é grave, ou conhece o setor da pesca profissional e simplesmente o ignorou em benefício da aquicultura e interesses conexos, o que ainda é mais grave", conclui Miguel Cardoso, acrescentando que, "perante tal afronta, o setor da pesca profissional não ficará plácido e sereno".

A Olhãopesca exige à tutela que diga "como fica o setor da pesca profissional no meio deste cenário, bem como onde está a tão apregoada compatibilização de atividades".

Miguel Cardoso diz que 80% da frota nacional opera até 3 milhas da costa e zonas para aquicultura vão até às 6

Figure 3.7. National newspaper reporting that the areas defined for aquaculture can cause constraints for fishing communities.

The conflicts with fishers and municipalities due to the pre-establishment of these areas were highlighted during the Aquaculture symposium on 5 May 2017, by the Secretary for State of Ministry of the Sea, referring to it as "a significant constraint". Immediately after the areas were defined, the Secretary for State said he received several complaints from municipalities, fishers and marinas. He also mentioned that an initial planned offshore aquaculture site had to change location three times before its implementation, due to the objections from the local marina, who were of the opinion that it would affect access for yachts. Another important constraint on the expansion of aquaculture, may be described as an institutional conflict, where there is a requirement by the Portuguese Agency of the Environment, to reserve coastal areas with good quality sand so that sand is available for beach nourishment of economically important tourist beaches.

3.6.5. *Issue 1 - Licensing procedures (stakeholder feedback)*

Figure 3.8 is an organogram showing the main State institutions involved in aquaculture licensing in Portugal. DGRM is responsible for coordinating the various procedures related to licensing, but it is also important to understand that depending on the licence required the dominant entity can change. Thus, for example, DGAV is responsible for granting a licence for depuration facilities for bivalve production, whereas APA is responsible for granting licences for longlines in the open sea. The administrative system associated with aquaculture activities in Portugal is shown in Figure 3.8 and an example from one mussel producer, with 42 licences to date, in shown in Figure 3.9.

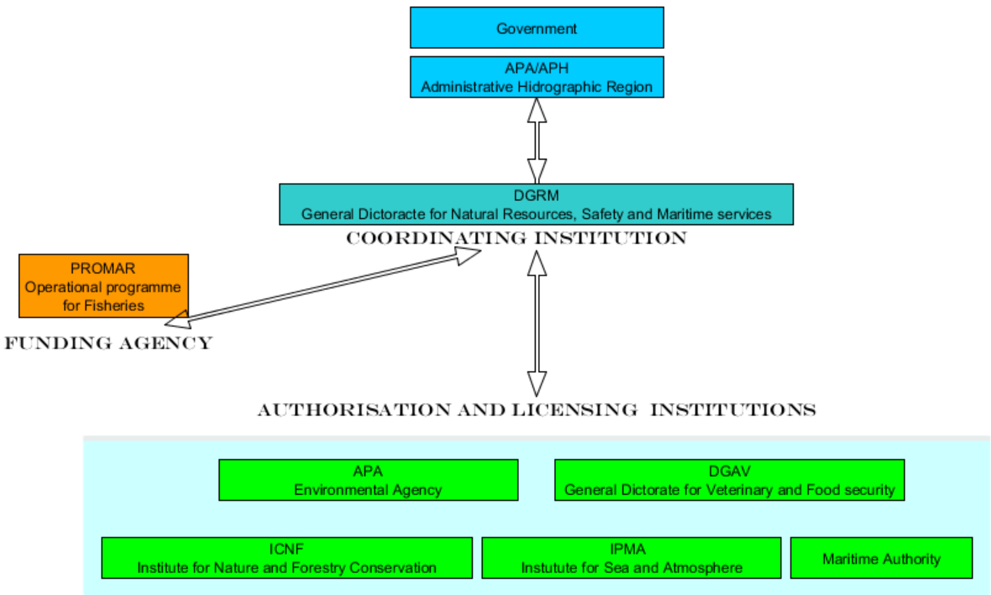


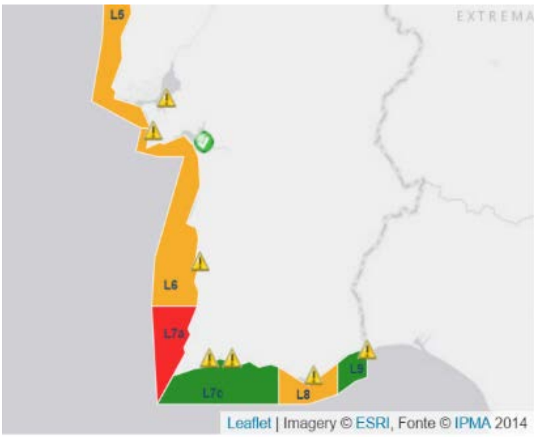
Figure 3.8. An organogram showing the main State institutions involved in the licensing process for aquaculture in Portugal.

Figure 3.9. An example of the licences required by a single offshore producer for bivalve aquaculture (with thanks to Finisterra Lda).

3.6.6. *Issue 2 - HABs (stakeholder feedback)*

Harmful algal blooms (HABs) are affecting the expansion of aquaculture offshore. For monitoring of HABs, IPMA (the Portuguese Institute of the Sea and the Atmosphere), is the official agency responsible for monitoring toxic algae, but they have had to adjust to the rapidly rising demand for their services.

One excellent innovation has been the development of online maps for the country (https://www.ipma.pt/pt/pescas/bivalves/index.jsp) showing which regions and which species along the coast are affected by closure orders due to high toxin levels from HABs. Figure 3.10 is an example from the IPMA website that includes the monitoring zones for the Algarve coast. This is an essential activity for public health and for the credibility of the industry. Nonetheless, there are criticisms: one, the spatial range of the monitoring zones are considered too large (Figure 3.10) because any toxins identified in any part of a specific zone necessitates the closure of the entire zone, even if samples from another section of the same zone are clear of toxins; two, the response time for decisions related to specific samples can cause problems for the industry, both from closure delays when a producer might be selling contaminated products to delays in re-opening a zone, thereby resulting in losses for the industry as sales cannot be resumed.



https://www.ipma.pt/pt/pescas/bivalves/index.jsp
on the *22-09-2016*)

	Harvesting of all bivalves allowed along coast
	Harvesting of only some species allowed along the coast
	Harvesting of all bivalves banned along coast
	Harvesting of all bivalves allowed in estuaries/lagoons.
	Harvesting of only some species allowed in estuaries/lagoons
	Harvesting of all bivalves banned in estuaries/lagoons

Figure 3.10. An example of the IPMA map that are produced weekly to show zones along the coast that are subject to official closure orders due to phytoplankton toxins. Note that the specific zones (e.g. L7c, L8 etc.) may extend for several kilometres.

Even without the potential changes from climate change, the oceanographic conditions along the Algarve coast can alter significantly from year to year, which provides a substantial challenge to managing offshore concessions to produce suitable products for the market. For example, in 2014, the area was dominated by high productivity but there were extensive closures due to toxins, while, in contrast, 2016 was dominated by higher temperature waters with lower productivity so that the condition index of the mussels was often poor. In both these situations businesses were unable to satisfy their clients requirements.

3.6.7. *Issue 3 - Disease (stakeholder feedback)*

Disease events have been reported especially at the end of 2015, when a mass mortality affected oyster production in the intertidal area of Alvor and oysters produced in offshore aquaculture at Sagres. Figure 3.11 shows some images and comments from the local media. The aquaculture producers have been confused about who has responsibility for what and whether there are any compensation funds, similar to those for the agriculture industry.

Figure 3.11 - Regional newspapers with references to disease effects in oyster aquaculture.

The regional director of the General Directorate for Veterinary and Food Security (DGAV) of the Algarve clarified many of these issue during the APA symposium in May 2017, in Setubal. There are only two bivalve diseases for which there is compulsory disclosure, *Bonamia ostreae,* which affects mostly flat oysters, and *Martelia refrigens,* in mussels and flat oysters (Table 3.6). There is a monitoring plan for the detection of these diseases detailing the sampling sites and number of individual bivalves that should be analysed. In the case of offshore production, 150 bivalves should be sampled for a single species production, or in the case of oysters and mussels grown together 75 individuals of each species. Although other diseases may affect stock species, only those diseases specified in EU legislation are investigated by State institutions, which in Portugal is the reference laboratory of the Portuguese Institute for Sea and Atmosphere (IPMA). Portugal would also like to include *Perkinsus* sp. which causes considerable mortality within their valuable clam industry *(e.g. Ruditapes decussata*), but as the species is not commonly farmed in other EU Member State, it is not included in EU legislation.

Table 3.6. Compulsory disclosure of non-exotic diseases in Portugal (adapted from DGAV, 2015)

Non-exotic diseases	Sensitive species (PT)	Vector species
Bonamia ostreae	European flat oyster (*Ostrea edulis*)	Common cockle (*Cerastoderma edule)* Banded wedge shell (*Donax trunculus*) Sand gaper (*Mya arenaria*) Hard clam (*Mercenaria mercenaria*) Common orient clam (*Meretrix lusoria*) Cross cut carpet shell (*Ruditapes decussatus*) Manila clam (*Ruditapes philippinarum*) Golden carpet shell (*Venerupis aurea*) Pullet carpet shell (*Venerupis pullastra*) Warty venus (*Venus verrucosa*) King scallop (*Pecten maximus*)
Marteilia refringens	European flat oyster (*Ostrea edulis*) Common mussel (*Mytilus edulis*)	Common cockle (*Cerastoderma edule*) Banded wedge shell (*Donax trunculus*) Sand gaper (*Mya arenaria*) Hard calm (*Mercenaria mercenaria*) Common orient clam (*Meretrix lusoria*) Cross cut carpet shell (*Ruditapes decussatus*) Manila clam (*Ruditapes philippinarum*) Golden carpet shell (*Venerupis aurea*) Pullet carpet shell (*Venerupis pullastra*) Warty venus (*Venus verrucosa*)

With regard to the OsHV-1 µvar (*Ostreid herpesvirus 1 µvar*), a monitoring programme was implemented in 2016 for *Crassostrea gigas* by the DGAV in response to the massive mortalities of 2015. Factors such as temperature (16-24°C), salinity, hydrodynamic conditions, and the presence of *Vibrio aestuarianus* are indicators for the occurrence of mortalities. Although the disease does not require compulsory disclosure under Directive 2006/88/EC on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals, a Member State may implement measures to stop the introduction or control the disease where there is a significant risk to farmed or wild animals (DGAV, 2016). For this monitoring programme, a number of sampling stations have been established: Ria Formosa, Ria de Alvor, Ria de Aveiro and Sagres region (offshore) (Figure 3.12). After a suspected case or confirmation of disease the DGAV will conduct an epidemiological survey, sampling 150 individuals for laboratory analysis, and send it for further etiological agent/pathogen investigations in the national reference laboratory at IPMA.

Figure 3.12. Sampling stations for the monitoring of the Ostreid *Herpes* virus (source: DGAV, 2016)

Nonetheless, there is a perception amongst all stakeholders that the current procedures for disease management in Europe is problematic and that it might be better to adopt the same approach as Norway introduced recently, which lists infectious diseases of aquatic animals based on the following principal factors (VKM, 2015):

- the infectious nature of the disease, including transmission efficiency;
- the consequences of the disease for farmed and wild aquatic animal populations;
- the feasible possibilities for disease control.

3.7. Relevance of the case study within AquaSpace

A striking aspect of the Algarve case study is that, in contrast to many other EU countries, space has been made available for aquaculture, but a more pressing problem is to provide tools to use this space effectively.

From the questionnaire results, in Part I, it is evident that the process to obtain licences for aquaculture activity is still the main concern of investors. In recent years, the Portuguese authorities have been working on improving this process, with the hope of reducing the time taken to licence from 3 years to 3 months. Other aspects are related to the environmental and technical limitations; this means that is necessary to strengthen and improve the transfer of knowledge and know-how being generated at universities and research centres on aquaculture. The respondents also consider that the regulations are ineffective/undeveloped so it is important that the responsible entities develop regulations in collaboration with industry stakeholders.

The main factors negative impacting upon investment in aquaculture in Portugal were identified as:

i) Difficulty/slowness to obtain permissions;
ii) Environmental and Technical limitations;
iii) Ineffective/Undeveloped regulations.

The most important incentives to encourage investment in aquaculture put forward by the respondents were:

i) To increase production;
ii) To increase economic income and sustainability of businesses; and
iii) To supply the markets with high quality products.

The most important legislation regulating aquaculture in Portugal:

i) National legislation;
ii) Maritime Spatial Planning Directive;
iii) Water Framework Directive and Common Fisheries Policy.

The environmental related Directives such as the Birds and Habitats Directive and the Marine Strategy Framework Directive were not considered as important.

The priority measures necessary to encourage development of aquaculture in Portugal were identified as being:

i) Pre-establishment of suitable zones for aquaculture.
ii) Regional programmes for environmental monitoring and the implementation of contingency and biosecurity plans;
iii) Development of a specific insurance plan for aquaculture.

3.8. Conclusions and future prospects

There is a clear strategy for developing offshore aquaculture in Portugal specifically for bivalves. There is also a clear objective to significantly increase the total production of aquaculture. The government's target is to double production by the year 2020, with a total production of 20,000 tonnes. Significant investments have been made in offshore production systems along the Algarve coast and although the designated investment programme, PROMAR, has ended, a new programme

"MAR2020" was launched in October 2016 (see http://www.mar2020.pt). This new operational programme will evaluate the applications and attribute funds for new aquaculture investment, with a total of €78 million available.

Nonetheless the licensing process for aquaculture is still slow and can take years; this aspect was highlighted during the stakeholder consultations as negatively impacting on future aquaculture investment. The government is still working on reducing the time taken to licence farms and expects to bring it down to four months. Already some important steps have been implemented: a good example is the website https://eaquicultura.pt/ which shows areas available for aquaculture, also there is additional information for investors covering licensing aspects. In this online platform there is reference to Decree-Law n.º 40/2017, published on the 4th April 2017, which introduces a new, simplified legal regime for licensing development of new aquaculture concessions.

Historically, offshore aquaculture production in the Algarve has not been significant with few concessions and therefore with no significant conflicts, but this situation is changing rapidly with increasing investments in the last five years (see Figure 3 and Table 5). In 2017, there are applications for three additional areas of maritime space in Portugal for use by aquaculture. These areas are currently open to consultation from the public. One of these applications is for for the production of the bivalves, *Ostrea edulis, Crassostrea angulata, Crassostrea gigas* and *Pecten maximus*, at a two-hectare site for a period of 10 years. This site is situated offshore from the town Albufeira in the Algarve. In the near future it is expected that more conflicts with other coastal users will arise along the coast with the expansion of areas designated for aquaculture.

One important aspect that the AquaSpace project has highlighted is the fundamental interest, among stakeholders, in clarifying the licensing process and the entities responsible (e.g. Figure8) and showing exactly what entity is responsible for which licence. One stakeholder has shown that it currently holds 42 licences and there are still some missing (see Figure9). Although DGRM is responsible for coordinating the licensing process, it does not have powers over the other institutions and it is also important to recognise that for some licenses specific institutions have the over-arching responsibility i.e. it depends on what the licence allows. There are other areas such as disease legislation, compensation and insurance for extensive mortalities (e.g. Fig 11), where the AquaSpace project has highlighted that space allocated for aquaculture should be used as effectively as possible and identified through a collaborative effort with all stakeholders.

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4. BASQUE COUNTRY, SPAIN

Ibon Galparsoro, Joxe Mikel Garmendia, Arantza Murillas, Leire Arantzamendi, Luis Lagos, Kemal Pınarbaşı, Javier Franco, Ángel Borja

Partners involved: AZTI (Lead), BLUEFARM and NOAA

4.1. General characteristics

The Basque Country has a long history in the fishing industry (Rallo and Borja 2004) and it is one of the biggest consumers of fish and shellfish products in Europe. Historically, aquaculture has not developed to its full potential due to a number of different factors including environmental and technological limitations. During the last decades, fishing activity has experienced a large decline due to the reduction of biological resources, which has translated into a reduction in effort (number of days at sea) and the total number of commercial vessels operating. This trend was recently confirmed for the years 2008 to 2014, by the European Commission in its 2016 Annual Economic Report (STECF, 2016)

The decline in fishing activity has led to new initiatives for the development of aquaculture as a means of maintaining ecosystem services - marine food provision, supplementing the artisanal fishing incomes and promoting diversification in coastal areas that are economically-dependent on fishing. Nowadays, open ocean production offers a new perspective for the marine blue economy in the Basque Country. The Basque Country Government has exclusive responsibility for the management and implementation of aquaculture. To this end, the Directorate of Fisheries and Aquaculture in the Department of Economic Development and Competitiveness of the Basque Government, in collaboration with various institutional stakeholders in the Basque Country, has developed the "Strategic Plan for Aquaculture Development 2014-2020” (Jaurlaritza and Vasco 2014). Within this plan, a series of measures and actions for the development of this activity in the Basque Country are proposed. One of the actions concerns the "development of offshore aquaculture", allowing for extensive production of marine species for strategic sectors of the fishing and food industry and which is expected to favourably impact the Basque economy. In addition, the Basque Fisheries Local Action Group (FLAG), *Itsas Garapen Elkartea* (Marine Development Association), created in 2016, also promotes the aquaculture sector as a way of achieving coastal diversification, by including it as part of its strategic plan (Resolución 15 de Julio 2016” publicada en el BOPV Nº 153, 12/08/2016).

The Strategic Plan for Aquaculture Development 2014-2020, embedded a process of spatial planning, which contains a Scoping phase for the identification of the species and technologies to be implemented; and a Zoning and Site Selection phase. In this phase, criteria are established and agreed; once suitable areas are identified, specific studies were performed to assess the environmental and socioeconomic impacts of the establishment of aquaculture in the selected zone. This information was then used during the licensing process. One aquaculture management area was established in 2016 (BOPV Nº 9 del 15 de enero de 2016).

4.1.1. *Geographical and biological context*

The case study is located in the coastal zone of the Basque Country, in the northeast of Spain, within the Bay of Biscay (Figure 4.1). Although aquaculture has not yet been conducted at industrial level, mussel production experiments have been carried out, which have provided insights to its possible production capacity and economic performance in the area. This makes the case study highly relevant as it will be a testing zone and provides an example of the viability of offshore aquaculture for other Atlantic Arc regions.

The licensed aquaculture zone is 567 ha (3,140 m x 1,400 m); although the viable production area is 214 ha, the total area of occupation is 290 ha. Within the area are 52 parcels for aquaculture. The area is located on soft substrata, within a depth range of 20 and 50 m (Figure 4.2). The aquaculture site is within 2.16 and 4.17 nm of the ports of Ondarroa and Mutriku, both of which have appropriate vessels and onshore infrastructure to construct, deploy, and service the longline installation.

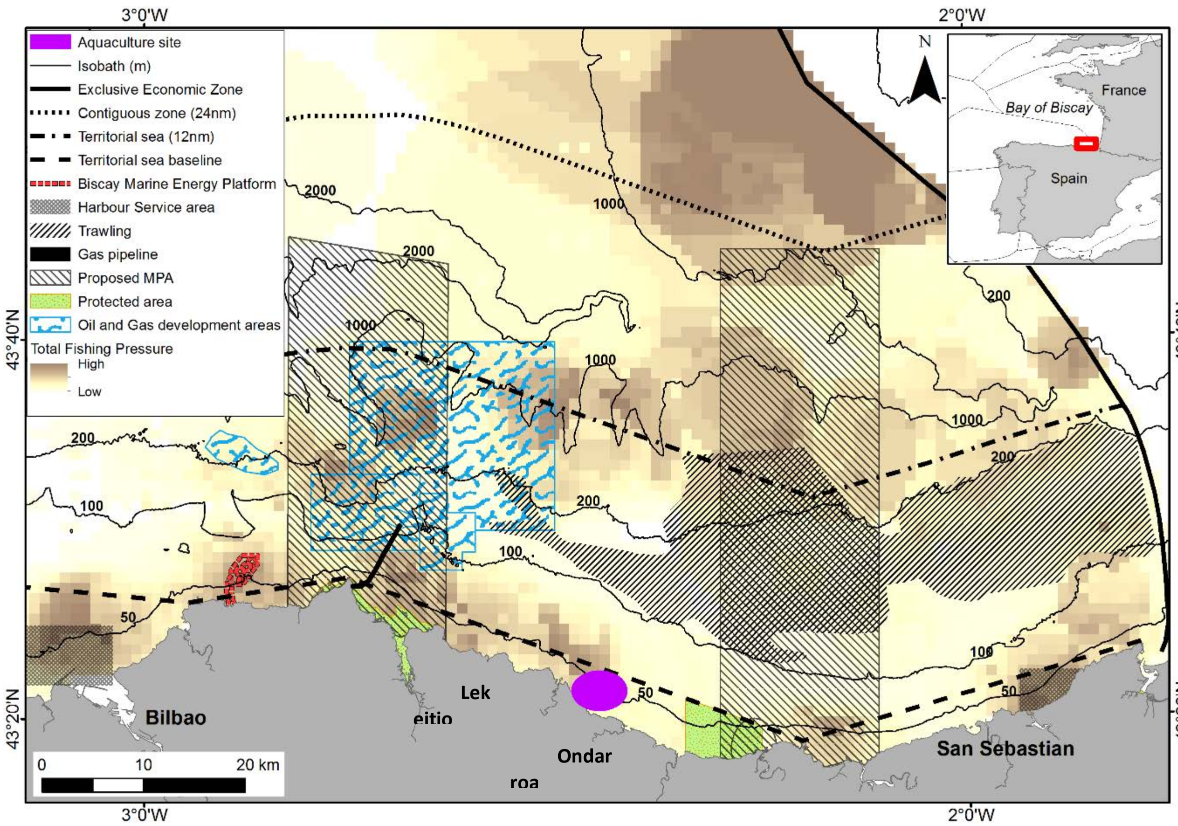

Figure 4.1. Aquaculture site (pink circle) within the Basque Country coastal zone and the spatial distribution of the main maritime activities and administrative boundaries. MPA: Marine Protected Areas.

The Bay of Biscay is well known for its high-energy sea conditions (González *et al.* 2004). Therefore, it presents structural and operational challenges for open ocean shellfish farming (Rodríguez *et al.* 2014). Specifically, according to the data recorded in the Basque Country, it has high wave heights in storm and extreme conditions (9.5 and 11m, respectively) and long wave periods (16-22 sec). The maximum wave height over a period of 30 days per year is 2.4 m. For a frequency of 5 days a year the wave height values are between 3.5 and 3.8 m, and one day a year values reach 4.8

metres. More specifically, the area selected in the Basque Country (Mendexa) is subject to somewhat lower wave energies than much of the Basque coastline, and is therefore a good choice for initiating a pilot programme.

The tide in the Bay of Biscay is semidiurnal, with an average height of about 2.7 m and a maximum height of 5m. Along the Basque coast the average tidal range is about 1.5m neap tides and almost 4 metres at spring tides. The annual maximum range exceeds 4.5 m (González *et al.* 2004). Currents are remarkable, with the average annual value of about 9cm s^{-1} and the maximum value (extremal) in 40 cm s^{-1} to 15 m depth. Monthly mean temperatures range from 12 ºC during the coldest periods to 21 ºC during the warmest periods.

Flat and sandy bottom seabed conditions have been selected (few places fulfil adequate conditions in the Basque continental shelf for aquaculture activity (Galparsoro *et al.* 2010)). The long edge of the rectangle is oriented along the coastline in a Northwest to Southeast direction and depths range from approximately 30 to 50 m. Actual growing depths may range from 7 to 30 m.

Initially, studies have focused on shellfish species, mussels (*Mytilus* sp.) and oysters, among others. These species represent some of the most popular locally occurring shellfish in the region. However, every cultivated shellfish product consumed in the region is imported.

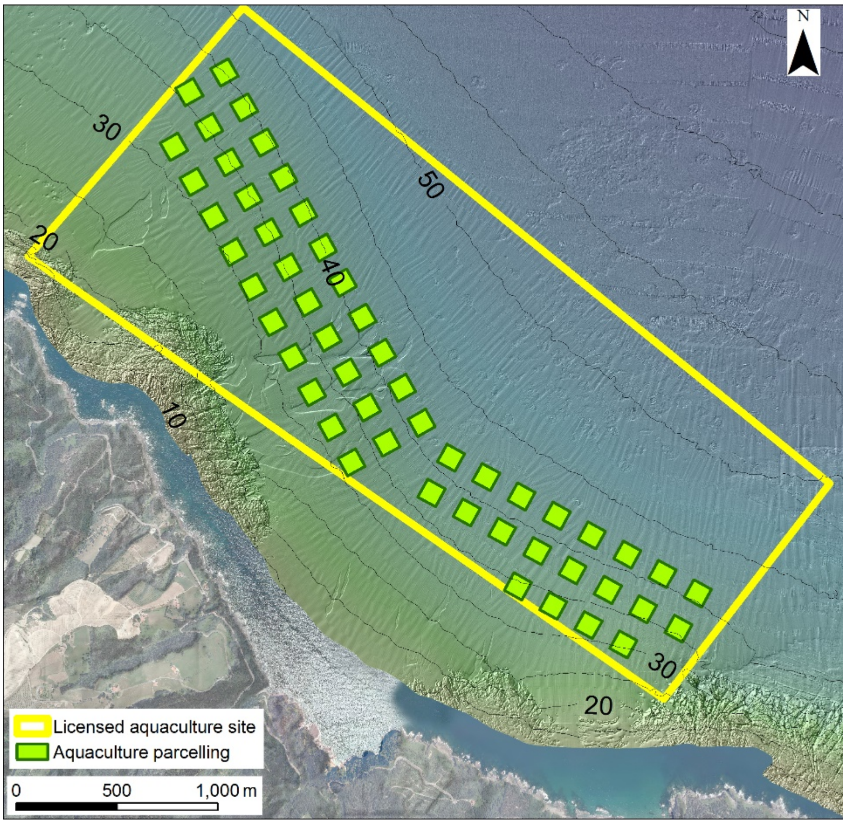

Figure 4.2. Licensed aquaculture site limits (yellow rectangle) and spatial distribution of the 52 parcels which longlines will be installed.

4.1.2. *Social and economic context*

In the Basque Country, the lack of adequate space in the littoral zone, the water quality for maritime and/or recreational purposes and the lack of industry interest and/or need for diverse aquaculture production activities, limit marine aquaculture development. The levels of overfishing and declining catch volumes of commercial fisheries in the Bay of Biscay, demonstrates the need to find alternatives that can help diversify extractive activities and generate new products and employment within the marine sectors of the Basque Country (Eusko Jaurlaritza/Gobierno Vasco, 2014).

The coastal region of Basque Country presents huge challenges regarding competing uses and ocean and weather conditions. However, the deep cultural roots of the maritime sectors and commercial fishing, reinforce the interest of exploiting any productive activity. Offshore aquaculture activities were defined in the Master Plan for Aquaculture of the Basque Country (Eusko Jaurlaritza/Gobierno Vasco, 2014) as an opportunity for economic diversification from fishing linked to the use of aquaculture. During site identification and selection processes a geospatial analysis of the other uses of the selected site was conducted and included fisheries, sand extraction, recreation, and a disposal area for dredged material, as well as ecologically and culturally sensitive areas. Artisanal fishing was identified as the main sector that could be affected by the creation of an area exclusively for aquaculture. The Regional Government has validated the possibility of excluding fishing within the area of the polygon through a commitment to shared management and benefits with local fishers' guilds ('*cofradías*', in Spanish). The two Basque federations, which represent the interest of all guilds present along the Basque coast, are also involved under the executive advisory of the *Itsas Garapen Elkartea* FLAG which is trying to promote aquaculture activity, but is also assessing the potential conflicts between artisanal fisheries and aquaculture.

4.1.3. *Economic framework for the future development of Basque aquaculture activity*

In this section, a general view of the national maritime economic activities in Spain is provided. This analysis was developed by Fernandez *et al*. (2015) by assessing the contribution of maritime activities to the Spanish economy in terms of value added and employment. This overall analysis includes the contribution of the Basque activities to maritime activities in Spain, (the aquaculture sector which is now under development was not included as no official economic data exists, its economic outcome is not included as part of the Gross Domestic Product). The reason for introducing this Spanish related information, is in order to gather knowledge about the role of the aquaculture sector in the global Spanish maritime economy and to show the position of this activity at national scale and in relation to the Atlantic Arc. It is not possible to extrapolate the potential growth rate associated with Basque production from the Spanish or Atlantic rates. Both rates are included because they represent the framework under which the potential Basque activity will be developed, that is, the economic context within which the Basque activity will have to exist in future. It is important to note that a specific Action Plan for Blue Growth in the Atlantic region exists, and the Basque case study will be framed within this context.

Within this framework, the main sectors related to marine living resources (including marine fishing, aquaculture, processing and preserving fish, crustaceans and molluscs, wholesale and retail sale of fish, crustaceans and molluscs), plus ship and boat building and maritime transport together account for 1.10% of all employment in Spain, and 0.67% of the value added. In terms of both value added and employment, it can be seen that the most important sector in the maritime economy is living resources, within which the key activity is the sale of fish, crustaceans and molluscs; this is followed by maritime transport, with shipbuilding playing a smaller role. However, in terms of productivity, maritime transport is in the lead, with living resources being less productive. In marine aquaculture, the value added increased between 2008 and 2011 at an annual rate of 20.8% in Spain, and 17% in the Atlantic Arc. This increase in value added was not accompanied by an increase in jobs, employment fell to an annual rate of 6% (10% in the Atlantic Arc), while the number of enterprises remained relatively steady, at around 5,000. In parallel, production increased from 2008 to 2011 by 11%, reaching more than 273,000 tonnes. Notably, 79% of the employment and 53.5% of the overall production in aquaculture in Spain is generated in the Atlantic Arc.

19,913 people were employed in aquaculture in Spain in 2014 which accounted for 5,946 annual work units. In marine aquaculture (excluding mussels and shellfish) the number of existing direct fulltime employment in 2015 was 1,900. This figure represents an increase of 1.9% from 2014. The greatest number of establishments consist of punts and "long-lines" (6,657), in which vertical crops of mussels and other shellfish are grown. The second major group of establishments is growing sites at beaches, intertidal zones and estuaries (1,152). Other establishments that grow in seawater do so in onshore facilities (78) or in nurseries (cages) at sea (46) (APROMAR, 2016).

4.2. *Spatial planning and management issues*

4.2.1. *Management and environment issues*

The designation of the aquaculture sites was promoted by the Basque government under the strategy for the diversification of marine socioeconomic activities.

To encourage the development of economic activity in the coastal zone of the “Maritime Terrestrial Public Domain” between Ondarroa and Lekeitio (Bizkaia, Basque Country), an aquaculture production site was proposed between the Ondarroa and Leketio municipalities. Each installation phases of the cropping system in the study area must provide full documentation to the Basque Government (project construction, analysis of technical and economic feasibility, environmental studies, etc.). The Basque government is the competent authority for presenting he project in the Spanish national government, and the applicant organisation will pay a fee for using space within the “Maritime Terrestrial Public Domain”.

During site selection, different criteria were considered. Both environmental and production suitability as well the legal framework and conflicts with other existing activities were considered. All of these aspects were analysed in the Environmental Impact Assessment (EIA) of the marine aquaculture facility and the complementary studies needed for authorisation of the aquaculture activity. More specifically, offshore systems for bivalve production (e.g. longlines or rafts, submerged mussels, oysters and clams) are characterised by their high production capacity, high final product quality and coping with environmental regulations of the competent public administration (i.e. Ministry of Environment and Europe). The mussel *Mytilus galloprovincialis* (Lamarck 1819) is a native species of the Basque Country. European exploitation of mussels is justified by their appeal as source of food (EATIP, 2012).

The identified on-growing (production) system in the open sea for this species in waters of the Basque coast is already known. At EU level, the system comes under the scope of an organic aquaculture system (Regulation EC 834/2007 on organic production), due to its low impact on the environment and its possible positive contribution to other aspects of marine ecological interest (biofiltration, uptake of CO_2, etc.). The cumulative impacts assessment found the activity has a moderate impact. Due to the aforementioned aspects of the production site it is considered as producing “acceptable environmental change”, which is in compliance with the concept of the ecosystem approach to aquaculture (EAA) (FAO, 2010, 2013; Soto *et al.* 2008).

4.2.2. *Aquaculture species, types and systems in the area*

As stated before, there is currently no industrial scale production but the process for its production has started. The production will focus on shellfish (initially mussels *Mytilus galloprovincialis* and oysters) cultivated in submerged longlines .

4.2.3. *Spatial use and conflicts with other activities and sectors*

The main sector affected by the creation of areas exclusively for aquaculture is the fishing sector. Artisanal vessels that used to fish in the current aquaculture no-take zone, as well as (to a lesser extent) the artisanal vessels that used to cross the area to reach their fishing grounds are affected.

4.2.4. *Statistics for production*

Pilot production and estimations have been calculated via a two-year experiment with mussel *Mytilus galloprovincialis*. The calculations are as follows:

Estimated average annual production: 40 tonnes·ha^{-1}

Estimated maximum annual production: 60 tonnes·ha^{-1}

Estimated total average annual production: 2,080 tonnes

Estimated total maximum annual production: 3,120 tonnes

Physical carrying capacity, Production carrying capacity, Ecological carrying capacity and Social carrying capacity were also considered when calculating the production model (Liria *et al.* 2016), which was needed for the Environmental Impact Assessment.

4.2.5. *Industry investment analysis*

The principal investment for this system relate to mooring needs, ropes, buoys and vessels for operational activities (the last item can be addressed by reusing existing vessels from the fishing industry). The suppliers of the above items are all present in the Basque Country. The engineering requirements for mooring calculations, projecting production and needs (i.e., food availability in the water column) are also available. Offshore aquaculture is a novel food production activity along the southern Bay of Biscay coast and related studies are scarce (note that mussel production in Galicia cannot be treated as offshore as it mainly takes place in '*ría*' [estuarine] systems). Currently, the most complete studies available for the Bay of Biscay are the ones cited in this report. However, these studies provide an adequate understanding about the offshore zone for use in the case study, thus they are considered as a baseline for this work.

Studies conducted in 2010 concluded that the right to develop bivalve production in the open sea area on the coastal stretch between Ondarroa and Lekeitio should be granted. Other species of invertebrates (e.g. clam, sea urchin, sea cucumbers, octopus, etc.), could also be of interest. The deep cultural roots of maritime and commercial fisheries reinforce the interest and possibilities of exploiting production activities that can be done in a sustainable and economically viable manner (Eusko Jaurlaritza/Gobierno Vasco, 2014). In fact, offshore aquaculture and its associated activities were defined in the Plans for Fisheries and Aquaculture of the Basque Country (Eusko Jaurlaritza/Gobierno Vasco, 2014; Mendiola *et al.* 2008) as an opportunity for economic diversification from fishing.

Identified needs that could be met through the development of aquaculture:

(i) The need for professional alternatives to the fisheries sector; species of commercial interest should promote new approaches to production activities (such as marine aquaculture);

(ii) The economic need; the designation of a new aquaculture production site is expected to stimulate private investment capital (local or international) in new business opportunities associated with aquaculture;

(iii) The need for employment; new business/sector opportunities may lead to a re-generation/diversification of employment in the agro-fisheries, food, water and services sectors, mainly; re-employment of fishing professionals, opportunities for graduates and Technical high school graduates, machinists, welders, skippers, divers, etc.;

(iv) The need for food products or biomass supplies; the zones facilitates production of new aquaculture species, food products for human consumption or raw materials; as well as the incorporation of new food products into the local seafood value chain, with well established distribution and market channels, and;

(v) The need to promote a good socio-political image: the aquaculture site and its activity will promote the image of the Basque Country in the areas of the Common Fisheries Policy (CFP) (Council regulation (EC) no. 2371/2002) and (international) European sustainable development as well as in local circles (commitment to the primary sector and generation of natural, healthy and innovative products).

4.2.6. *EU, national and local policy*

EU policy

*The main framework for Maritime Spatial Planning (MSP) is Directive 2014 (89/EU (MSP Directive) (*European Commission, 2014*).*

Commission Decision 2010/477/EU approves the criteria (and associated indicators) to be used to assess the degree of achievement of good environmental status (GES) of an area in relation to the 11 descriptors listed in Annex I of the Marine Strategy Framework Directive (MSFD; 2008/56/CE)

(European Commission, 2008). In the initial assessment of the Spanish North-Atlantic area (MAGRAMA, 2012), it was indicated that the activities of aquaculture and mariculture in the area can lead to pressures/impacts that may affect 7 out of the 11 MSFD descriptors: biodiversity, non-indigenous species, populations of all commercially exploited fish and shellfish, food webs, human-induced eutrophication, sea-floor integrity and contaminants in fish and other seafood for human consumption.

The activities in the aquaculture zone have associated pressures. In this sense it is important to consider the potential impact of these pressures on the ecological and chemical state of the coastal waters under the Water Framework Directive (WFD, 2000/60/EC) (European Commission, 2000). Aquaculture could directly affect the characteristics of the substrate and therefore indirectly affect the benthic community.

According to Regulation (EC) No 854/2004, sampling plans for the presence of toxin-producing plankton in production waters, must take into account the possible variations in the presence of plankton containing marine biotoxins. The monitoring of pollutant concentrations is covered by Regulation (EC) No. 1881/2006.

National policy

Maritime spatial planning has not yet been implemented in Spain but the transposition of the MSP Directive has been completed (Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente. Real Decreto 363/2017, de 8 de abril, por el que se establece un marco para la ordenación del espacio marítimo. Boletín Oficial del Estado, 66, 11/4/2017, pp. 28802-28810).

National marine objectives and legislation related to spatial management of activities in the marine area, are sectoral and do not consider interactions between different activities. Spanish regions may also have different regional social and economic interests and also objectives affecting their territory and specifically their littoral and marine space. These differences may also arise in a north-south division, thus in regions located on the North-Atlantic, the Mediterranean coastline of Spain and the Canary Islands. The main instruments used in Spain for the ordination of the littoral space are:

- *Littoral Ordination Plans*
- *Guidelines for the ordination of the territory*
- *Sectorial plans or Aquaculture Strategic Plans*
- *Others: Director Plans of Natura Net, Network of protected natural areas, etc.*

The regions of Galicia, Cataluña, Basque Country, Principado de Asturias and Canary Islands have been very active in the elaboration of regional strategic plans and specific instruments for spatial ordination and also for guidance or studies for zoning of their marine space for aquaculture.

The development of these plans and studies related to the ordination of the littoral and marine space for aquaculture still demand a lot of coordination work by the Spanish government. This coordination must equally account for all the regions, and require them to achieve the agreed objectives. In this context, the “Guidelines on criteria for site selection and establishment of zones of interest for aquaculture in Spain” were elaborated and annexed in the Spanish Aquaculture Multiannual Plan. It was intended to be used as a tool for the regional administrations and aquaculture industry investors in the selection of suitable sites for aquaculture and therefore, facilitate expansion of aquaculture production in Spain.

The Inter-Ministerial Commission on Marine Strategies (CIEM) was created in 2012. CIEM is a body designed to coordinate the activities of the different Ministerial Departments of the Spanish government. It was established by Royal Decree 715/2012 of 20 April 2012.

Spanish law 41/2010 lays out the general principles for planning in the marine environment through the preparation, adoption and implementation of the Marine Strategies.

Regarding aquaculture activity, applying for and obtaining permits and authorisations granting public maritime domain space for aquaculture, has to be carried out by the Ministry of Agriculture, Food and Environment (MAGRAMA).

Local policy

Competencies for maritime and coastal affairs are shared between central and regional governments.

Sea use and the management of maritime activities in the Basque Country is carried out by the Spanish Government. Based on the Spanish autonomous system, competence for fishing regulation in territorial waters is shared between the Spanish State and the Basque Country Government. Therefore, the Basque Government is responsible for fishing regulations for the internal waters (Arregi et al. 2004). The Basque Government has also adopted other initiatives for managing sea use such as, the establishment of a renewable energy extraction platform (Biscay Marine Energy Platform; bimep) and the declaration of marine protected areas within the area of competence.

*Aquaculture is one of the sectors for which the Autonomous Community of the Basque Country has exclusive competence. For this reason, the Fisheries and Aquaculture Department of the Department of Economic Development and Competitiveness, in collaboration with the various institutional agents of the Basque Country, have prepared the regional strategic plan for the development of aquaculture activity for 2014-2020. Other relevant legislation relates to the protection and sustainable use of the coast (Law 2/2013) (*BOPV, 2013*) and the law that regulates maritime fisheries (Law 6/1998) (*BOPV, 1998*).*

Under the requirements established by Regulation (EC) 854/2004, the Department of Economic Development and Competitiveness of the Basque Government issued an order on the declaration of the coastal zone between Ondarroa and Lekeitio (Order of January 8, 2016) (Figures 1 and 2).

4.3. Stakeholder engagement and participation

Relevant stakeholders related to different aspects of aquaculture activity, development and performance were targeted as part of this case study. The aspects that they engaged with included: legislation and management of marine activities and sectors, environmental and other social aspects, and the specific technical issues related to aquaculture. Hence, the main stakeholders in the promotion, licensing and management of aquaculture in the Basque Country were identified. Only the stakeholders *directly* involved in one of the previously cited aspects of aquaculture were included. These included national and local administration authorities, managers, promoters, researchers from universities, fishermen associations, education, etc.

The output of the collaborative work conducted in associate with these stakeholders was their views on the main constraints to aquaculture in the Basque Country. The most relevant issues identified include:

- An overview of stakeholder perspectives on the current state of open sea aquaculture in the Basque Country;
- Limitations faced by stakeholders and promoters, and;

- Feedback from stakeholders on the new tools developed in AquaSpace.

The aforementioned issues were addressed in the context of two organised workshops and a questionnaire that was distributed to stakeholders who could not attend the workshop.

In total, 27 stakeholders participated. The first workshop was held on 10th December 2015. Eleven stakeholders attended the workshop. During the workshop, the AquaSpace project was presented, including the background and main objectives of the project, and more specifically the importance of engaging local stakeholders in order to identify the main issues and aspects in the promotion and expansion of aquaculture based on their experience.

The second workshop was held on 11th November 2016. Twenty-one stakeholders attended. In this workshop, the tools developed in AquaSpace were briefly presented, focusing mainly on the functionalities of the tools and their applicability to aquaculture planning and development. Feedback on the applicability, willingness to use them and the identification of new functionalities were requested from the stakeholders through a questionnaire.

4.4. *Tools used in the case study*

4.4.1. *Description of tools*

Different tools have been implemented and utilised during the aquaculture site selection and subsequent analysis. For site identification and site selection for offshore aquaculture, hydrodynamic modelling approaches were mainly used in order to identify the areas that were more sheltered and in which longlines could be installed. Apart from that, the other tools that were used were mainly based on GIS analysis in which information regarding seafloor type, depth and other environmental layers were used to apply the selection criteria. GIS tools were also used for the analysis of interactions with other uses by simple spatial overlapping/intersection analysis.

4.4.2. *Application of the tools*

The tools were implemented at case study level to assist with the main issues cited above (i.e. site identification, analysis of conflicts and trade-off analysis). During this process, the tools were tested, and specific recommendations for the AquaSpace tool development were transferred to WP3. Finally, the AquaSpace tool was used (for the first time in the Cantabrian sea) to identify the areas that could potentially host offshore mussel production.

4.5. Case study results

4.5.1. Stakeholder output/feedback

Stakeholders provided their vision and perspectives regarding the potential expansion of aquaculture activity in the Basque Country, these are related to: (i) policy, rules, regulations and institutional issues, (ii) the environment, (iii) other uses/sectors, (iv) socioeconomics, and (iv) aquaculture and other items (tools, etc.) (Table 4.1).

4.5.2. Policy, norms, regulations and institutional issues

In relation to the issues that make open sea aquaculture in the Basque Country less attractive for investment, there is general agreement that this relates to three main issues (technical and environmental limitations, long-term investment, and lack of associated infrastructures). Stakeholders related to conservation and public administration (Government) (which would be expected to be opposed perceptions) are the ones that gave the most consistent responses related to less attractive items (mentioned above) and priorities for aquaculture (to increase economic income and business sustainability).

Generally, stakeholders rarely agreed, and they gave different responses on the objectives and priorities for aquaculture.

The different sectors are aware that aquaculture activity is limited/controlled/regulated to some extent by EU norms. Specifically, there is agreement that EU environmental legislation heavily influences the development of Basque aquaculture. However, there is a lack of regulative measures at the local scale.

Furthermore, it is interesting that the Habitats Directive was rarely mentioned. This may be because the respondents are more aware of the production or economic perspective.

Finally, with respect to the Basque Country Strategic Plan for Aquaculture Development, some good aspects were mentioned by research stakeholders (the Strategic Plan establishes the background for promoting public and private initiatives; and it tries to plan the space allocated to aquaculture, thus, it is a first attempt to facilitate the establishment of a policy that promotes aquaculture development, the challenge is to move towards implementation). Good aspects mentioned by promoters include: the significant Basque Country resources for aquaculture activities, and the Strategic Plan enables those activities to be consolidated and carried out with success. Good aspects mentioned by the representatives from the Administrations included, in addition to creating structures for participation, it facilitates forward planning and provides the necessary resources to attract and fund new projects. However, one weakness highlighted by research stakeholders was that the plan does not clarify the ways in which promoters and entrepreneurs can access assistance, information etc. These responses seem to be influenced by the particular interests of each sector; this is especially evident in the case of the Promoters.

Table 4.1. Description of the stakeholder 1st workshop and feedback and output.

Case study	Stakeholders	Stakeholder workshop	Feedback and output	Recommendations from stakeholders
Basque Country (SE Bay of Biscay; Spain)	Two **Administration** levels; Spanish Government (Ministry of Agriculture, Food and Environment), Basque country Government (Department of Agriculture, Fisheries and Food) Two **Non-Governmental Organisations** (Regional NGO, Local NGO) **Industry representatives** (two promoters) One **Education** organisation (Aquaculture Training Institute)	10th December 2015 / Bilbao / 27 participants / 10 contributions to questionnaires	**Policy, norms, regulations and institutional issues** -Stakeholders do not share common perspectives on the objectives and priorities of aquaculture. -Environmental legislation affecting aquaculture: EU Directives affect the development of Basque aquaculture. -Stakeholder participation should be improved to guarantee participation in the preparation of Strategic Plans (i.e. Local community, conservationists, local institutions, NGOs, small-scale fishermen) -The on-going Strategic Plan for Aquaculture is considered a good initiative by all stakeholders. **Aquaculture and environment** -Agreement on the adequacy of the selection of the promotion of open sea shellfish production with longlines. -Lack of innovation (longlines) and species to be cultivated (mussels and oyster) due to market competence. -Agreement on the general environmental impacts from aquaculture: contaminating agents from different sources, potential invasive species, sanitary problems (parasites and diseases). -Agreement on the most limiting environmental factors when initiating an aquaculture activity: species selected, prevailing ocean-meteorological conditions, and connection with natural population (potential disease source). **Aquaculture and other uses/sectors** -Main conflicting sector with aquaculture development is fishing. -Measures to avoid or minimize this conflict should be adopted (involvement in the aquaculture activity or subsidence) **Aquaculture and socioeconomics**	Measures proposed to solve the conflicts with other uses and sectors: ***-Maritime Spatial Planning is seen by stakeholders as a good framework that would help the promotion of aquaculture activity*** ***-Spatial Planning should be developed to take into account social, environmental and economic criteria, aiming, if possible, to achieve consensus among users.*** ***-It is necessary to declare zones for aquaculture interest in which the activity could be prioritized.*** ***-Use of aquaculture facilities as limits for strictly protected areas, where fishing activity is banned. E.g. the use of longlines as barriers to limit the entrance of fishermen into protected areas.*** ***-Better coordination among sectors.*** ***-Spatial Planning should be developed with good communication and promotion of the plans.*** ***-Coordinated actions and decisions should be promoted where the negatively affected sectors could be identified at an early stage and become involved in the project to minimize the negative impacts of decisions, and if possible, profit from it.***

	Two **Research institutes** (University and a Research Institute) One **Fishermen's Association**		-Positive public perception of aquaculture. -Aquaculture can be an attractive activity; however: there are high (maintenance) costs. -Favourable aspects of aquaculture activity: recovery of fishing grounds and repopulation. -Most limiting economic aspect for aquaculture promotion: high initial investments and market risks. -Current infrastructures, services and logistic of the Basque Country are sufficient to allow aquaculture activity, although there is a lack of special residues collection facilities in ports. **Aquaculture and other items (tools, etc.)** -Most commonly used tools: GIS, remote sensing and maps. -Few stakeholders use public sources (or websites) for information. -There is no interest in addressing the tools knowledge gaps.	***-Involvement of the fishing sector in the business and compensation measures with an important income from aquaculture.*** ***-Aquaculture activity should be located away from ports and recreational zones where it may interfere with bathers.*** ***-Allocation of aquaculture activity within inner waters in order to limit the use of fishing gear in this area.*** ***-Strict protection of the marine environment in accordance with international commitments and environmental assessment. It is agreed that a good environmental status of marine waters are necessary for any existing and future activity.***

Stakeholders are aware of the administrative burdens involved in the development of open sea aquaculture.

Regarding stakeholders' participation and involvement during the development, evaluation and consultations on the Basque Country Strategic Plan for aquaculture, three stakeholders (two Conservation stakeholders and one Promoter) were not invited to take part and did not participate in the process. Those stakeholders not involved in the process also identified other sectors and groups that should have been involved in the process including the local community, conservationists, local institutions, NGOs and small-scale fishermen.

In general, the Strategic Plan for Aquaculture development in the Basque Country is considered a good initiative by stakeholders. The only stakeholder that showed opposition to it was a stakeholder involved in conservation.

There is a low level of agreement among sectors about the critical management measures for aquaculture development in the Basque Country: only two answers (to develop Spatial Planning for the activity; and the existence of contingency and biosecurity plans) are shared by two sectors (Research and Conservation; and Conservation and Administration, respectively). This means that each sector has its own interpretation of the situation. Considering other critical measures: pre-establishment of suitable zones for aquaculture (Research); assistance or training on management of production by promoters and fishermen (Research); environmental monitoring - regional programmes (Conservation); assistance for training and management around aquaculture laws, ordination and strategy for public Administration technicians (Promoters); subsidies for occupying space to initiate the activity (Administration).

4.5.3. *Aquaculture and environment*

Stakeholders supported the selected aquaculture site through the Basque Country Aquaculture Strategic Plan. It should be noted that the Basque Government has been the main promoter of the environmental and socioeconomic studies that resulted in the selection of the aquaculture site, production technology and cultivated species. Some of the stakeholders gave negative views. Regarding the cultivation technology (longlines), research stakeholders highlighted the lack of innovation, because it is based mainly on traditional aquaculture; regarding the cultivated species (mussel and oysters) researchers consider that those species are already cultivated in other very productive areas and thus they consider that it may be very difficult to compete on the market. Regarding other potential species, conservationists showed their opposition to fish production because of their dependency on wild fish exploitation (fishmeal in aquafeeds). In that sense, conservationists showed less opposition to longline shellfish production as it is expected that this mariculture has the lowest environmental impact (mainly because feeding is not needed and because they do not need antibiotics).

With respect to environmental impacts of aquaculture, all sectors are concerned with contaminants from different sources (i.e. antibiotics, anaesthetics, eutrophication, organic, excess of food, pelagic contamination, detritus, discharges) (70% of respondents) and the possible negative effects of potential invasive species (escapes and native fauna displacement) (40% of respondents). Sanitary problems, involving parasites and diseases (i.e. introduction or appearance of shellfish diseases and the impact on native, wild species and communities), have also been cited by two sectors (Research and Conservation) (30% of respondents).

There is a total agreement between both respondent sectors (Promoters and Administration) about the most limiting environmental factors when initiating an aquaculture activity: the species selected, prevailing ocean-meteorological conditions, and the connection with the natural population in the context of potential disease vectors.

4.5.4. *Aquaculture and other uses/sectors*

There is no general agreement about the sectors/interests that are in conflict/compete with aquaculture in the Basque coast. Only Promoters and those from the Administration identified fishing as one use that could be negatively affected by the closure of a site in turn for aquaculture production. Research is the only sector which did not identify any negative perception regarding conflicts of use.

The four sectors (Research, Conservation, Promoters and Administration) agree that there is a positive public perception of aquaculture.

4.5.5. *Aquaculture and socioeconomics*

Although the majority of the sectors think aquaculture can be an attractive venture, cited reasons against it were high maintenance costs (Conservation) and high costs (Research). Those responsible for conservation do not consider aquaculture as a necessary activity.

There is general agreement that current infrastructure, services and logistics along the Basque coast are sufficient to allow this kind of activity, but there is disagreement with regards to a lack of residues collection facilities in ports (Administration).

“High initial investments” and “Market risks” were considered the most limiting economic aspects when initiating and developing an aquaculture activity (80% of respondents). As mentioned before, this could be related to the production technology used (not new) and the cultivated species (mussels), which has a very low market price.

Other indirect aspects such as the recovery of fishing grounds and re-population were mentioned as positive aspects of aquaculture.

4.5.6. *Aquaculture and other items*

The most commonly used tools are GIS, followed by remote sensing and maps.

A limited number of stakeholders use public data sources (or websites) to gather information related to aquaculture zoning. This could be due to a lack of awareness of the existence and accessibility of these sources, they may not be familiar with using these sources, or they may think that can get enough information from other sources.

Acknowledging this knowledge gap, most of the stakeholders showed an interest in acquiring training on these tools. The remaining 40% of respondents are possibly not interested in these tools, do not consider them useful or necessary for their activity, or have enough knowledge and do not need more training.

4.5.7. *Assessment of tools for aquaculture development in open water*

During the second workshop the tools developed in AquaSpace were presented and another round of questionnaires were distributed (Figure 4.3). The concepts behind the tools and examples of their applicability were presented in order to gather stakeholder opinions. The tools presented were: the AquaSpace tool, the WATER tool and the Investor Appealing Index.

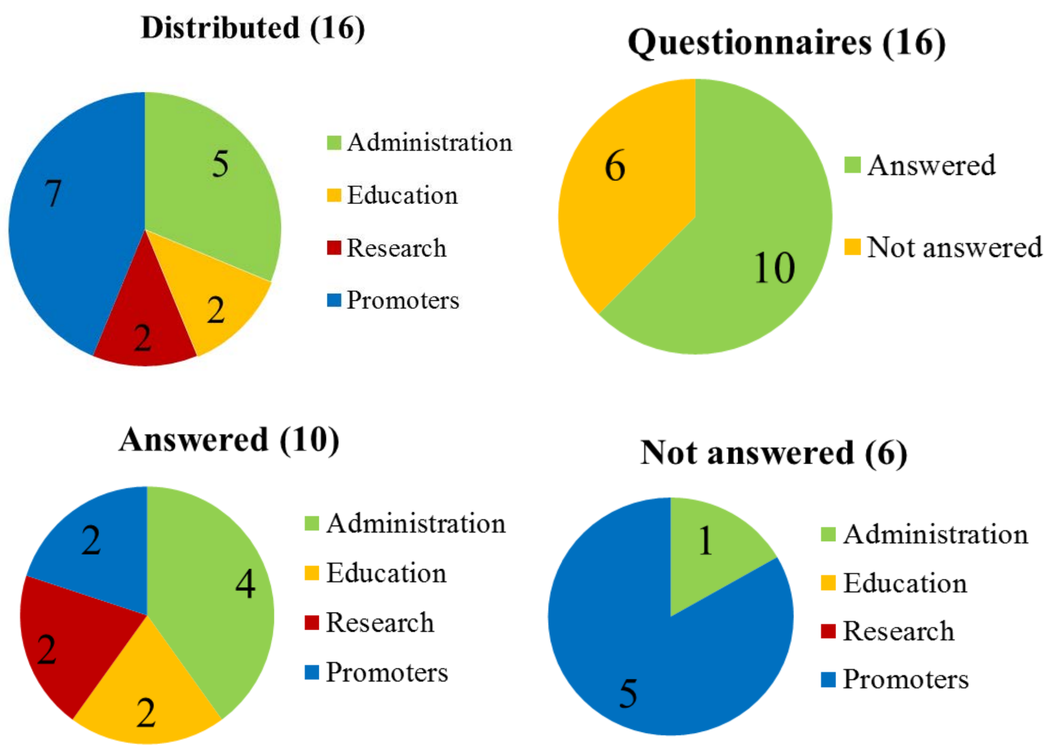

Figure 4.3. Participation of the stakeholders in the questionnaires distributed at the 2nd workshop in the Basque Country.

Stakeholders found the tools to be very useful. Furthermore, they agreed that the main aspects related to the selection of areas for the establishment and development of aquaculture, were considered in the tools developed in the AquaSpace project. However, some of the stakeholders noted that the conflicts of use and direct and indirect socio-economic consequences were not considered, while spatial planning and ecosystem services were considered partially (Figure 4.4). Approximately, 67% of stakeholders showed interest in using these tools. In relation to the usability of these tools, stakeholders found that they are difficult to use because advanced computer skills are required. When asked about new functionalities that could be interesting for them or the main field for tool applications, some main points raised were: (i) to support sectoral planning (fishing-aquaculture-goods traffic..); (ii) the ability of the tools to be utilised by students and future planners with different abilities; (iii) future developments in environmental monitoring and protection; (iv) need to incorporate continental aquaculture; (v) need to develop tools for the traceability of aquaculture products; (vi) further development of functionalities for environmental assessment; (v) more in-depth coverage of socio-economic aspects (aquaculture vs other sectors) would be useful; and (vi) they should be more simple, user friendly and web-based.

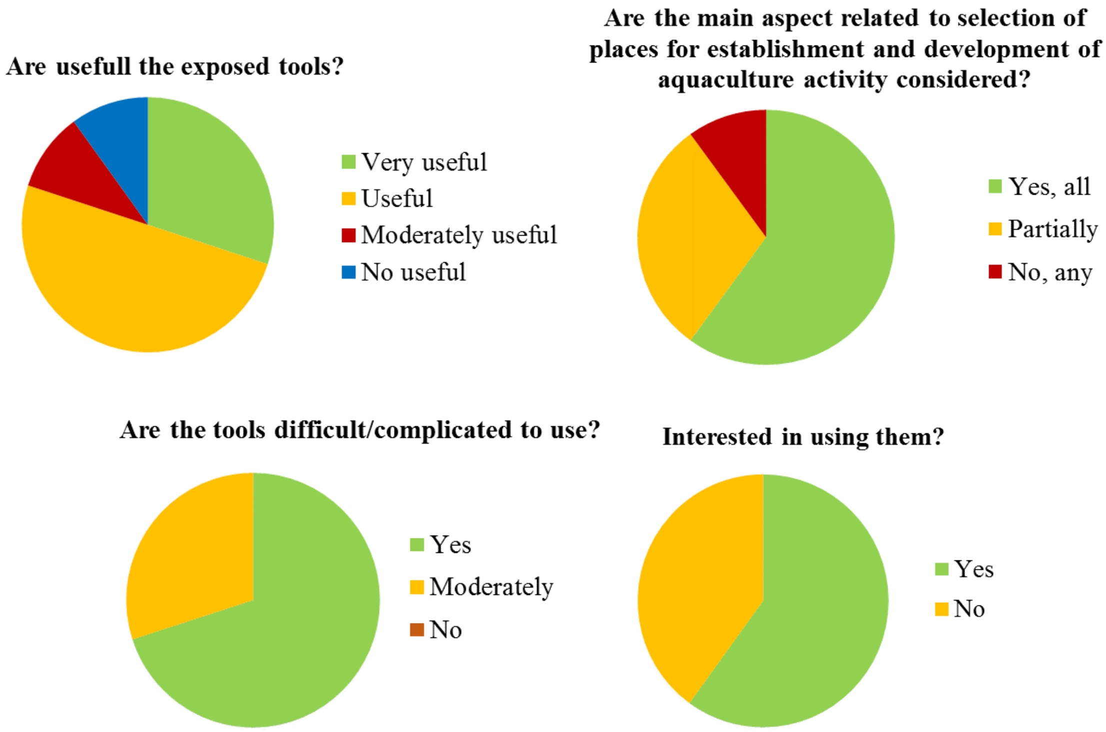

Figure 4.4. Questions and answers collected during the 2nd workshop with stakeholders

4.5.8. *Other relevant aspects*

Municipalities and associations of Ondarroa and Lekeitio, have expressed their interest in benefiting from the socioeconomic impacts of the resulting activity. The success of this activity may involve:

(i.) Improvement in the quality of life for the collective of Basque fisheries sector;

(ii.) Increase in the volume of locally produced food products with designation of origin;

(iii.) Reduction and/or diversification of fishing effort;

(iv.) Attracting investment and business by the aquaculture industry, generating the overall economy and employment for coastal areas;

(v.) Attraction of investment and strengthening of innovation; and

(vi.) Increase in aquaculture professional capacitation.

4.6. *Application of tools*

The aforementioned tools were implemented in an ongoing process of identification and assessment of development opportunities of open sea aquaculture in the Cantabrian sea. The first step in this process, was the performance of a multi-criteria analysis for suitable site identification using a GIS platform. Apart from this, development of the Bayesian Belief Network was started in order to assess the conflicts between aquaculture activity and fisheries, to try and identify relocation opportunities for fishermen. Finally, the specifically developed AquaSpace tool was implemented in the case study. This tool was used to assess the cost and benefit of different aquaculture options. Two different analysis were performed:

a) Intersectorial:

The offshore aquaculture as a new activity in the study area.

Interactions and conflicts of the use of space by artisanal fisheries (mainly)

b) Economic:

A general economic view of the aquaculture activity is presented according to future productivity and market expectations, (due to the lack of a current aquaculture industry in place). This specific view is conducted in two steps which is described in detail in the Aquaspace Tool manual (Deliverable 3.2). First, a quantitative potential assessment of the economic performance of aquaculture activity in the Basque Country is provided, by considering the current pilot production. To do so, a baseline scenario is used, where the average annual production at the end of year 5 will reach around 36 tonnes ha^{-1}, with a total number of 48 longlines producing 749 tonnes. This production is adopted for the purpose of carrying out an economic assessment. Other potential alternative scenarios for which different endogenous factors (e.g. a different allocation of the production parcels) could be considered, will allow production to reach about 45-60 tonnes ha^{-1}. The contribution of the aquaculture site to the economy is then assessed in terms of earnings before paying expenses, that is, the revenue (prices*quantity - tonnes) and added value (revenues minus intermediate/operating expenses such as fuel and feeding costs, among others) variables. In particular, for a total revenue of €1 ha^{-1} - taking first-sales prices around €0.65 kg^{-1} – an added value tax (added value/revenues) of 0.65 is obtained, being the profitability tax (profits/revenues) of 0.25. Secondly, in addition to the already shown aquaculture economic performance, the aquaculture economic effectiveness is also analysed with the idea of providing an assessment of the extent to which the specific economic objectives set for this activity are achieved. The effectiveness is measured by using the so-called aquaculture attractiveness through Return on Fixed Tangible Assets (ROFTA), that is, the return on the aquaculture investment measures as the following ration: RoFTA = Benefits/investment value. This value for the pilot production is around 0.09%.

Aquaculture activity in the Basque Country was initially promoted with the idea of contributing to diversification of the small-scale fishing activity (SSF) along the coastline. Under this framework, it is important to state that positive economic results from aquaculture activity will be added to the SSF revenues to get the total revenue from both activities. However, if the diversification is not introduced then, it is important to move into an additional concept, that is, the opportunity cost. The potential revenue that is forfeited by not developing an alternative (to the aquaculture activity) maritime use is called the opportunity cost. It could be expressed as the difference between the revenue resulting from the alternative use and that from the aquaculture activity.

Given that it is difficult to identify an alternative activity for an aquaculture investor, it is usually considered as the idea of investing money in other financial activities, therefore, the Annual Equivalent Return of a potential investment, (AER) - risk-free or not - could be established for comparative purposes. In particular, given the estimated ROFTA the opportunity cost will be 0.03% if the adopted investment AER reaches 0.06%.

Finally, the economic impact (induced direct and indirect impacts) of the aquaculture production on the rest of the local economy is assessed by using the general input-output model for Spain. Each revenue of €1 from aquaculture will generate an increase of €1.94 euro on the total economy.

4.6.1. *Output from AquaSpace Tool*

The main outcomes from the experience during the development, testing and implementation of the AquaSpace tool, were then transferred into a SWOT analysis.

The main aspects that open sea aquaculture is facing in this case study are related to constraints imposed by environmental conditions (waves exposure and production capacity) and conflicts with other users. Tools implemented in the case study have demonstrated their usability when tackling such issues but have also shown weaknesses and the new functionalities that are needed.

Higher spatial and temporal resolution environmental parameters data are critical for a precise site identification and characterisation. Availability of good quality data, would make a difference when running existing tools and methods. This means that the outcomes produced by existing tools would be much better if good input data was available. This in turn, would help to identify suitable areas for the establishment of new aquaculture infrastructures, as well as more reliable production capacity estimations. This would reduce uncertainty in the assessment of aquaculture viability and as a consequence, promote interest from industry and investors. At the same time, reliable estimations of production capacity would also help trade-off analysis between aquaculture and existing activities. An objective assessment would be very useful for mangers and decision makers.

4.7. Relevance of the case study within Aquaspace

The submerged longline culture method studied in this case study, is the only method for shellfish aquaculture in offshore conditions for now. This culture method could be used for algae or other species of commercial interest. The main interest is that open sea shellfish aquaculture has not been developed in the region (Cantabrian sea), and the aquaculture testing site in the Basque Country, is the first experience at regional level. Thus, the outcomes from this case study will lead to defining proposals focused on some local aspects (i.e. socioeconomics, spatial planning, regulation, user conflicts, ecological tools, etc.) of high relevance and clearly related to the cost-effective and profitable development of aquaculture in the open ocean waters of the Bay of Biscay.

Table 4.2. Strengths, Weaknesses, Opportunities and Threats identified when developing and implementing the AquaSpace tool.

Strengths	**Weaknesses**
Interactive Multi-criteria: considers and integrates policy, management, environmental, technical and social aspects in an integrative way Reporting and graphical demonstration of results Performs economic assessment and impact analysis It provides basic information to run analysis at European scale (i.e. the user can perform initial analysis without any extra information). Gives added value to publicly available information layers (EMODnet) Scenarios and "what-if" options for user Good visualisation capability Modular. More functionalities could be added Free	Needs advanced GIS (ArcGIS) skills during installation Need basic GIS skills to run the analysis Local data integration is complex (requires advanced user skills) Fixed mapping scale (1 km^2) The analysis resolution is too broad for local analysis Aquaculture species suitability is binary and should be gradational. Long processing time Lack of data for some of the environmental parameters Need for aquaculture specific information Limited economic data provided by statistical institutes to assess the economic impacts on the economy Market assessment is not included
Opportunities	**Threats**
Promotion of workshops in which the tool could be used with open discussions Implementation of the tool in web servers Get users inputs to feed into the tool Installation package (easier and automatic installation of the tool) Database structure is defined and the user can improve the results by adding higher resolution/reliability input data Background layer improvement by users Creation of a user platform	Licence cost for ArcGIS Competition with other site selection tools which have better background data Long term financial and technical stability Limited technical support

Better information will be publically available Improvement in suitability maps for aquaculture species Different mapping options Development of new functionalities Development of the tool for free GIS software	

4.8. *Conclusions and future prospects*

If Blue Growth is fully implemented and Blue Economies are to be promoted, aquaculture is one of the activities that is expected to grow significantly. This situation, as well as the expected increase and establishment of new activities, and at the same time the acknowledged need to restore and maintain good environmental status of marine ecosystems to keep them healthy and productive, and claim for better MSP. In turn, this requires better scientific knowledge on ecosystem functioning which could be transferred into reliable ecosystem models to be implemented into management tools. New tools developed under this concept should be integrative and consider the environmental, political, social and economic aspects equally.

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5. BÉKÉS COUNTY CASE STUDY, HUNGARY

Éva Kerepeczki (NARIC HAKI), Béla Halasi-Kovács (BHG), László Berzi-Nagy (NARIC HAKI), János Körösparti (NARIC ÖVKI), Gergő Gyalog (NARIC HAKI), Gábor Andrási (NARIC ÖVKI), Péter Palásti (NARIC HAKI)

5.1. General characteristics

Regulation of freshwater aquaculture has major links to the Water Framework Directive (WFD), the Habitats Directive and Birds Directive. Since the main goal of the WFD (reaching and maintaining good ecological status of water bodies) is not applicable to man-made round dam fishponds –where hypertrophic conditions are required for efficient production of natural food organisms - they have not been incorporated into WFD legislation and watershed management plans since 2015. The Birds and Habitats Directives resulted in a network of Natura 2000 sites to protect natural habitats and wild species. In Békés county 31 sites covering an area of more than 80,000 hectares is designated as Natura 2000 sites (14.4% of the total county area) among them Biharugra Fishponds. However, designation as a Natura 2000 site does not pose any management restrictions or duties on farms.

Deriving from the traditionally extensive or semi-intensive characteristics of Central and Eastern European pond aquaculture practices, the pressure aquaculture exerts on the environment is often small. Under extensive conditions the fish ponds are reported to even decrease the excessive nutrient content of the inflow water in some cases. Semi intensive fish ponds, if managed properly, provide continuous natural feed sources to the fish. However, the low intensity of these practices supports lower yields on average compared to intensive practices, the aquatic ecosystems of fish ponds provide a substantial (40-50%) natural growth of the cultivated fish species (omnivores) in this semi-natural state. In addition to the natural feed sources, a well-managed fish pond readily utilises low protein supplements (e.g. cereal grains and manure) and transform those nutrients into natural feed sources through the food chain, further boosting the productivity of the pond. The utilisation of different natural feed sources provided by the pond is often further facilitated by polyculture settings, using commercial fish species with different feeding habits. The production intensity of this near natural state fits very well with the carrying capacity of the environment and requires infrequent remediation (weed harvesting, sediment removal, liming etc.). The ecosystems of these ponds often provide rich habitats for wild animals and strengthen many other ecosystem services besides the provision of fish. Integrated practices are gaining popularity, however these are often the result of local cooperation, instead of forward planning. Integrated watershed management is the next required step in the context of EAA (Soto at al. 2008) which should be implemented in Hungary and in Eastern Europe.

5.1.1. *Geographical characteristics of Békés county and Biharugra Fishponds*

The ponds of Biharugra Fish Farm Ltd. are located in the Eastern part of Hungary, in Békés county, next to the Romanian border. The ponds are in the vicinity of the settlements of Biharugra, Zsadány and Geszt (Figure 5.1). The area is part of the micro-region called Kis-Sárrét. The region has typically high water retention capabilities. The landscape bears the marks of rivers, the peripheral areas show higher grounds of sediment origin, while the central areas are lower and valley-shaped. In the 19th century river regulation in the Körös valley resulted in the drainage of the original wetlands and marshlands. The previously inundated or frequently flooded areas became dry and this brought about increased soil salinity. Parallel to the drying, in the lowlands where water remained in the form of excess water, large areas had low agricultural value. As a result, the modified natural habitat became suitable for the establishment of fishponds. The ponds were constructed between 1917 and 1960. The Biharugra Fishponds are in two separate areas, the Biharugra Fishponds and the Begécs Fishponds. The total area covered by the ponds is nearly 2,000 ha.

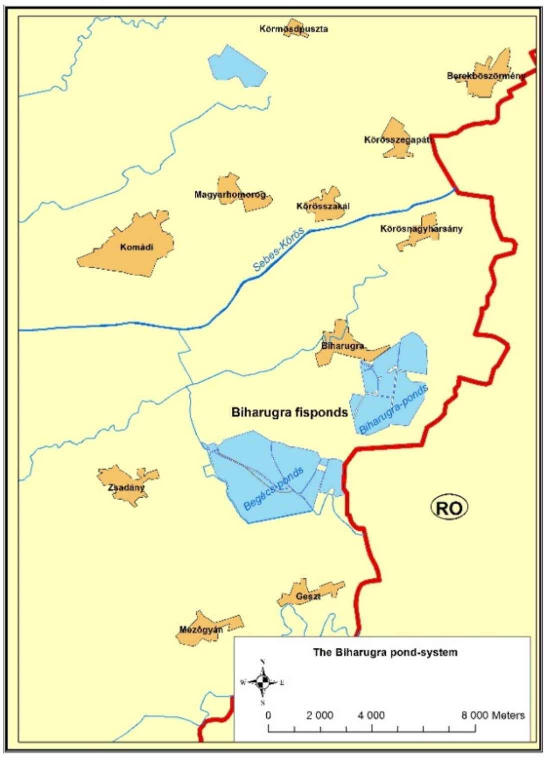

Figure 5.1. Geographical location of the Biharugra Fishponds

5.1.2. *Ecological features*

The wildlife was heavily affected by the altered water regime of the territory. The once unique and interconnected ecosystem is now becoming more fragmented and some habitats have vanished. Recently reeds, bulrush and other rushes typically accustomed to marshes can only be found in the lower lands, fishponds and in the reconstructed wetlands, which serve natural conservation roles. As part of the original vegetation saline grasslands and loess steppes still cover significant areas. The pondweed, reeds and bulrush are part of the original aquatic and semi-aquatic vegetation in the areas of Biharugra, Geszt, Zsadány and Mezőgyán. The wildlife fauna of Kis-Sárrét is rich however the habitats show mosaic complexes. The Carpathian endemic species are highly important. Because of the near Apuseni Mountains, sub-mountainous species can also be observed.

The construction of Begécs and Biharugra fishponds on one hand resulted in the disappearance of valuable marshy and saline habitats, on the other hand the water management of ponds created refuges for the original wildlife of Kis-Sárrét. The specific environmental conditions provided by the ponds and the pond farming technology create refuges for the aquatic and semi-aquatic wildlife in the otherwise dried out region. Furthermore, these ponds serve as stepping stones maintaining connections between populations of different wild species. The large water surface is beneficial for the microclimate and water management of the area, however their importance to maintain wildlife is even higher. Among the taxa supported by these conditions and activities, the waterfowl population is the most significant. Around 200 bird species frequently visit the pond areas, which serve as important nesting and feeding habitat for them (Figure 5.2). Besides the avian fauna, the fishponds provide habitats for otter (*Lutra lutra*), reptilian and amphibian species. Another important aspect of wildlife is the protected and vulnerable fish species characteristic of the fishponds or in the water courses feeding the ponds. The invertebrate species of dragonflies and damselflies (*Odonata*) are also frequently found in the area. The natural environment of Biharugra fishponds is of international importance, it is listed as an area of international wetland importance under the Ramsar Convention as well as subject to national legal protection. Imposing protection of fishponds serves the explicit purpose of conservation of largely extended wetlands.

The natural value associated with the fishponds is strongly linked to the proper management. The fishpond ecosystem is artificially maintained with high fish biomass, with the aim of transforming most of the added nutrients into fish biomass, which is then removed from the system at harvest. An important feature of this ecosystem is the high density of planktonic organisms, which rely on the easily accessible nutrients in water. This state is primarily maintained by the fish stock, the additional management (e.g. weed cutting, manuring) is only used to keep the fundamental conditions.

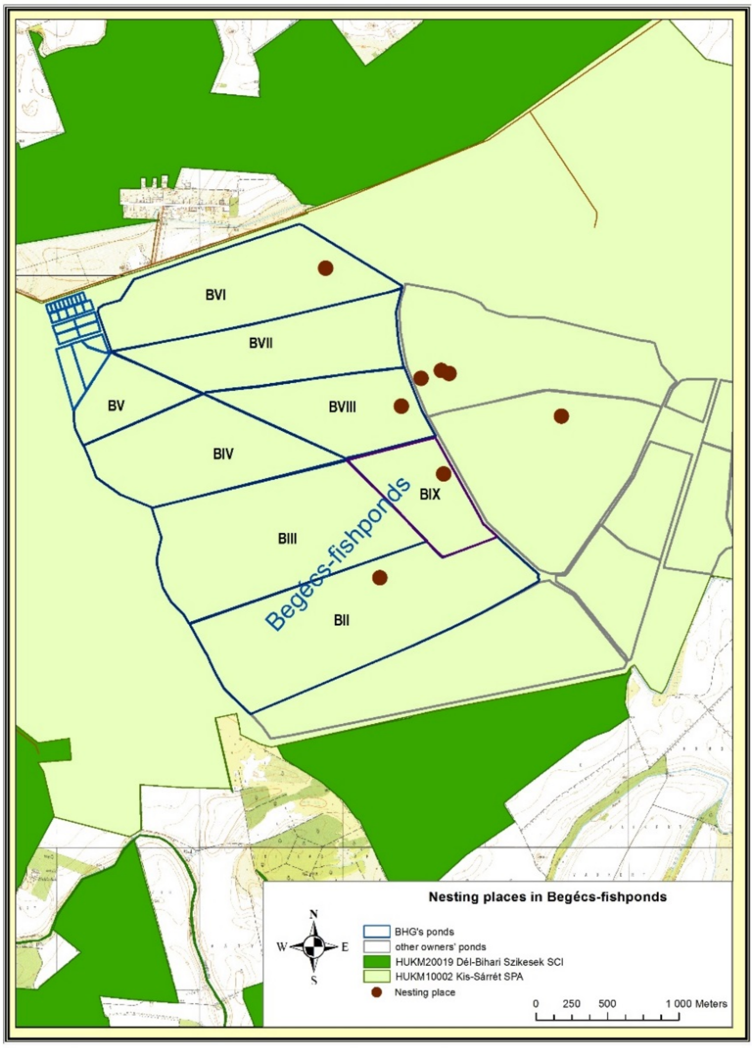

Figure 5.2. Location of fishponds and important nesting sites in Begécs-fishponds

Consequently, the management of stocking material and quantity is crucial in pond production. The higher nutrient input in fishponds leads to enlarged populations at every trophic level of the pond, meaning that fishponds provide habitats to more organisms than it would under natural conditions. Another important aspect of fishponds is the schedule of annual filling and drainage. The delays between fishing procedures result in the coexistence of various habitats (aquatic, semi-aquatic, terrestrial) and in this way, support a complex habitat structure. The size of the pond system significantly relates to its role in sustaining natural values (Halasi-Kovács 2012).

5.1.3. *Socio-economic context*

Békés county (Figure 5.3) has the seventh largest area (5,630 km^2, 6%) of the 19 counties of Hungary, it has a population of 351,148 (2015) and is ranked 11th in terms of county population. The majority of the population (75%) live in towns but the economy is less developed, its GDP per capita expressed in purchasing power standard is only 38% of the EU average (2013). Its economy is based on the service sector, industry and the agriculture. Békés has important levels of employment in agriculture (10%) including aquaculture.

Based on the disadvantaged geographical location, poor infrastructural conditions and the unfavourable situation of the local economy, the county is not attractive to new investments. The settlements around the fish farm (Biharugra, Körösnagyharsány, Geszt, Zsadány, Okány) primarily depend on agricultural activities. The number of registered companies in this area is generally low. Unemployment is very high (30-40%) in the region and emigration is continuous. The population shifted to the older ages and half of the registered unemployed people have finished primary school or lower. The underdeveloped areas struggle to create new job opportunities and the quality of life is generally degrading (Puskás and Halasi-Kovács 2012).

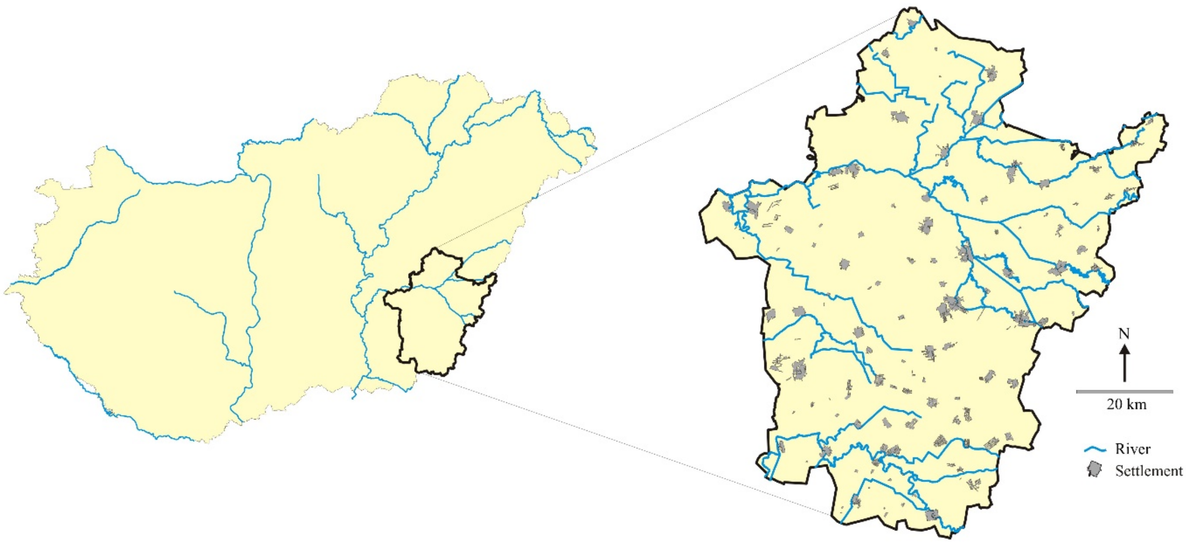

Figure 5.3. Map of Békés County

5.2. Spatial planning and management issues

The total operating pond area in Békés is 2010 ha representing 8% of the Hungarian pond areas (2014). The main pond system is situated in the surroundings of the village of Biharugra, which with an area of 1927 ha is the second largest fish pond system in Hungary.

The major species produced in Békés is common carp (*Cyprinus carpio*), followed by the intensive tank-based production of African catfish (*Clarias gariepinus*). Other carp species (silver, grass, bighead carp) and carnivores (European catfish, pikeperch, pike) are cultured in smaller quantities.

Although the production intensity of fish ponds is generally low and there are cases when aquaculture removes the surplus nutrients from the water, issues with environmental policies do exist. The effluent water from fish ponds has higher levels of suspended solids and organic matter and has the potential to harm the natural recipient water bodies. The barrage dam ponds similarly alter the downstream section of the rivers. Aquaculture also contributes to the invasion of non-native fish species and can possibly result in conflicts with natural protection agencies. Furthermore, nature conservation policies and protection of waterfowl often result in conflicts with pond fish production, as predatory animals are commonly responsible for losses in fish yield. This issue is a frequently recurring problem and is of high importance. Compensation from the governments in Central Europe is generally low or insufficient, or predator specific, ignoring other predators. In Hungary such compensation is lacking.

Whilst the case study focuses on pond culture, the share of intensive production of African catfish and sturgeon indicates the growing importance of this segment and the potential of the intensification of fish production based on ample volume of water resources and the know-how available in the county. The integration of tank-based and extensive pond systems enables a sustainable way to further develop aquaculture in the region.

Table 5.1. Aquaculture production, Békés county 2014

	Extensive pond culture			**Intensive tank-based culture**		
	Common carp	Silver carp	Grass carp	African catfish	Sturgeon	Caviar
Produced fish (tons)	957	155	51	695	8.7	0.64
% of Hungarian production	9.3	11	10	32	18	96

Trends in freshwater pond culture are moving towards sustainable intensification and more structured production technologies, like pond-in-pond method, are spreading.

5.2.1. *National and EU policy (summary of multi-annual strategic plans)*

EU Member State specific strategies had to be developed in line with the national challenges and opportunities with a focus upon improving environmental sustainability of the aquaculture sector; and there is considerable emphasis on environmental services provided by aquaculture sites. The Hungarian long-term strategy involves a plan for:

- maintaining the current pond area for extensive aquaculture and strengthening its ecological functions (habitat provision, microclimatic effects, landscape formation),
- modernisation of existing production units (development of new technologies),

- diversification of the aquaculture sector in terms of produced species (with high market potential) and activities (multi-functionality, angling, ecotourism),
- knowledge transfer and exchange of best practices at the national level and also between Member States,
- development of the post-harvest value chain and boosting the local population's demand for freshwater products.

Thus, spatial expansion of pond aquaculture is envisaged to a limited extent by the national aquaculture strategy, and low financial incentives are available to build new ponds.

5.3. Stakeholder engagement and participation

1st STAKEHOLDER WORKSHOP
13 January 2016 Biharugra, Békés County, Hungary

The workshop was jointly organised by the Biharugra Fishfarm Ltd, the Research Institute for Fisheries and Aquaculture (NARIC HAKI) and the Research Department of Irrigation and Water Management (NARIC OVKI). The venue was the Birdwatch Centre of the Körös-Maros National Park near to Biharugra Fishponds which enabled the participation of local stakeholders. The aim of the Hungarian workshop was to discuss the main issues of pond based freshwater aquaculture with all the relevant stakeholder groups, producers, national aquaculture associations, researchers, academics, national parks, NGOs, water authorities, environmental agencies and decision makers from local and national levels. There were 55 participants at the workshop.

The stakeholder presentations at the workshop summarised the future prospects for pond aquaculture. Delegates from relevant sectors made presentations and commented on the relationship between pond farming, water management, nature conservation and environmental issues.

List of participants at the 1st AquaSpace stakeholder workshop in Hungary (invited speakers in bold)

Industry (companies):		
1	Borbála Benkhard	Biharugra Fish Farm
2	Béla Halasi-Kovács	
3	Nándor Puskás	
4	Attila Sebestyén	
5	István Dankó	Aranykárász (fish farm)
6	Szilárd Csaba	Agropoint (fish farm)
7	**Csaba Kakuk**	i-Cell Mobilsoft (fish farm)
8	**Máté Katics**	Czikk-Halas (fish farm)

9	Ferenc Lévai	Aranyponty (fish farm)
10	Zsolt Jaberits	
11	**János Sztanó**	Szegedfish (fish farm)
12	**István Szűcs (PhD)**	Hungarian Aquaculture Association
13	**László Váradi (PhD)**	
	Management:	
14	Annamária Hegedűs	Inspectorate for Environmental Protection and Nature Conservation (Government Office of the city of Gyula)-environmental authority
15	Ildikó Kopcsákné Lakatos	
16	Magdolna Lipták	
17	Máté Kurucz	Körös Valley District Water Directorate
18	János Szabó	
19	Péter Lengyel	Ministry of Agriculture
20	**Ágnes Tahy**	General Directorate of Water Management
21	Ilona Vígh	Municipality of Biharugra
22	Anikó Juhászné Mári	Körösi Vízgazdálkodási Társulat -management of water infrastructure
23	Attila Szántó	
	Other sectors:	
24	Péter Bánfi	Körös-Maros National Park
25	István Bíró	
26	Attila Terhes	
27	**László Tirják**	
28	Péter Szinai	Balaton-felvidéki National Park
29	Attila Králl	Hungarian Ornithological and Nature Conservation Society (civil sector)
30	Dénes Nagy	
31	Péter Tóth	
32	János Tőgye	
33	**Béla Kelemen**	Geosafe Környezetgazdálkodási Mérnöki Iroda (SME on environmental consulting)
34	László Rózsa	
	Academic sector:	
35	Gábor Andrási (PhD)	

36	László Ardó (PhD)	NARIC (National Agricultural Research and Innovation Centre), HAKI (Research Institute for Fisheries and Aquaculture) and ÖVKI (Research Department of Irrigation and Water Management)
37	László Berzi-Nagy	
38	Emese Bozánné Békefi	
39	Gyöngyvér Fazekas	
40	Gergő Gyalog	
41	Dóra Groó (PhD)	
42	Máté Havasi (PhD)	
43	Zsigmond Jeney (PhD)	
44	Éva Kerepeczki (PhD)	
45	Gyula Kovács	
46	János Körösparti	
47	Neetu Shahi	
48	Flórián Tóth	
49	Zou Zhiying	
50	Zoltán Bokor (PhD)	Szent István University
51	Balázs Duray (PhD)	
52	Fruzsina Tóth	
53	Béla Urbányi (PhD)	
54	**Mónika Bojtárné Lukácsik**	Research Institute of Agricultural Economics
55	Ágnes Harovits	

The stakeholder workshop was viewed as an important milestone in the consultation process among the representatives of different sectors (industry, authorities, national park, NGO, academic institutes, local and national decision-makers) involved in aquaculture. Interactive dialogue and joint problem solving is not commonly used in Hungary and Eastern Europe, thus the goal of the workshop to gather different stakeholders and discuss current constrains was a breakthrough activity and was accepted very positively. The continuation of the consultation and seeking a joint solution for the concerns identified is a significant development in supporting the aquaculture sector.

2nd STAKEHOLDER WORKSHOP
4 May 2017 Szarvas, Békés County, Hungary

The 2nd workshop was a continuation of the 1st Aquaspace stakeholder workshop and aimed to collect feedback on project results and case study implementation. The venue was the conference facility of NARIC HAKI. 27 representatives from the Agricultural Ministry Angling and Fisheries Department, General Directorate of Water Management, MA-HAL Hungarian

Aquaculture and Fisheries Inter-branch Organisation Hungarian Ornithological and Nature Conservation Society and several fish farms, research institutes participated in the meeting. Tools and methods used in the Case study were presented including i) multi-layer GIS mapping for selection of suitable aquaculture sites, ii) biophysical and socio-cultural valuation of ecosystem services which will be further developed into an integrated method and iii) cross-sectoral stakeholder consultation on constraints to the development of the aquaculture industry. Finally, invited speakers contributed to present project results, give feedback and opinions on suggested tools and topics.

List of participants at the 2nd AquaSpace stakeholder workshop in Hungary (invited speakers in bold)

Industry (companies):		
1	Béla Halasi-Kovács	Biharugra Fish Farm
2	Bence Sziráki	MA-HAL, Hungarian Aquaculture and Fisheries Association
3	István Dankó	Aranykárász (fish farm)
4	István Darázs	Fishfarm of Kisköre
5	**István Németh (PhD)**	MA-HAL, Hungarian Aquaculture and Fisheries Association
6	János Sztanó	Szegedfish (fish farm)
7	Máté Katics	Czikk-Halas (fish farm)
8	Tibor Müller	Szarvas-Fish Ltd. (fish farm)
9	Zoltán Rozgonyi	Munka Agricultural Ltd.
Management:		
10	**Gábor Csörgits**	Ministry of Agriculture
11	**Gábor Kolossváry**	General Directorate of Water Management
Other sectors:		
12	László Tirják	Körös-Maros National Park
13	**Péter Tóth**	Hungarian Ornithological and Nature Conservation Society (civil sector)
14	György Hajtun	press, Magyar Mezőgazdaság journal
Academic sector:		
15	Attila Mozsár (PhD)	NARIC (National Agricultural Research and Innovation Centre), HAKI (Research Institute for Fisheries and Aquaculture) and ÖVKI (Research Department of Irrigation and Water Management)
16	László Berzi-Nagy	
17	Emese Bozánné Békefi	
18	Gergő Gyalog	

19	Dóra Groó (PhD)	
20	Zsuzsanna Sándor Jakabné (PhD)	
21	Éva Kerepeczki (PhD)	
22	Péter Palásti	
23	János Körösparti	
24	György Kerezsi	
25	Csaba Bozán	
26	Mónika Bojtárné Lukácsik	Research Institute of Agricultural Economics
27	Ágnes Irma György (PhD)	

The workshop was characterised by a constructive atmosphere and participants shared their insights, ideas, problems and supported recommendations from each other. A short questionnaire was completed by the attendants and all of them supported future cross-sectoral dialogue beyond the AquaSpace project lifetime. Suggested future topics were: legal inconsistencies, water management issues, promotion/marketing of fish consumption, traceability of fish products, processing possibilities, conservation of natural values.

5.4. Tools used in the case study

5.4.1. *Multi-layer GIS mapping and databases*

GIS is an appropriate toolkit for spatial planning and site selection through the integration of numerous layers, like soil properties (chemical, physical, soil structure), relief features (for the engineering planning tasks), the amount and quality of the available water for irrigation as well as available infrastructure conditions (canal and road system, electric power supply).

The suitable databases for planning and mapping include: land registry maps, settlement maps, hydrological maps and data, national and regional statistics, open access maps and databases (e.g. land cover database: CORINE). In national spatial planning a basic and important dataset is the M: 1:10000 topographic map, the derived files from that map (e.g. determine the lowland areas – paleochannels – for hydrological tasks with the Digital Terrain Model - DTM); hydrological and water use database of General Directorate of Water Management.

5.4.2. *Biophysical and socio-cultural valuation of ecosystem services*

Ecosystem services related to semi-intensive fish ponds were identified by expert panel discussions and followed typology and classification of MEA (2005) and de Groot et al (2002) methodology indicators selected on the basis of existing biodiversity data, production and water chemistry parameters at the Biharugra Fishponds case study site. Via semi-structured interviews (Patton 2002) the importance of provisioning, regulating, supporting and cultural services were rated by local inhabitants in five villages in the vicinity of the Biharugra Fishponds.

5.4.3. *Stakeholder meetings*

As a result of the 1st AquaSpace case study workshop it was recognised that direct interactions via face to face meetings are very beneficial in identifying and discussing constraints on pond fish production and to gather specific inputs from a targeted audience to solve problems and help aquaculture development. The Stakeholder meetings were regarded as a tool whereby several stakeholder groups and sectors that are affected or interested in pond aquaculture can communicate and share solutions, ideas and good practices. The need to co-organise stakeholder meetings with well-defined topics in the future was suggested to Hungarian Aquaculture and Fisheries Association at the 2nd stakeholder workshop and the president of the association ensured his support to continue stakeholder consultation on the highlighted issues.

5.5. Case study results

5.5.1. *Multi-layer GIS*

The territory of Szarvas district, Békés county (HU) was included in the GIS site selection mapping. On the initial map applied for the selection of the small-scale fish ponds, the lakes and the buffer zones surrounding them, as well as the settlements appear (Figure 5.4.). Different layers of the zone map identify those areas where environmental factors, anthropogenic effects or legislation preclude the construction of ponds:

- Digital Terrain Model (DTM) and derived thematic maps (elevation, relief intensity, closed depressions, channel network base level),
- Lithology map (a complex index taking into consideration the depth and thickness of the uppermost aquitard),
- Thematic soil map (unsuitable features for water management, high clay content),
- Highly sensitive water protection areas,
- Nitrate Vulnerable Zones,
- Map of relative frequency of excess water,
- Complex Excess Water Hazard Index (excess water hazardous areas) (Pásztor et al. 2015),
- Nature conservation areas and their buffer zones, areas planned for protection and areas of green corridors, Natura 2000 sites,

- CORINE Land Cover land use map,
- Areas in the regional development plan which will be developed for aquaculture purposes
- Stagnant waters (natural and artificial lakes, ponds),
- Groundwater protection area.

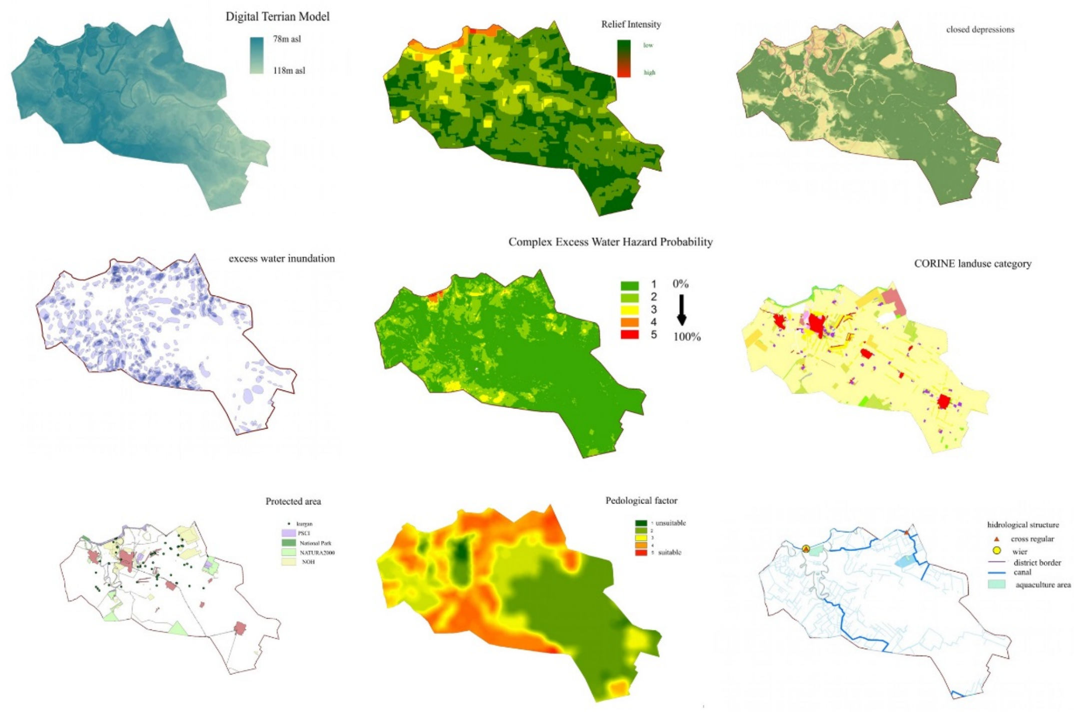

Figure 5.4. The most important individual layers combined in the mapping process

In the course of site selection, the operation of lakes, current and planned influential linear facilities, and natural and artificial drainage systems were taken into account. Important linear facilities:

- river and canal network (major drainage structure canals, service canals),
- public road and dirt-road network,
- linear facilities (electrical network, underground cable, pipeline),

Numerical, statistical and measured data were used for GIS analysis. These data were included in a comprehensive database. Attribute data used:

- hydrography data (water regime, canal discharge),
- database of hydraulic structure (cross-section of flow, flowing speed),
- database of freshwater quality (biological oxygen demand, pollutant, etc.),
- regional watershed management plan.

A GIS base map was created by overlaying the different layers with each other (Figure 5.5). In the spatial planning documentation for the technical description, the map materials closely connect with each other.

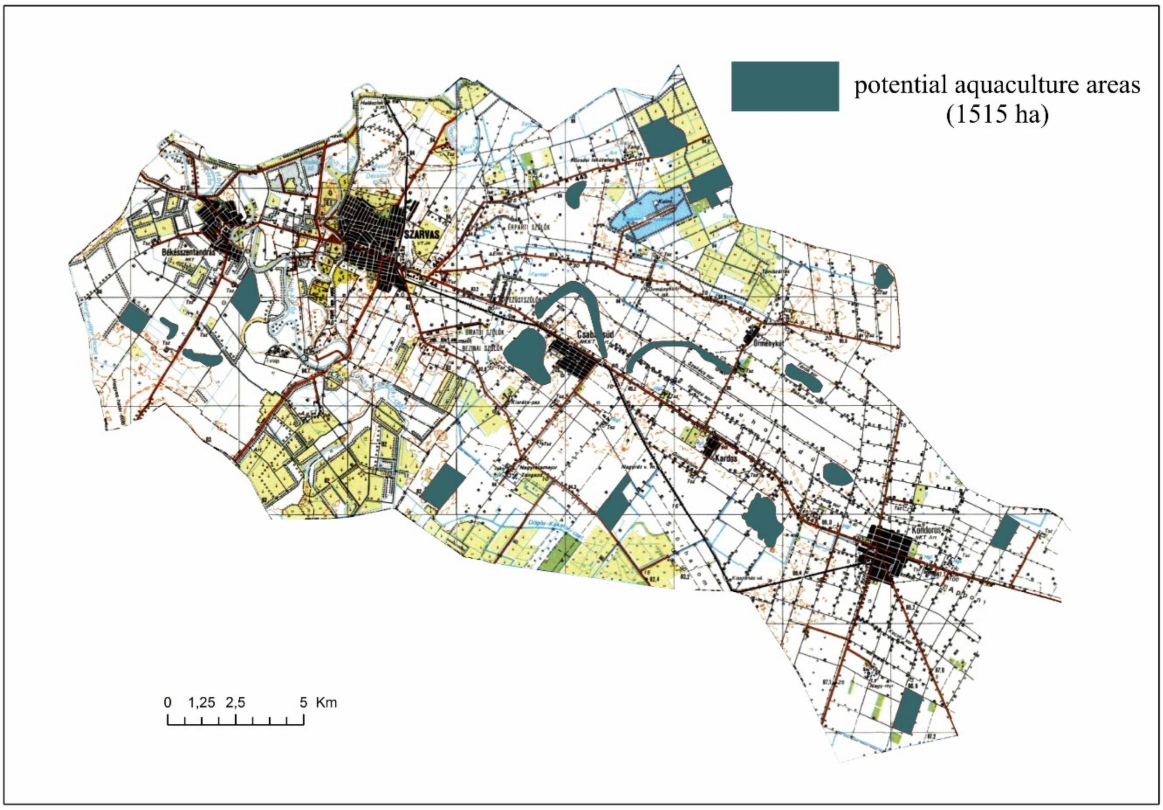

Figure 5.5. The GIS base map created by overlaying different geographical, hydrological and land use layers

5.5.2. *Valuation of ecosystem services*

According to stakeholder feedback at the workshops and personal communications the value of ecosystem services provided by fish ponds is a highlighted topic among pond owners, governmental officers and academic experts. This is a new approach to identify and evaluate benefits from inland fish production beyond marketable values and to maintain them. During case study implementation, the goal was to develop a biophysical assessment method that could be conducted in other fish pond systems as well. Identified and validated ecosystem services provided by extensive and semi-intensive fish ponds include: (following the typology of de Groot et al. 2002):

- Fish
- Reeds
- Water retention
- Excess water protection
- Water quality regulation
- Microclimate regulation
- Nutrient cycling
- Pollination
- Habitat and nursery for wildlife
- Landscape beauty
- Recreation
- Artistic inspiration
- Research subject
- Educational sites

After identification of the ecosystem services, the relevance for Biharugra Fishponds were validated and measurable indicators were assigned to each ES (Berghöfer and Schneider 2015). After checking the availability of data only five services could be considered (Table 5.2 and 5.3).

Table 5.2. Biophysical value of relevant case study ecosystem services (ES)

ES	Indicator	Unit	2011	2012	2013	2014	2015	2016
Fish	yield, harvested fish biomass	kg/y	440 569	334 935	666 804	861 349	839 365	892 593
		kg/ha/y	698	530	831	1073	1046	1112
	common carp yield	kg/y	256 191	268 163	517 012	658 372	578 975	657 920
	ratio of common carp	%	58%	80%	78%	76%	69%	74%
	natural yield (above calculated feed yield)	kg/ha/y	-	-	-	628 785	579 162	606 963
Reeds	Area	ha	150.6	150.6	150.6	150.6	150.6	150.6
Water retention	water volume intake	m³	635 040	1 131 840	3 589 920	5 797 440	16 351 280	14 477 641
	water volume discharge	m³	-	1 400 000	-	2 295 000	3 002 400	2 808 000
Habitat	No of semi-natural habitat types	No	8	8	8	8	8	8
	ratio of non-pond semi-natural habitats	% of area						
	No of species of selected taxa*	sum of species no	110	118	105	109	104	-

*selected taxa: birds, reptiles, amphibian, otter, ermine

The most significant challenge was the poor availability of datasets, biodiversity data are very limited since many taxa are not examined at all, or just sporadically. The only detailed records about birds exist thanks to engaged ornithologists and NGO activities. Weather and climate data were not accessible either. In the case of polluted rivers and canals, the fishponds were reported to decrease nutrient content in the water column (Gál et al, 2016), however different results are shown in Table II, only the concentration of total inorganic nitrogen was lower in the outflow water than input values.

Table 5.3. Comparison of input and output concentration values related to water quality regulation

ES	Indicator	unit	2014	2015	2016
Water quality regulation	Input and output concentrations				
	Chemical oxygen demand out	mg/l	8.8	7.4	5.0
	Chemical oxygen demand in	mg/l	44.3	35.1	42.3
	Ammonium nitrogen in	mg/l	0.073	0.060	0.116
	Ammonium nitrogen out	mg/l	0.352	0.186	0.100
	Total inorganic nitrogen in	mg/l	0.900	0.667	1.167
	Total inorganic nitrogen out	mg/l	0.395	0.313	0.230
	Difference	%	-56%	-53%	-80%
	Total nitrogen in	mg/l	0.920	0.980	1.360
	Total nitrogen out	mg/l	1.308	1.500	1.303
	Total phosphorous in	mg/l	0.105	0.057	0.040
	Total phosphorous out	mg/l	0.202	0.181	0.172
	Total suspended solids in	mg/l	18.3	23.0	9.0
	Total suspended solids out	mg/l	30.4	37.4	40.8

To evaluate all ecosystem services provided by the Biharugra Fishponds and involve local inhabitants, a socio-cultural assessment was conducted. In five neighbouring villages 70 interviews were conducted, asking people about the importance of ecosystem services, they could give a value between 1 and 5 to the listed ecosystem services. According to the answers the services were ranked and are shown in Figure 5.6. The highest and maximum value was given in all settlements to the Habitat service, presenting the high importance of wildlife and biodiversity for local inhabitants.

The interviews enabled communication with local people and explored their preferences and highlighted the value of fishponds to them. Interestingly, most inhabitants rarely or never visit fishponds, though the younger generation has the opportunity to visit the ponds through school activities.

The valuation efforts provide a basis for the recognition of beneficial services of semi-intensive fishponds and raise awareness of pond fish production and aquaculture products.

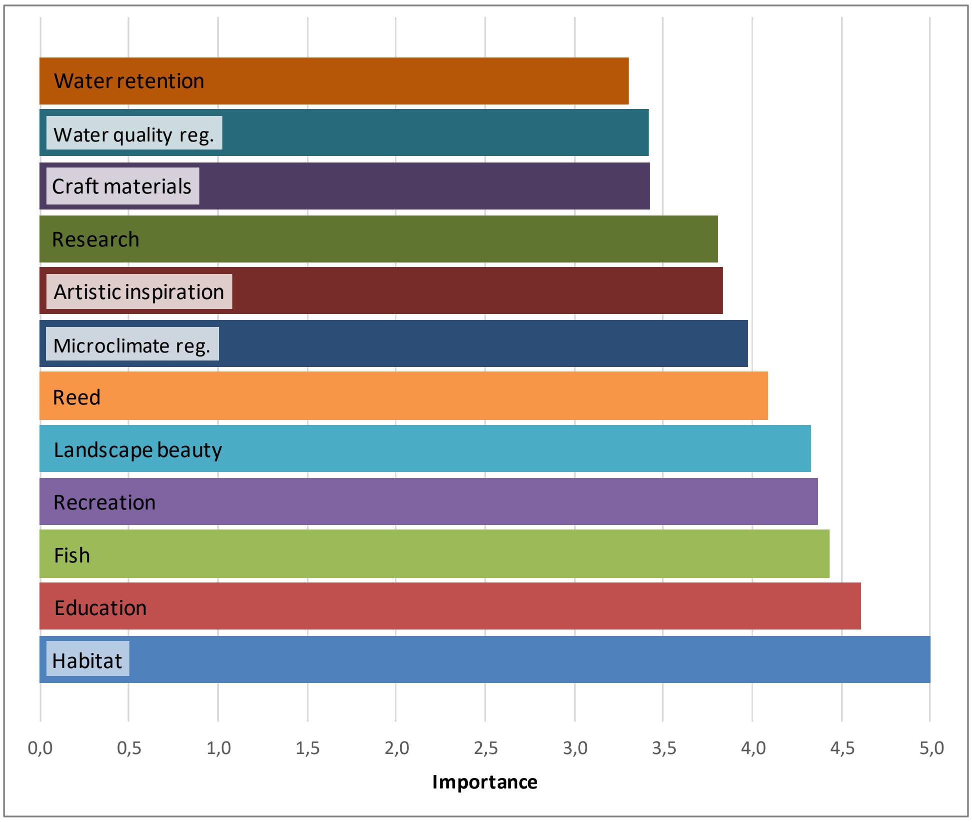

Figure 5.6. Importance value given to the ecosystem services of Biharugra Fishponds

5.5.3. *Stakeholder meetings*

At the 2nd stakeholder workshop the participants were asked to recommend topics for future cross-sectoral meetings. They suggested broadening the invited groups and facilitating dialogue with authorities and decision makers. The output was a summary of the meeting with tangible solutions and recommendations. The results show a significant number of issues as follows, showing the high levels of interest in the discussions.

- regulation and legislative background to clarify contradictions and inconsistencies
- harmonisation of production and consumption, to better understand consumer demands
- natural values of fishponds and best practices on how to maintain them
- water use, discharge and storage
- flesh quality of produced fish
- water quality constraints, water treatment
- processing technologies
- marketing, enhancing fish consumption
- standards
- sharing best practices
- traceability and labelling of fish and processed products
- ecosystem services
- regional water management and aquaculture
- angling and fishponds/relationship with natural waters

5.6. Relevance of the case study within Aquaspace

The freshwater case study is different from mariculture cases in that:

- The land and water resources are not shared between aquaculture and other sectors but privately owned by fish farmers based on market mechanism principles (pond area is bought/rented and the amount of water utilised is paid for by the fish farmers)
- Being half way between fed and non-fed aquaculture, carp farming can either increase (such as cage farming) or decrease (such as mussel farming) the nutrient content of waters, depending on the farm management
- Its visual impact is not considered to be negative
- The main interactions are with terrestrial sectors and not with marine sectors. Both competitive and synergistic interactions exist. The main areas where conflicts/synergies arise relate to water and land
- The farming environment (pond) is a man-made construct and not natural (such as bays or estuaries in case of cage and mussel farming).

5.7. Conclusions and future prospects

Regarding the participation and perspectives of stakeholders, they were very active and farmers were open to consult and share their opinions on current and future needs and challenges for aquaculture. After the 2nd workshop aquaculture producers' associations adopted the idea of cross-sectoral dialogue in critical issues and the organisation is willing to continue this beyond the project's duration. The next step is to establish and agree the future format and background for consultation workshops.

AquaSpace provided new knowledge to the case study by highlighting the importance of consultation and participatory processes for different stakeholder groups (face-to face meetings), and how these can eliminate false assumptions and increase awareness of aquaculture industry efforts. Aquaspace also enabled the stakeholders to:

- adopt the EAA principles: consider other sectors aspects and use a holistic ecosystem or watershed approach
- utilise experience in MSP and ICZM for freshwater development i.e. modelling approach, its limitations and possibilities
- integrate more databases and issues into one tool
- show that multi-layer mapping is a suitable basis/method that can be refined according to stakeholder needs. However specific data were not available or do not currently exist (more detailed water resource data, other water user needs, predictions based upon climate change scenarios)

- demonstrate that spatial planning can use more abundant datasets. In freshwater areas few and very fragmented data are available (no open access, many administrative organisations involved in data).

Regarding implementation or consideration by managers or decision-makers to adopt the approach and concepts developed in AquaSpace it can be stated that

- the concepts used in AquaSpace were welcomed and appreciated by stakeholders ("AquaSpace provided the only forum where ornithological organisations can communicate with fish farmers and related governmental bodies" - NGO feedback)
- Multi-layer GIS needs huge efforts and data collection/acquisition, to extend GIS tool to national scale but would be useful to integrated watershed management and land use planning
- Valuation of ecosystem services at national level would also be beneficial: lack of human, institutional and financial resources, although could be used in economic compensation of wetland and natural value maintenance
- Stakeholder meetings: a co-creation tool of new solutions was also welcomed and supported by all stakeholders.

Regarding the role of the outcomes from AquaSpace in the development of national spatial planning it is concluded that there are the following needs

- spatial planning for pond aquaculture: WFD watershed management is very general and has lower resolution than is needed to plan aquaculture water use
- to enhance aquaculture development and expansion where suitable water resources are and will be available

The benefits that can be derived from using spatial planning tools to address the national issues are the implementation of more efficient land use and water use planning based on detailed and integrated maps.

5.8. References

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6. CARLINGFORD LOUGH, UK

Adele Boyd, Matt Service, Heather Moore

6.1. General characteristics

Carlingford Lough is a sea lough at the mouth of the Newry (or Clanrye) River on the east coast of Ireland, bordering both the Republic of Ireland (County Louth) and Northern Ireland (Counties Down and Armagh) (Figure 6.1).[2] The upper reaches of the Lough are shallow and dominated by fine muddy sand and intertidal mud-flats, whilst the seaward entrance to the Lough is a mixture of boulder, cobble and bedrock forming numerous small islands and reefs (Figure 6.2). Table 6.1 gives a detailed description of the Habitat types depicted in Figure 6.2.

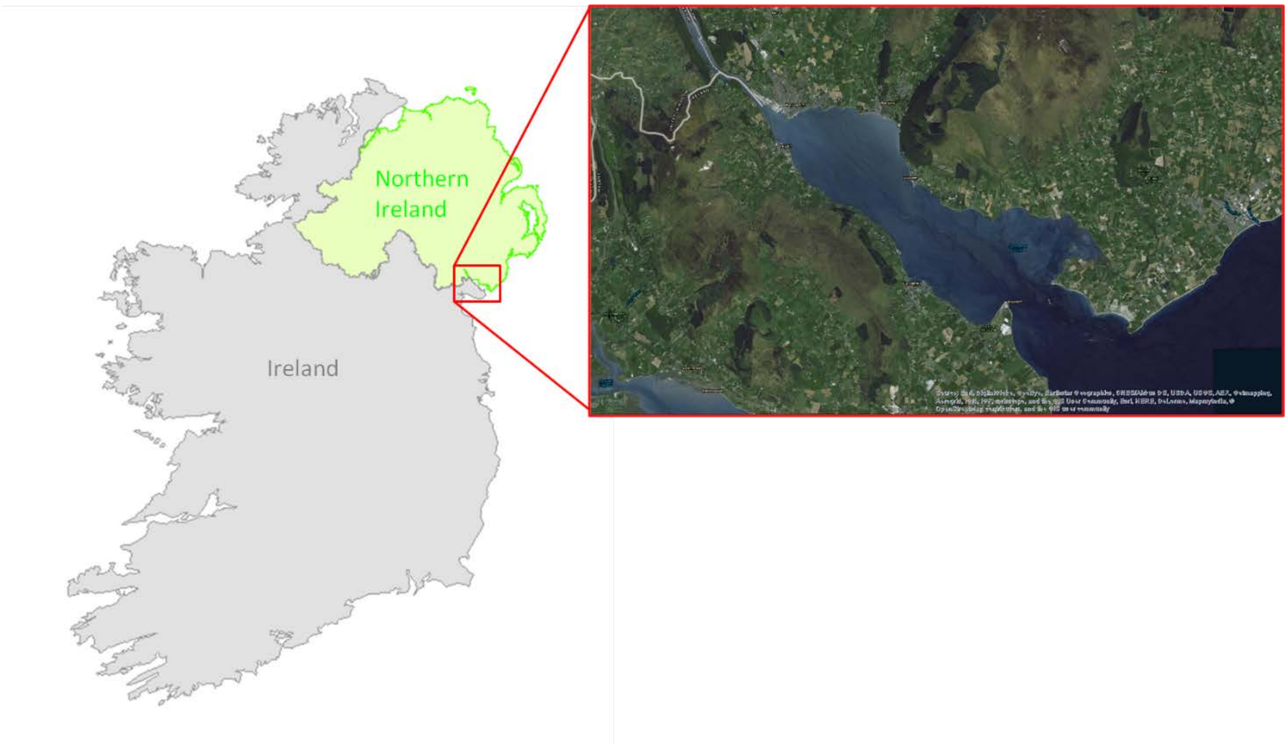


Figure 6.1: Location of Carlingford Lough

[2] Politically, the Republic of Ireland comprises of 26 counties whilst the remaining six counties form Northern Ireland, currently one of the four jurisdictions of the United Kingdom.

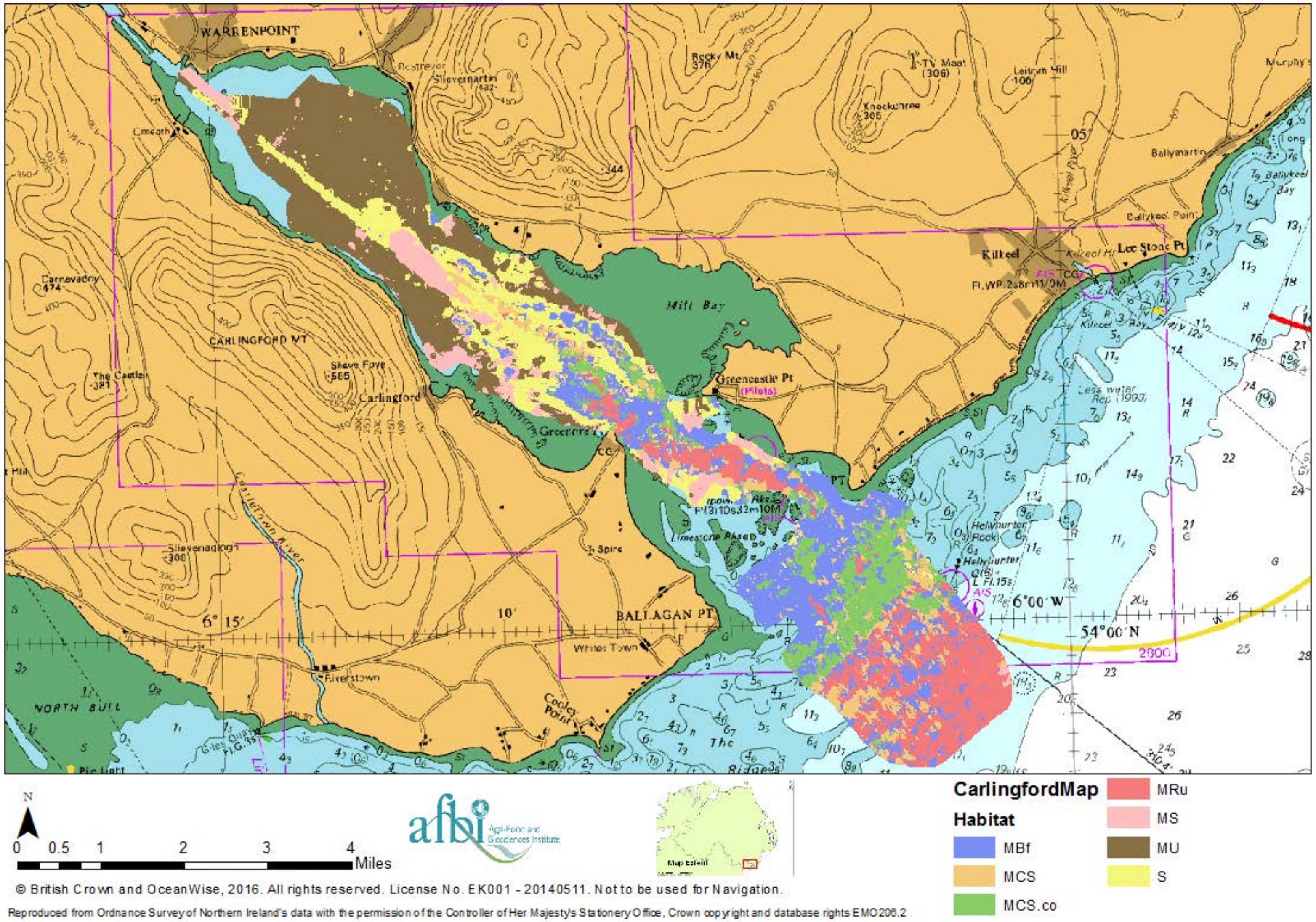


Figure 6.2: Carlingford Lough Benthic sediment characteristics as taken from Mitchell and Service 2004. See Table 1 below for a detailed description of the Habitat codes listed above.

Table 6.1: Description of the Habitat codes associated with the map of Carlingford Lough benthic sediment characteristics shown in Figure 6.2. Adapted from Mitchell and Service 2004.

Habitat code	Substrate escription	Characterising fauna/flora	Energy environment	Comments
MBf	>70% medium-large boulders or bedrock	*Flustra foliacea*, echinoderms, tall, often thick, hydrozoan and bryozoan turf, *Caryophyllia smithii, Polymastia* spp.	Moderate energy	Can include sparse kelps ('kelp park')
MRu	>70% small-medium boulders and cobbles with interstitial gravel, pebbles and sand	Short hydrozoans and bryozoan turf, *Antedon petasus*, ophioroids	Moderate energy	Heterogeneous with patches of larger boulders
MCS.co	>70% pebbles and/or cobbles on sand and/or gravel	Hydroid and bryozoan turf, inc. *Flustra foliacea*, Echinoderms *Asterias rubens, Crossaster papposus, Antedon petasus, Balanus* spp., *Pomatoceros* spp. where specified	Moderate energy	Homogeneous, level and compacted
MCS	>70% sand or gravel, with some pebble	*Pagurus* spp., *Liocarcinus depurator, Pecten maximus, Asterias rubens.* Diatom film common in Church Bay.	Moderate energy	
S/Fine S	Medium to coarse sand, well sorted and stable; fine sand where specified	*Asterias rubens, Pagurus* spp., *Liocarcinus depurator,* worm casts and often *Zostera marina* on fine sand (e.g. East Antrim). Diatom film in sheltered areas.	Moderate to low energy	
MS and MS_burrows where specified	>70% muddy sand	Evidence of bioturbation (*Carcinus maenas, Goneplax rhomboides, Nephrops norvegicus, Calocaris macandreae* where specified). *Liocarcinus depurator, Pagurus* spp., *Buccinum undatum, Amphiura* spp. Diatom film in sheltered areas.	Low energy	
MU	>70% mud	In Carlingford Lough: *Virgularia mirabilis* (sea pens), *Philine aperta.*	Low energy/ sheltered	

Carlingford Lough is one of five sea Loughs located within northern Irish waters, all of which are aquaculture production areas (Figure 6.3). There are two trans-boundary Loughs, Carlingford Lough and Lough Foyle. The operational border between Northern Ireland and the Republic of Ireland in Carlingford Lough is shown in Figure 6.4 (it should be noted that at the time of writing the international maritime boundary between Northern Ireland and the Republic of Ireland has not been formally agreed or delimited). The de facto border in Carlingford is the navigation channel which runs down the middle of the Lough. The border between Northern Ireland and the Republic of Ireland in Lough Foyle however, is not so easily defined and therefore there is currently no mechanism for licensing aquaculture sites within this Lough. There are currently 21 licensed aquaculture sites within Belfast Lough, 14 in Carlingford Lough, 12 in Strangford Lough, and 4 in Larne Lough.

The AquaSpace project aims to apply the Ecosystem Approach to make more space for Aquaculture. The Ecosystem Approach to Aquaculture (EAA) is a strategy which has been summarised into six main steps (FAO and World Bank 2015). These steps and how this case study relates to them are outlined below.

1) ***Scoping to understand broader issues:***

   Within the Carlingford Lough Case Study, the Geographic Information System (GIS) ArcGIS v10.3 has been exploited to enable us to build a comprehensive picture of the multiple stakeholders involved within the area. Meetings have been carried out with various users to highlight the main issues affecting aquaculture development within Carlingford Lough.

2) ***Identification of opportunities and assessment of Risks:***

   Through this Case Study a demonstrator of the AkvaVis model has been developed for Carlingford Lough. This demonstrator version of the model allows the user to identify areas suitable for aquaculture production and applies a risk assessment scoring system (using predetermined parameters) to the areas selected.

3) ***Carrying capacity:***

   Within the Carlingford Lough Case Study, the SMILE model has been applied to determine both the ecological carrying capacity and the production carrying capacity of the study area.

4) ***Allocation of user/areas access:***

   This stage within the EAA process still needs to be addressed within Carlingford Lough. The work undertaken on this area within the AquaSpace project (such as the development of the Carlingford Lough AkvaVis demonstrator model) will help progress towards this.

5) ***Development of management plans and 6) Monitoring of management plans:***

   These two stages of the EAA process have yet to be undertaken within Carlingford Lough. Utilising the Carlingford Lough GIS project and the SMILE carrying capacity model AFBI have produced a cumulative impact assessment report for Carlingford Lough. This report, which analysed the cumulative impacts of current aquaculture activities on the marine designated features within Carlingford Lough, will be a vital component in the development of a Management Plan for the area.

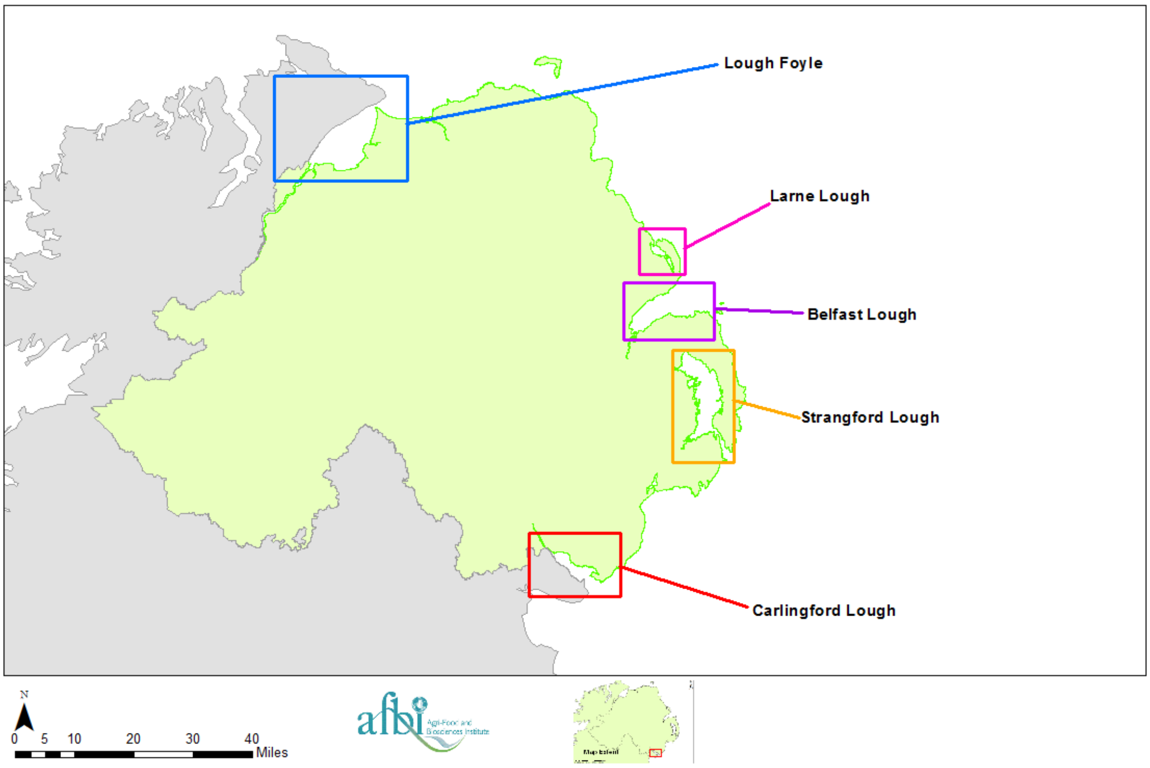


Figure 6.3: Map showing the location of the five Northern Irish Sea Loughs.

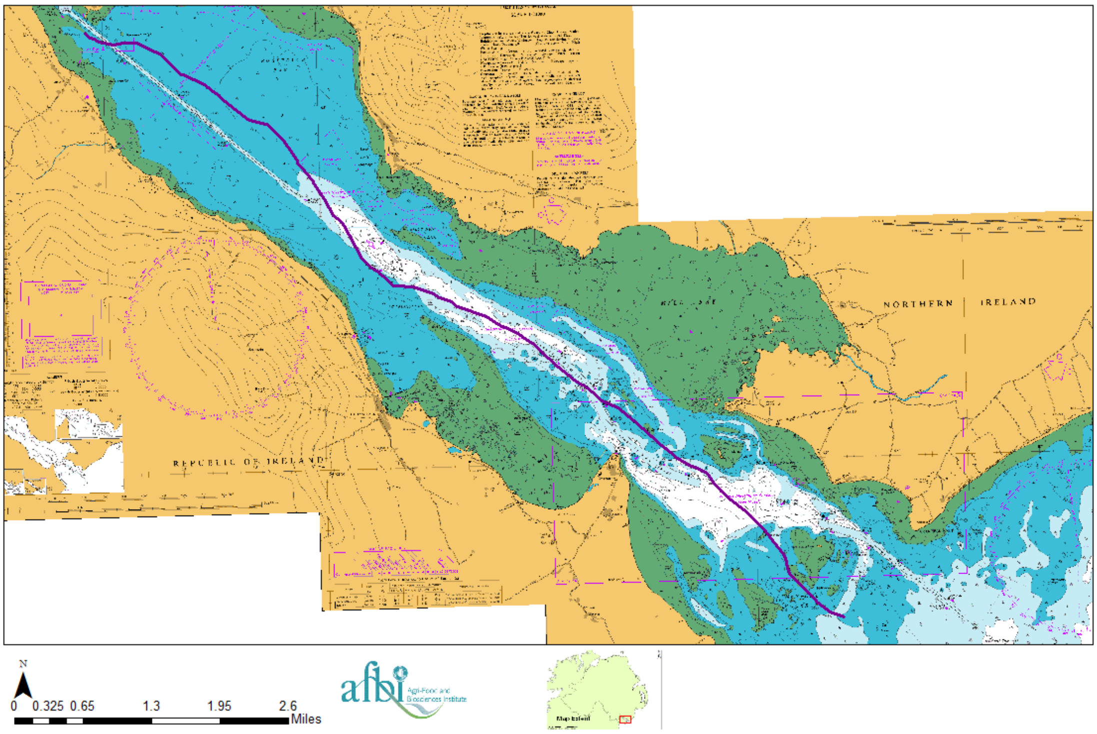


Figure 6.4: Map showing the operational border between Northern Ireland and Ireland within the waters of Carlingford Lough.

6.2. *Spatial planning and management issues*

6.2.1. *Current Aquaculture Activities*

Aquaculture within Carlingford Lough occurs on licensed sites within both the intertidal and subtidal areas of the Lough. Subtidal aquaculture involves the bottom culture of the blue mussel *Mytilus edulis* (Figure 6.5), whilst intertidal aquaculture occurs predominantly in the form of off-bottom (trestle) culture of the Pacific oyster *Crassostrea gigas* (Figure 6.6). *M. edulis* seed is dredged from naturally settled wild seed mussel beds (outside Carlingford Lough) then re-laid onto licensed aquaculture beds within Carlingford Lough for on growing to harvestable size.

Figure 5: The blue mussel *Mytilus edulis* cultured in Carlingford Lough.

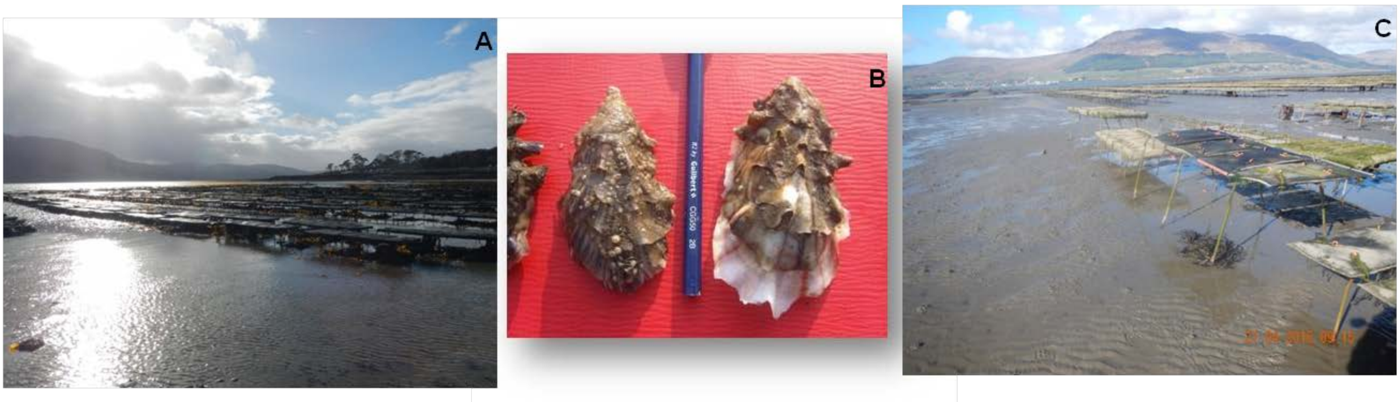


Figure 6.6: A and C show oyster trestles on licensed aquaculture sites within Carlingford Lough. C shows some examples of *Crassostrea gigas* cultured in Carlingford Lough.

Aquaculture sites licensed for bottom culture of shellfish cover approximately 931 hectares of the subtidal area of Carlingford Lough. Approximately 240.1 hectares of the intertidal area of the

Lough is licensed for the off bottom (trestle) culture of oysters (Figure 7). The total area of Carlingford Lough (both intertidal and subtidal) is estimated to be approximately 4,890 hectares (as calculated in ArcGIS V 10.3). Therefore, approximately 23.9% of the total area of the Lough is licensed for aquaculture. However not all of these licensed sites are currently active and of those sites that are active, not all of the licensed area is utilised.

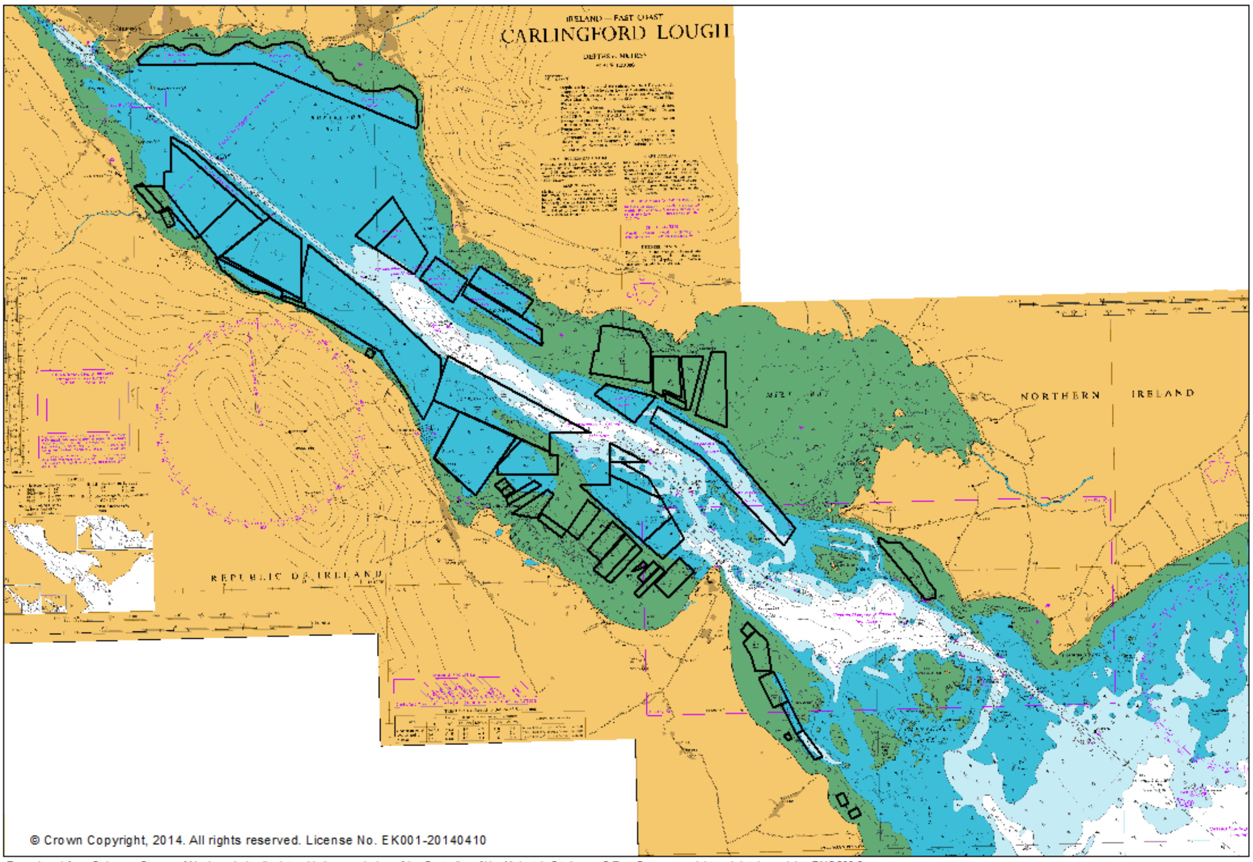


Figure 6.7: Map show licensed aquaculture sites within Carlingford Lough (areas outlined in black).

There are currently fourteen licensed aquaculture sites on the Northern Ireland side of Carlingford Lough (Figure 8). Of these sites one is licensed for the intertidal trestle culture of Pacific oysters (*Crassostrea gigas*), four are licensed for the intertidal trestle culture of Pacific oysters (*C. gigas*) and native oysters (*Ostrea edulis*), three are licensed for the bottom culture of mussels (*Mytilus edulis*) and native oysters (*Ostrea edulis*) and six are licensed for the bottom culture of mussels (*M. edulis*). Although several sites are licensed for the bottom culture of native oysters (*Ostrea edulis*) records of exports of shellfish from Carlingford Lough aquaculture beds and imports of shellfish onto licensed aquaculture sites in Carlingford Lough for the period 2010 to 2015 show only *M. edulis* and *C. gigas* being produced within the Lough. These records also indicate that not all of the sites licensed for aquaculture are actively producing shellfish, at present.

There are currently forty-one sites licensed for shellfish aquaculture within the Republic of Ireland side of Carlingford Lough (Figure 9). Information regarding activities and production at these sites was obtained through interviews with the producers and through documents supplied by BIM, in 2013. Records for 2009-2011 for shellfish production within the Irish area of Carlingford Lough show only mussels and oysters being cultivated (BIM 2013).

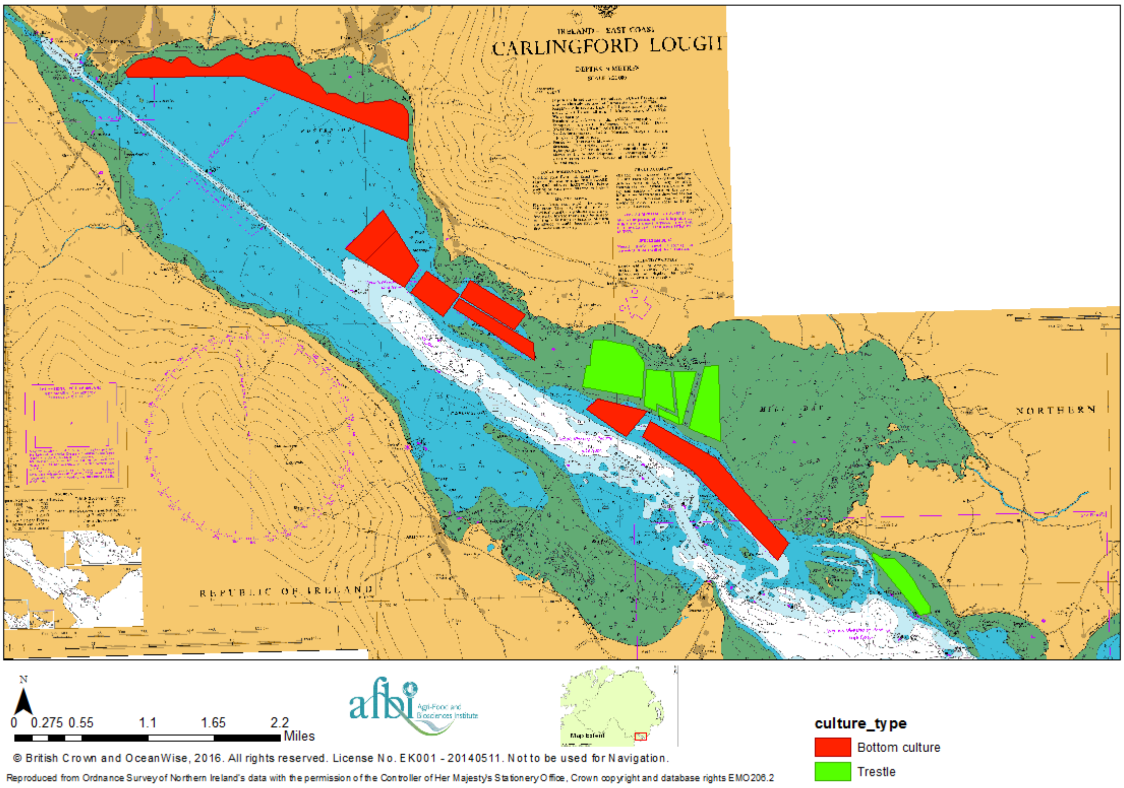


Figure 6.8: Map showing the location and culture method used at the licensed aquaculture sites within the Northern Irish area of Carlingford Lough.

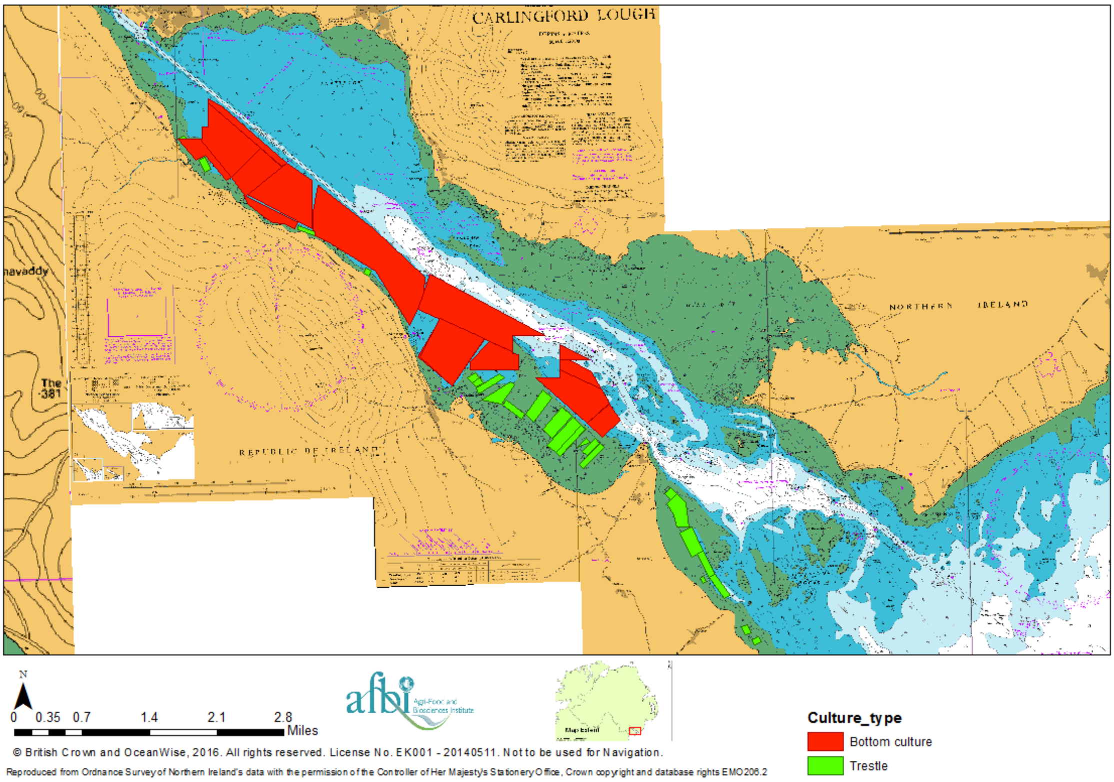


Figure 6.9: Map showing the location and culture method used at the licensed aquaculture sites within the Irish area of Carlingford Lough.

6.2.2. ***Management Issues***

As a trans-boundary water body, Carlingford Lough has a range of regulatory and management issues. These issues are confounded by the multiple uses of Carlingford Lough. Figure 6.10 highlights just some of these multiple uses of Carlingford Lough.

In the Northern Ireland area of Carlingford Lough, the Department of Agriculture, Environment and Rural Affairs (DAERA), is responsible for the granting of fish culture licences, shellfish fishery licences and marine fish fishery licences under the Fisheries Act (Northern Ireland) 1966. In the Republic of Ireland area of Carlingford Lough, the Aquaculture and Foreshore Management Division of the Department of Agriculture, Food and the Marine (DAFM) is responsible for aquaculture licensing under the Fisheries (Amendment) Act, 1997.

6.2.3. ***Environmental Issues***

One example of the environmental issues occurring within Carlingford Lough is the spatial conflict between Aquaculture and nature conservation. The areas of Carlingford Lough within Northern Irelands jurisdiction have been designated as a Special Protection Area (SPA) for breeding Sandwich and Common Terns and overwintering (non-breeding) Light Bellied Brent Geese under the European Council Directive 2009/147/EC on the Conservation of wild birds (often referred to as the Birds Directive). The Northern Ireland area of Carlingford Lough is also designated as an Area of Special Scientific Interest (ASSI) under the Nature Conservation and Amenity Lands Order (Northern Ireland) 1985. The Environment (Northern Ireland) Order 2002 contains measures to improve ASSI management and protection. The Northern Ireland area of Carlingford Lough is also designated as an Area of Outstanding Natural Beauty (AONB) (also designated under the Nature Conservation and Amenity Lands Order (Northern Ireland) 1985) and a RAMSAR site (as designated under the Convention on Wetlands of International Importance (also known as the Ramsar Convention)). An area in the North Western region of Carlingford Lough has been proposed for designation as a Marine Conservation Zone (MCZ) under the Marine and Coastal Access Act (2009). Figure 6.11 shows the location of all the above mentioned designated sites within the Northern Ireland areas of Carlingford Lough.

On the 14th of January 2016 the then Department of the Environment opened a public consultation on a proposed extension to the existing Carlingford Lough SPA boundary. The proposal extends the site boundary to include marine areas within Carlingford Lough and the Irish Sea (Figure 6.12). No additional species were proposed at this time.

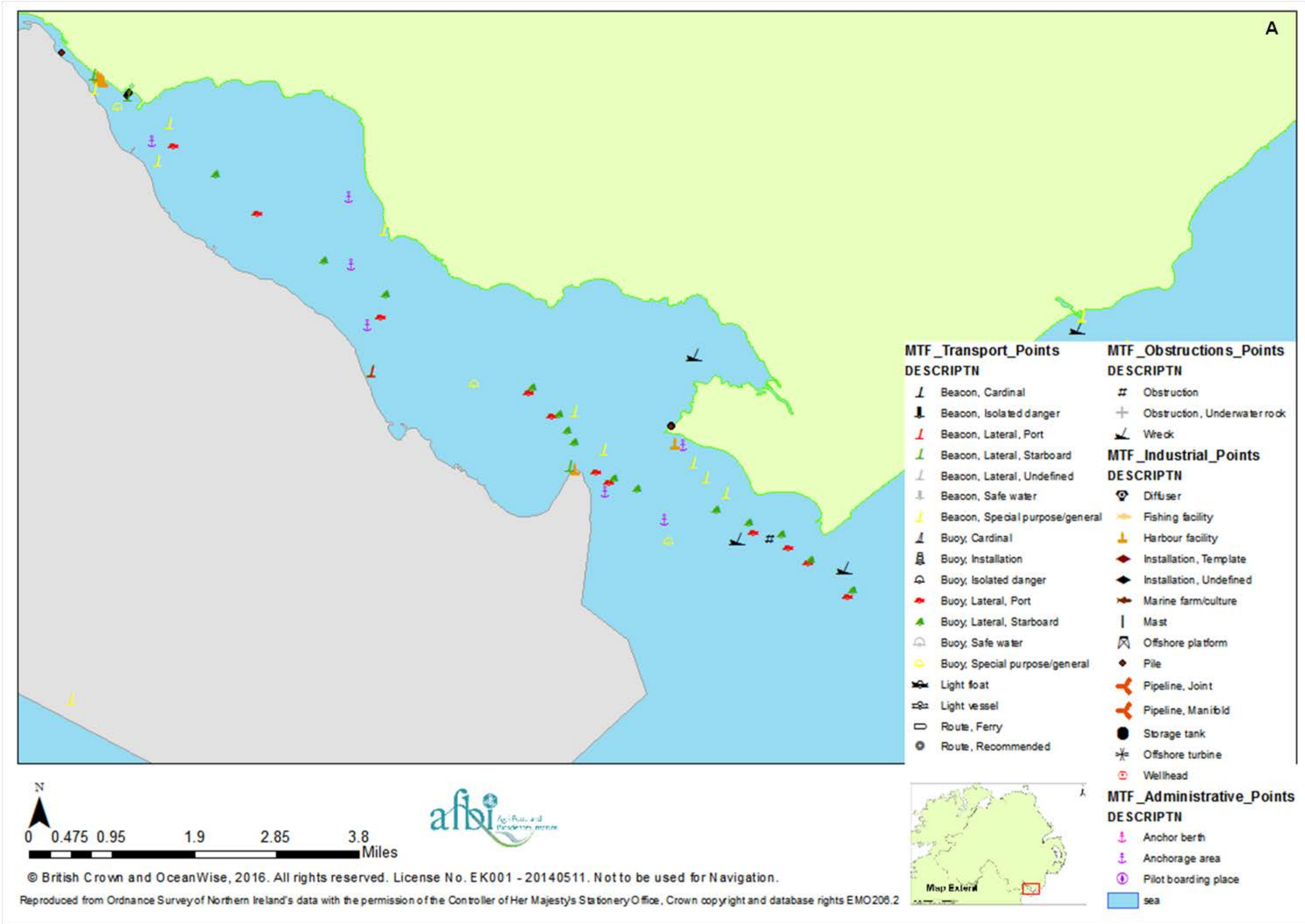
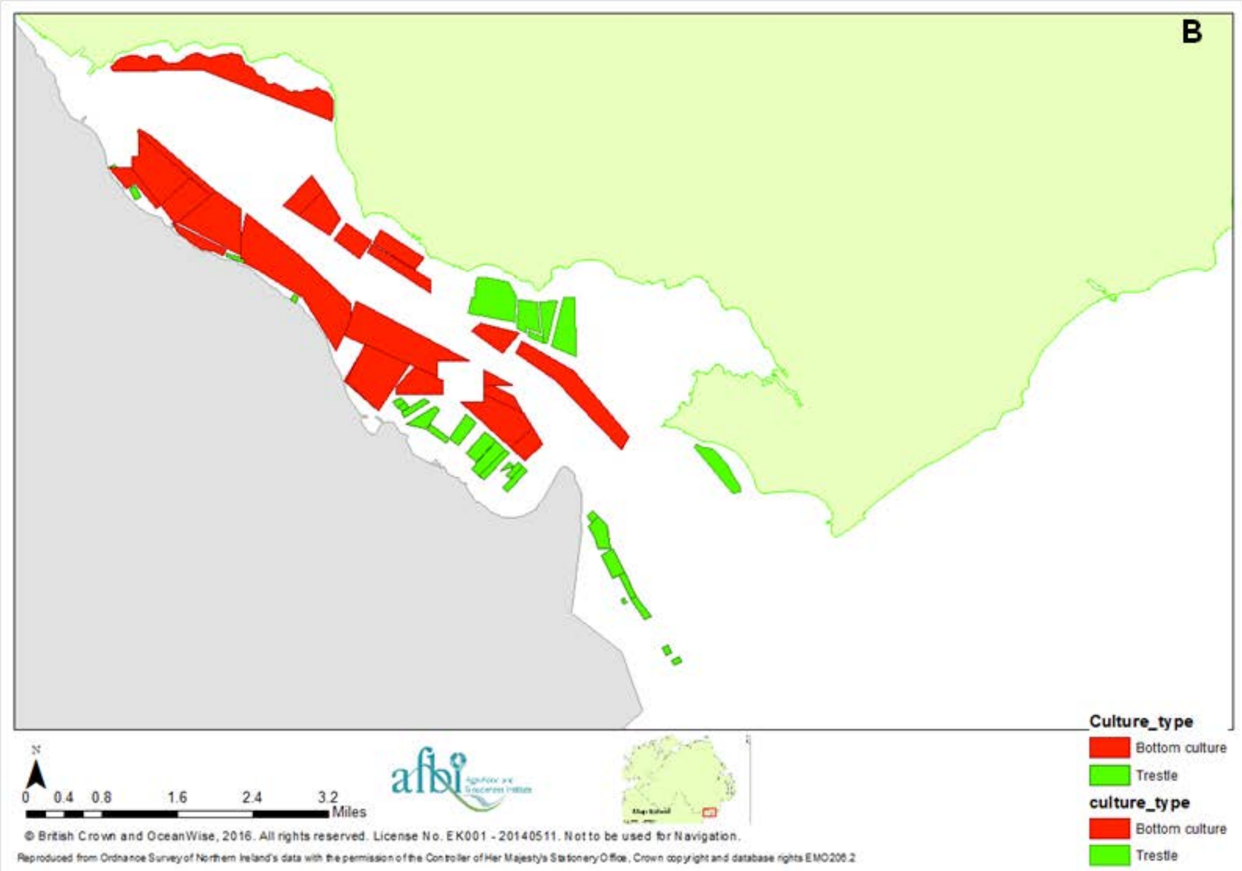


Figure 6.10: Maps highlighting just some of the multiple uses of Carlingford Lough. A). Shows, local wrecks, harbour facilities, and anchorage areas within the Lough.



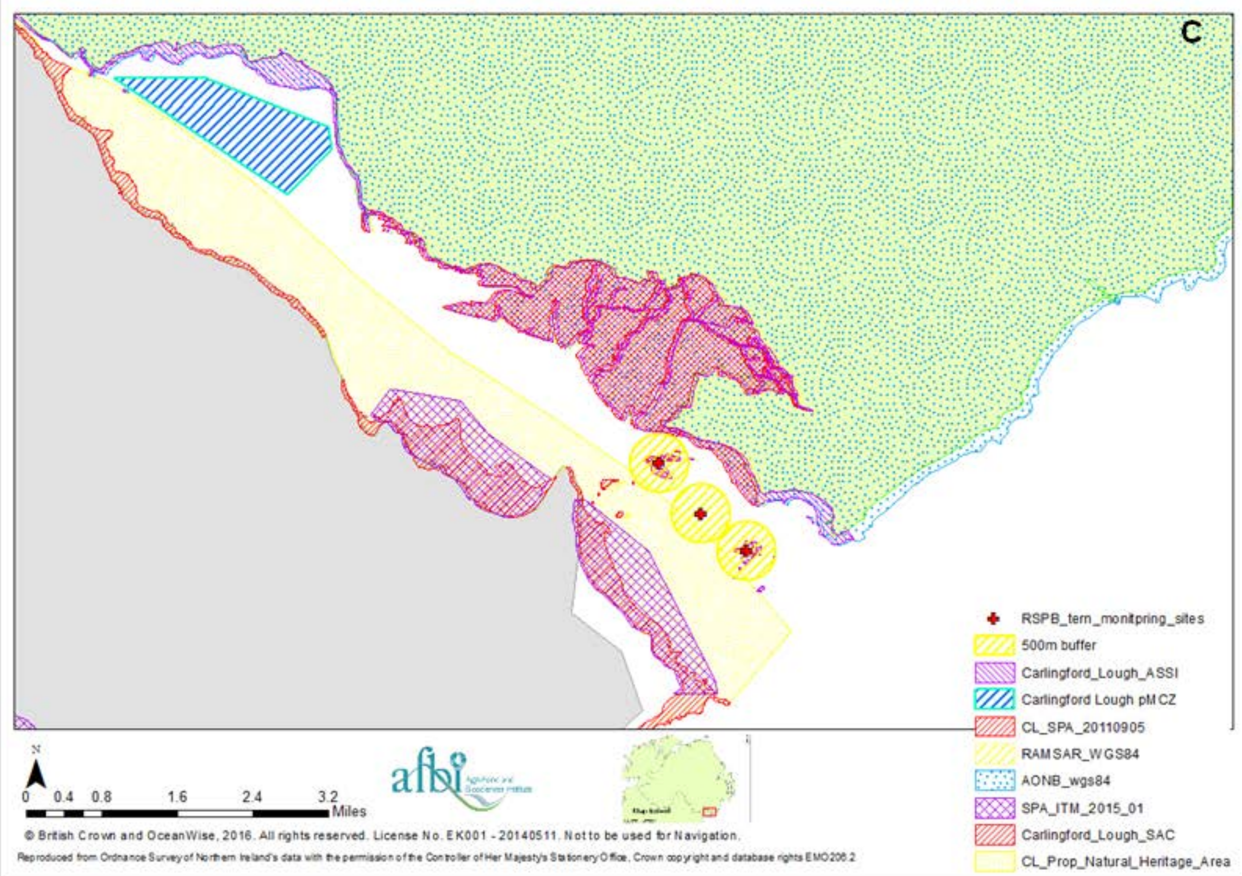


Figure 6.10 continued: B). Shows the location of licensed aquaculture sites and C). Shows the location of all the conservation designated areas within Carlingford Lough.

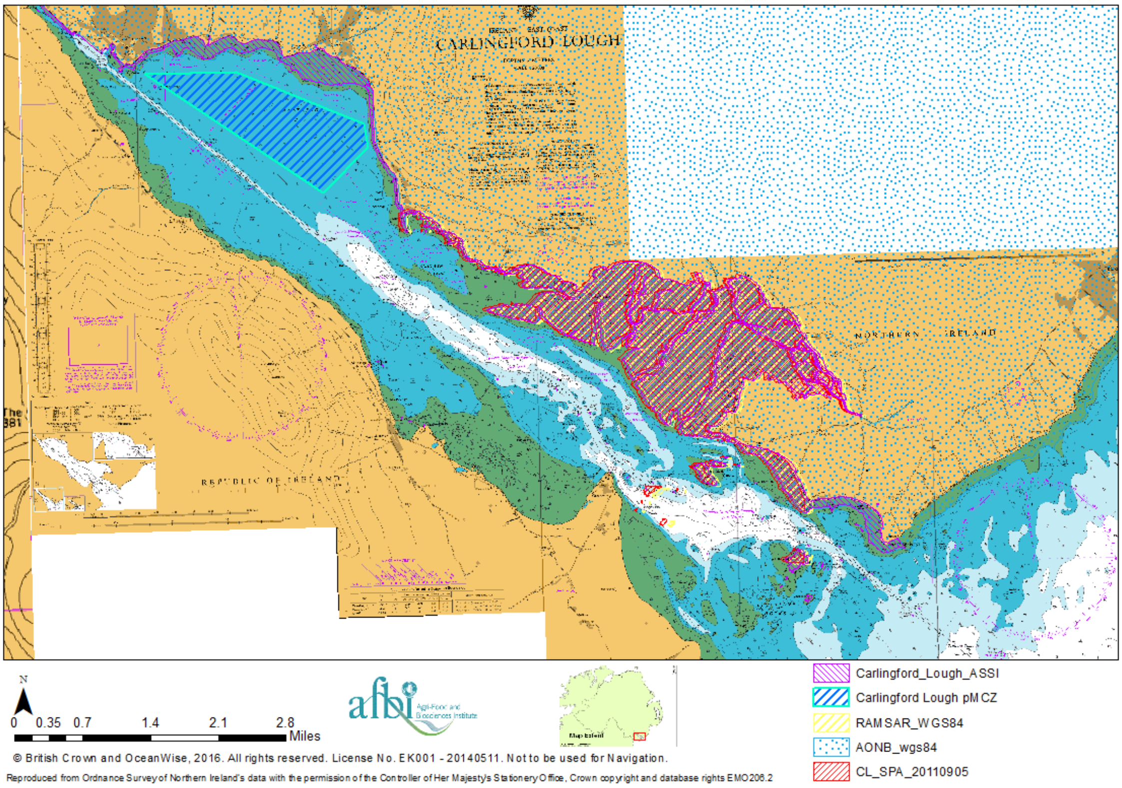


Figure 6.11: Map showing the nature conservation designated areas within the Northern Irish area of Carlingford Lough.

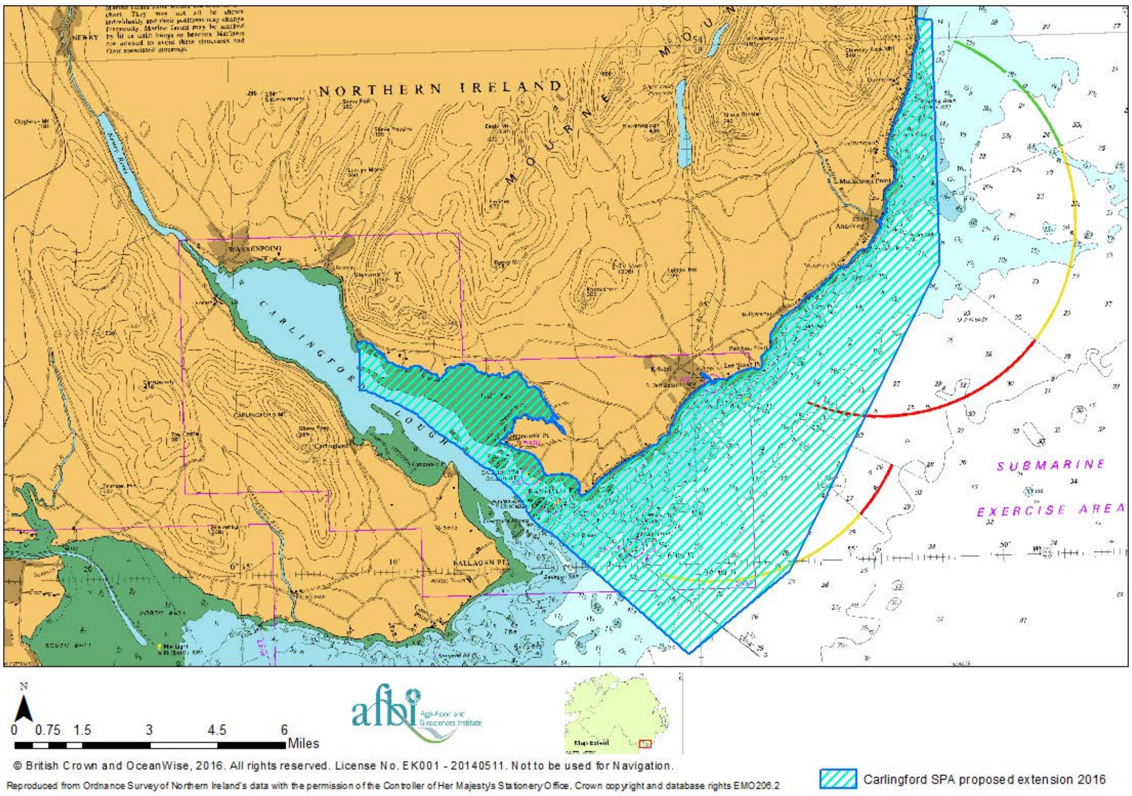


Figure 6.12: Map showing the proposed extension to the Carlingford Lough Special Protection Area (SPA).

From ArcGIS it is possible to ascertain the total area occupied by licensed aquaculture sites within the boundary of the Carlingford Lough SPA. The total area of the SPA occupied by currently licensed aquaculture sites is approximately 92.74 hectares (Figure 6.13). This equates to approximately 11.2% of the total designated area of the SPA. If the proposed extension to the Carlingford Lough SPA boundary is adopted, this will result in approximately 264.02 hectares of the area of Carlingford Lough licensed for aquaculture being within the new SPA boundary. If the proposed extension is accepted, then the total area of the Carlingford Lough SPA will increase to 11,143 hectares. Therefore, licensed aquaculture sites will occupy approximately 2.37% of the total area of the new SPA boundary.

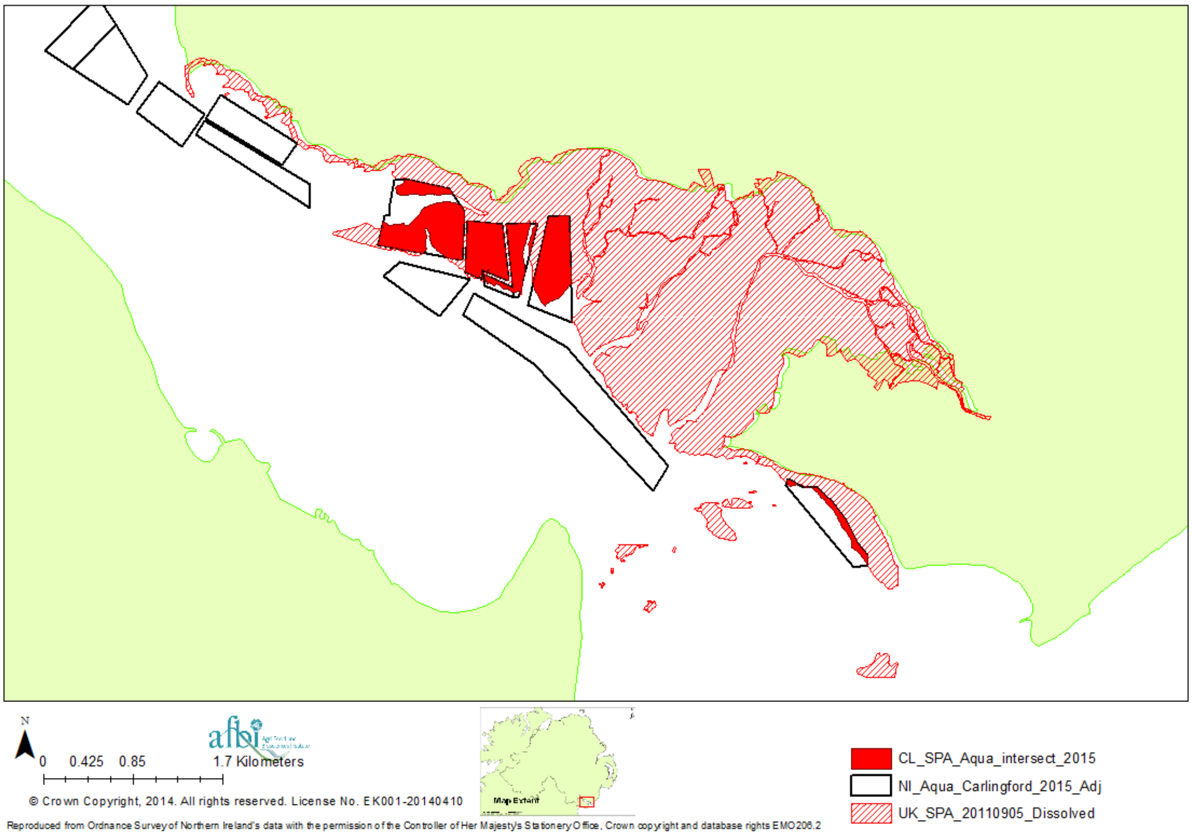


Figure 6.13: Map showing licensed aquaculture sites within the boundary of the Carlingford Lough SPA. The area of the SPA is shown as the hashed red polygon and the portions of licensed aquaculture sites within the boundary of the SPA are shown as the solid red polygons on the map).

The areas of Carlingford Lough within the Republic of Irelands jurisdiction have been designated as a Special Area of Conservation (SAC), under the European Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (often referred to as the Habitats Directive), for the Annex I habitats Annual vegetation of drift lines and Perennial vegetation of stony banks. The Republic of Ireland area of Carlingford Lough has also been designated as a SPA for overwinter (non-breeding) Light bellied Brent Geese and a proposed Natural Heritage Area (as designated under the Wildlife (Amendment) Act 2000) (Figure 6.14).

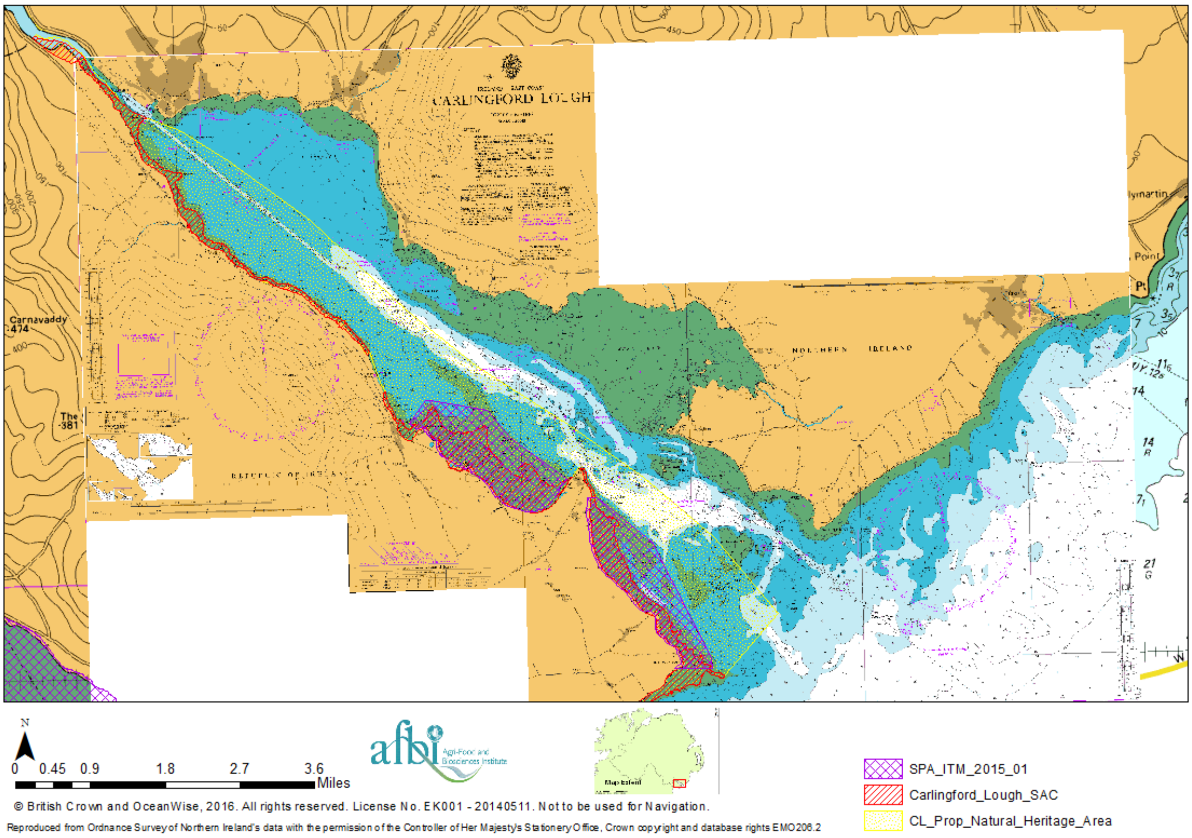
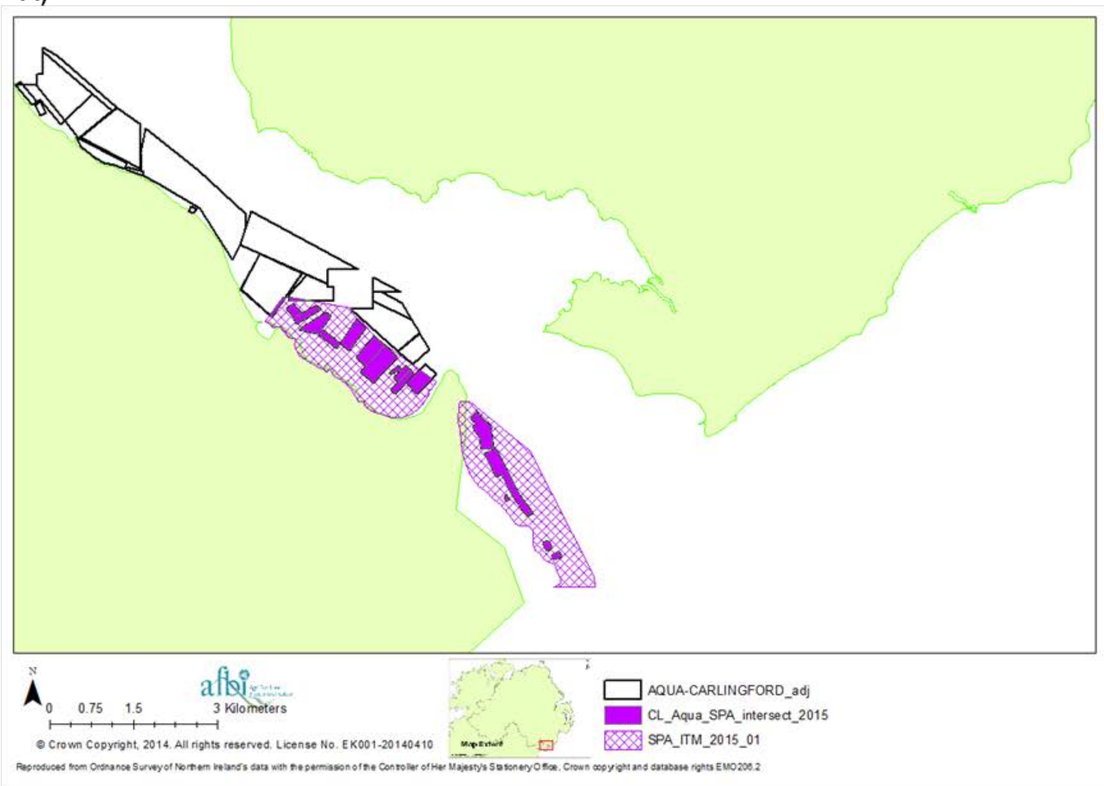


Figure 6.14: Map showing the nature conservation designated areas within the Irish area of Carlingford Lough.

From ArcGIS it is possible to ascertain the total area occupied by licensed aquaculture sites within the boundary of the Carlingford Shore SPA and Carlingford Lough SAC. The total area of the Carlingford Shore SPA occupied by aquaculture is approximately 120.39 hectares (Figure 6.15). This equates to approximately 20.22% of the total designated area of the SPA. The total area of the SAC occupied by aquaculture is approximately 48.98 hectares (Figure 6.15). This equates to approximately 9.31% of the total designated area of the SAC.

A)



B)

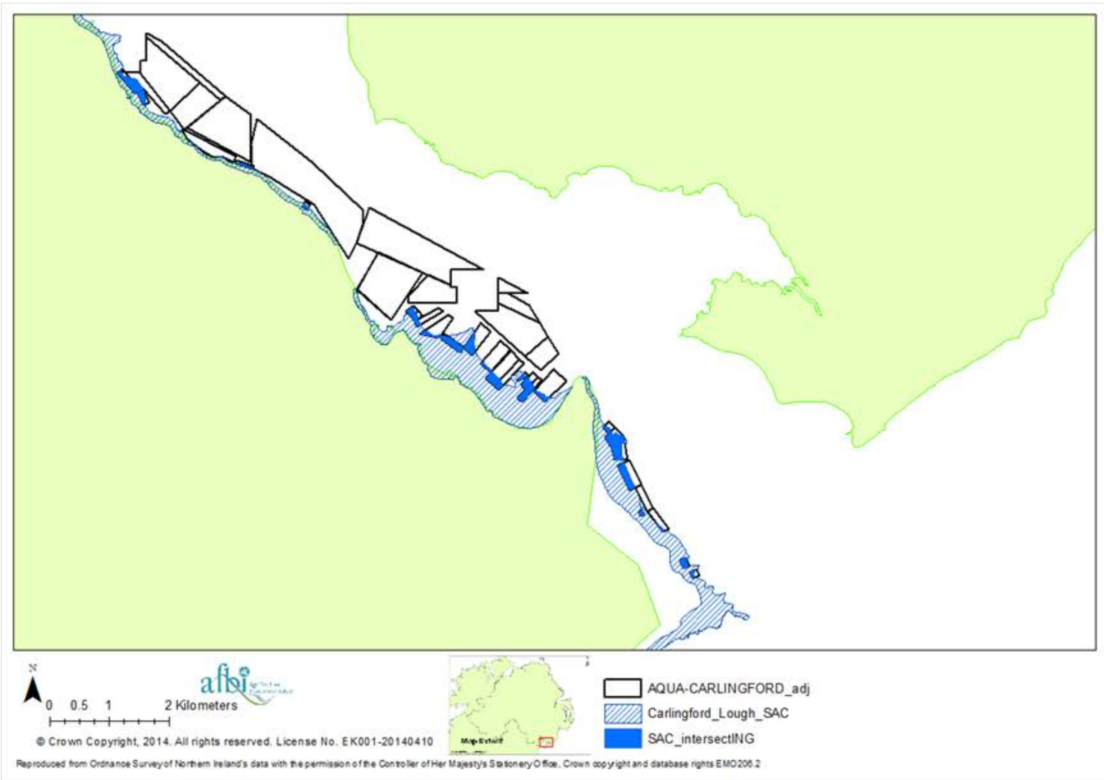


Figure 6.15: Map showing the areas within the boundary of the Carlingford Shore SPA occupied by licensed aquaculture sites (solid purple on map). B) Map showing the areas within the boundary of the Carlingford Lough SAC occupied by licensed aquaculture (solid blue on map).

6.2.4. *Statistics for production*

Northern Irish aquaculture production figures for 2014 (DAERA) estimate the industry at that time to be worth approximately £4.7 million at point of first sale (Table 6.2).

Table 6.2: Northern Ireland Shellfish Aquaculture Production Figures 2014 (DAERA).

Species	Tonnage produced (Metric)	Value (£)
***Mytilus edulis* (Bottom cultured)**	2770	3,805,000
***Mytilus edulis* (Rope/trestle cultured)**	96	164,450
***Crassostrea gigas* (straight to market)**	17	33,839
***Crassostrea gigas* (half grown)**	355	750,050
Total shellfish	**3,238.04**	**4,753,339**

There are currently 53 licensed shellfish aquaculture sites within Northern Ireland waters, 14 of which are within Carlingford Lough (DAERA 2014). At the time of writing, the proportion of the values shown in Table 6.2 that can be attributed to aquaculture within Carlingford Lough is unknown.

Production values for aquaculture species (*Mytilus edulis* and *Crassostrea gigas*) within County Louth (which includes Carlingford Lough) in the Republic of Ireland for the same period (2014) are noted as €1.9 million (BIM 2015).

6.2.5. *Aquaculture development trend*

Applications have been submitted to DAERA for new licensed sites for the culture of Pacific oysters within Carlingford Lough. Due to the conservation status of Carlingford Lough, all applications for new aquaculture sites are subject to assessment under the Conservation (Natural Habitats, etc) Regulations (Northern Ireland) 1995, known as a Habitat Regulations Assessment (HRA). This is then followed by a consultation period. Therefore, before a new aquaculture site within or adjacent to a SPA or SAC can be licensed it must first be demonstrated (by means of the HRA report) that this site will not impact upon the conservation objectives of the designated site in question. If this cannot be demonstrated, then the licensing department (DAERA) cannot grant a licence. It can therefore take many months/years from the date of application until new aquaculture licenses are granted. Therefore, whilst the aquaculture industry is trying to expand within Carlingford Lough, this expansion is seriously hampered by nature conservation legislation. The same is true of many other coastal areas within Northern Ireland.

There is currently a moratorium on the granting of new licences for the bottom culture of mussels within Northern Irish waters.

6.3. Stakeholder engagement and participation

Within Carlingford Lough stakeholders include; local aquaculture producers, fishermen, boat and yacht clubs, conservation authorities, NGOs, Government departments and local harbour authorities. It was originally proposed to hold a workshop to introduce the concepts of the AkvaVis demonstrator model to show how current research tools can be used locally to help visualise relevant issues and constraints.

However due to ongoing issues with active licence applications within Carlingford Lough, the organisation of a local stakeholder workshop has been delayed. These applications have been subject to Habitat Regulations Assessments which have been circulated to stakeholders for consultation. AFBI continue to have regular engagement with the local industry and Government departments and are aware of the issues constraining expansion of aquaculture in Carlingford Lough. AFBI are currently involved in a number of projects with the industry to investigate solutions to some of these issues.

Meetings have recently been undertaken with the local Harbour Authority (Warrenpoint Harbour Authority) and local aquaculture producers to discuss issues of competing priorities and constraints to aquaculture growth within Carlingford Lough.

AFBI attended a Bottom Mussel Workshop in Wexford organised by Bord Iascaigh Mhara (BIM) (Irelands Seafood Development Agency). This workshop was attended by local government departments, local producers and research scientists and discussions/talks centred on the current issues facing the bottom mussel aquaculture industry.

AFBI have also been invited to attend the next meeting of the Carlingford Lough Co-ordinated Local Aquaculture Management Systems (CLAMS) group. Issues regarding aquaculture development and expansion will be discussed at these stakeholder meetings.

6.4. Tools used in the case study

The main tools being utilised within the Carlingford Lough case study are summarised below;

6.4.1. GIS Assessment

An extensive Geographic Information System (GIS) project containing available data for Carlingford Lough has been created within ArcGIS v10.3. All available information relating to the designated features of the Carlingford Lough SPA (Northern Ireland), the Carlingford Shore SPA (Republic of Ireland) and the Carlingford Lough SAC (Republic of Ireland) were converted into a format that was transferable to the GIS programme ArcGIS v10.3. This data was mapped alongside information relating to aquaculture activities within Carlingford Lough.

This tool is currently utilised by AFBI on behalf of local government departments to determine the potential impacts of aquaculture and the potential overlap of proposed aquaculture applications with nature conservation features.

6.4.2. *Ecological Carrying Capacity Model*

In order to assess the ecological carrying capacity of aquaculture activities within Carlingford Lough, the Sustainable Mariculture in northern Irish Lough Ecosystems (SMILE) model is currently being utilised. The SMILE model is used for the collation and processing of scientific information. The SMILE model was developed in 2007 and it enables the application of an integrated framework for the determination of sustainable carrying capacity within the shellfish production areas for which it was developed (namely, Carlingford Lough, Strangford Lough, Belfast Lough, Larne Lough and Lough Foyle) (Ferreira *et al,* 2007).

The SMILE model is currently utilised by AFBI on behalf of local government departments to determine the ecological carrying capacity, the production carrying capacity and the cumulative impact of aquaculture activities.

6.4.3. *AkvaVis*

AkvaVis is a decision support system for aquaculture, developed in Norway which takes into consideration site selection, carrying capacity and management monitoring (Ervik *et al* 2008, described in Ferreira *et al* 2012).

6.5. Application of tools

A demonstrator AkvaVis model for Carlingford Lough has been developed in partnership with AquaSpace project partners IMR and CMR utilising some of the available AFBI data for the area.

6.5.1. *AquaSpace tool developed through WP3*

It was initially planned to use the data gathered through the GIS assessment in the Carlingford Lough case study to trial the AquaSpace tool developed as part of work package 3 of the project. Problems were encountered with early versions of the software and it is believed that the Carlingford Lough Case study is too localised for the AquaSpace tool to produce any meaningful outputs.

6.6. *Case study results*

6.6.1. *GIS Assessment*

The Fisheries and Environment Division of the Department of Agriculture, Environment and Rural Affairs (DAERA) commissioned AFBI to produce an updated Cumulative Impact Assessment report for Aquaculture activities within and adjacent to Natura 2000 designated sites (SPAs and SACs) in Carlingford Lough to reflect the changes to the industry since the publication of the 2013 assessment report (AFBI 2013). This document therefore assessed the potential impacts of current aquaculture activities on the designated features and conservation objectives of the Natura 2000 designated sites detailed above. The GIS project for Carlingford Lough was an integral part of this assessment. A few brief examples of how the GIS assessment was used within the report are described below;

- Through the GIS assessment it was determined that there was no spatial overlap between licensed aquaculture sites and Tern (one of the designated features of the Carlingford Lough SPA) breeding sites (Figure 6.16 and 6.17).
- Through the GIS assessment it was determined that there was no spatial overlap between licensed aquaculture sites and eelgrass beds (the preferred food source of Light Bellied Brent Geese, one of the designated species of the Carlingford Lough SPA) (Figure 6.18).

This report was finalised by AFBI and released by DAERA in December 2015. The report is available via the link below.

https://www.daera-ni.gov.uk/sites/default/files/consultations/dard/cumulative-impact-assessment-carlingford-lough-aquaculture-activities-dec%202015.PDF).

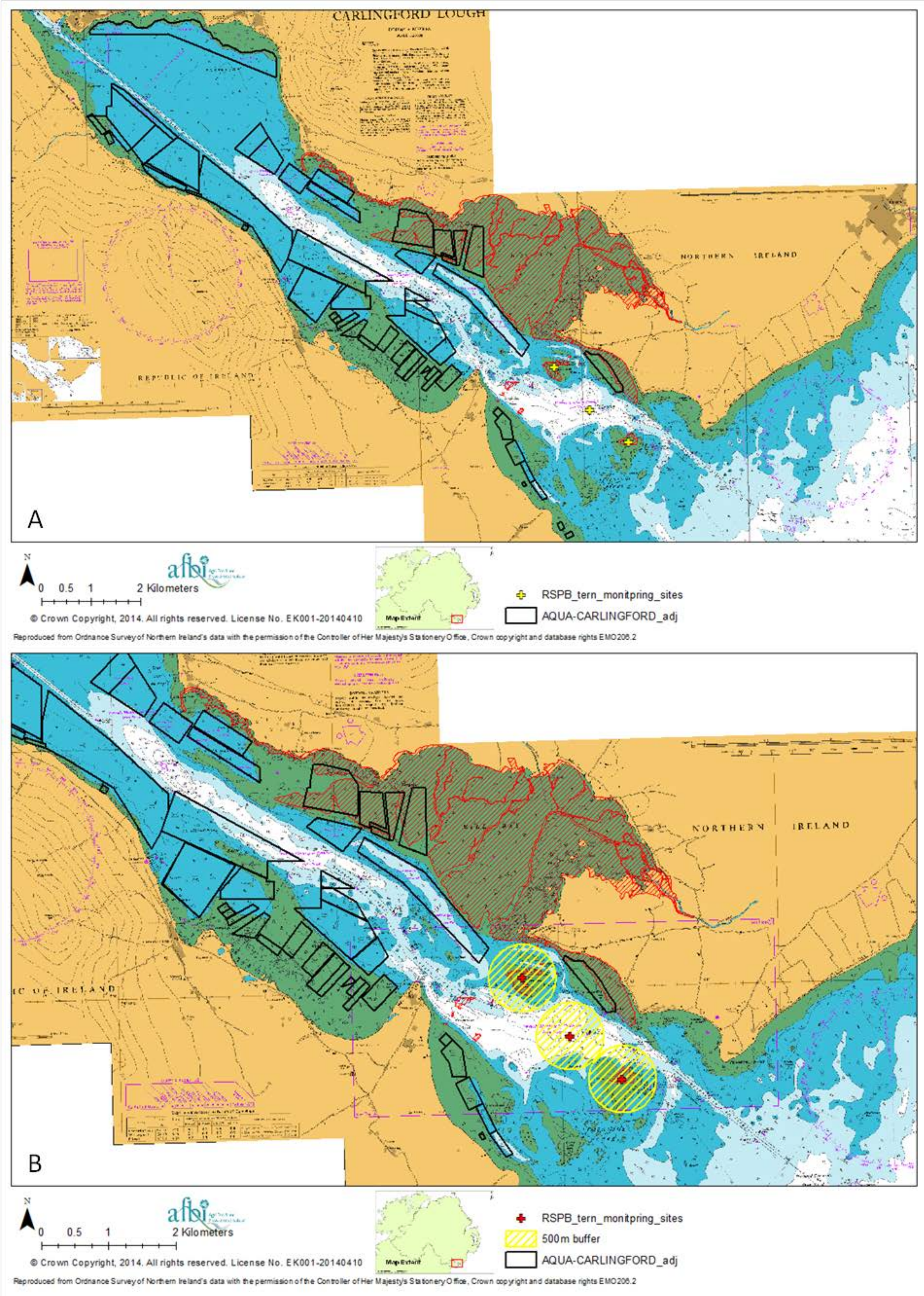


Figure 6.16: A. Map showing the islands monitored by RSPB for Breeding Tern species within Carlingford Lough. B. Map showing the licensed aquaculture sites within Carlingford Lough and the Islands within Carlingford Lough on which Tern species breed to which a 500 m buffer has been applied (yellow hashed area).

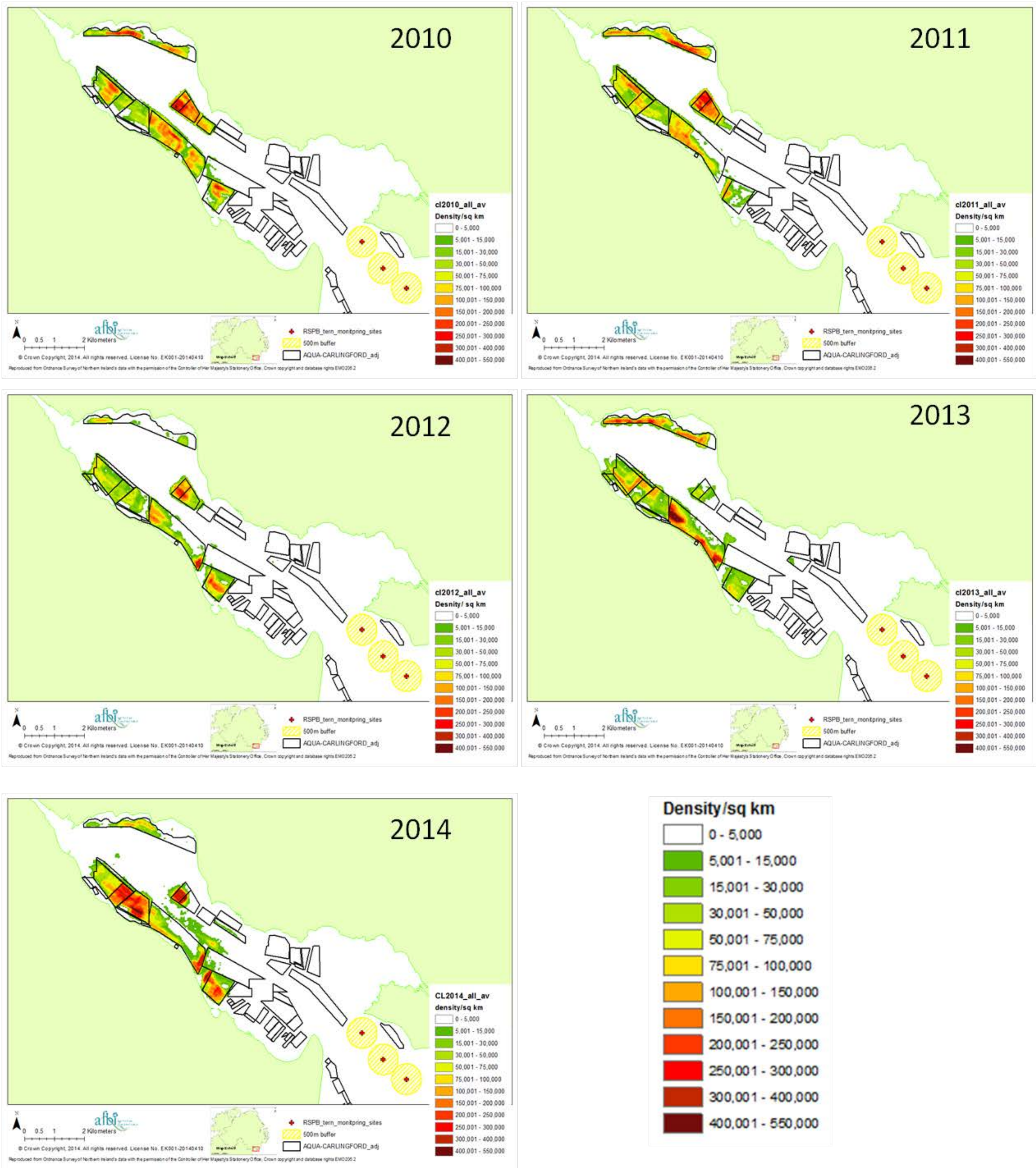


Figure 6.17: Maps showing annual vessel activity within licensed subtidal aquaculture areas in Carlingford Lough for the years 2010, 2011, 2012, 2013 and 2014. These maps were produced from black box data (supplied by DAERA) processed in ArcGIS v10.0.

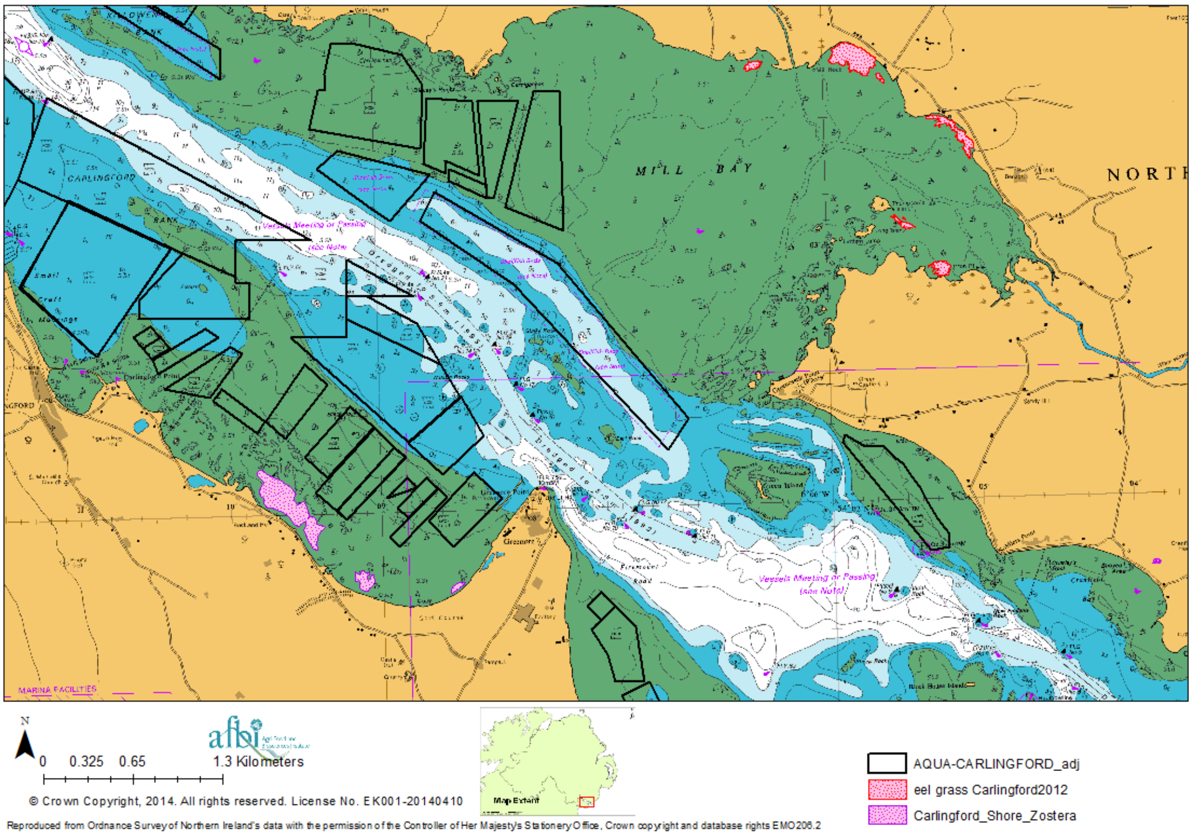


Figure 6.18: Map showing the distribution of intertidal eelgrass on both the Northern and Southern shores of Carlingford Lough alongside all licensed aquaculture sites within the Lough.

Presently, there are active applications for new aquaculture sites within the Northern Ireland area of Carlingford Lough. DAERA have commissioned AFBI to produce Habitat Regulations Assessment (HRA) reports for these applications. The GIS project developed for Carlingford Lough is currently being utilised within these HRA documents to assess the potential impacts of proposed aquaculture activities on the designated features and conservation objectives of the designated sites outlined above.

One of the main challenges within this portion of the case study was the availability of data and the time-consuming process of data analysis.

6.6.2. *Ecological Impact Assessment Model*

For the purpose of this project, using updated data supplied by AFBI relating to bathymetry and water currents within Carlingford Lough, our project partners Longline Environment (LLE) have updated the Hydrodynamic model component of the SMILE model enabling a finer scale model grid to be produced (Figure 6.19). LLE have also revised the boundaries of some of the Ecowin.net model (also referred to as the Ecological model) boxes (one of the components of the SMILE model) to better fit the new Hydrodynamic model components (Figure 6.20).

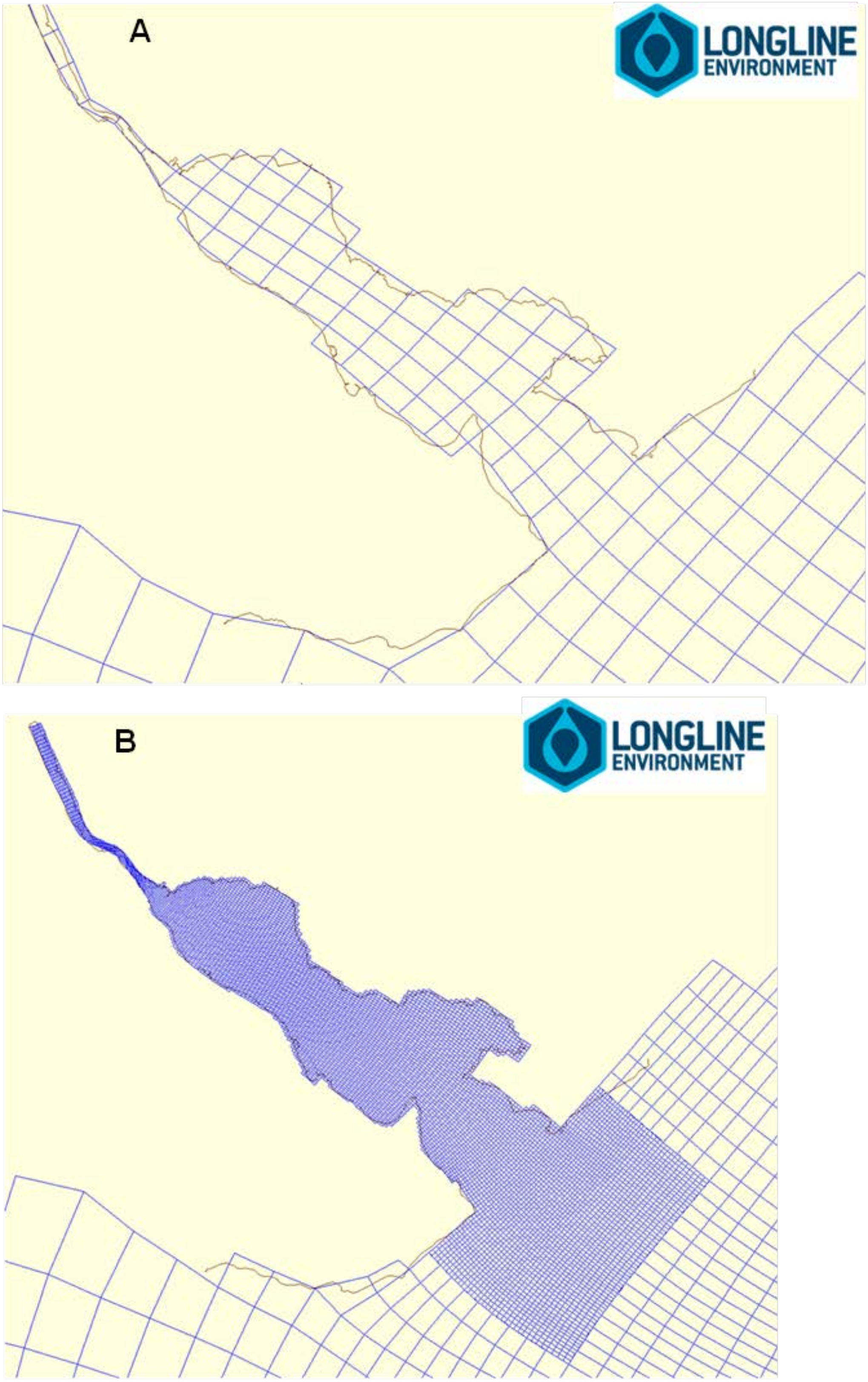


Figure 6.19: A. Hydrodynamic model boxes developed for the original SMILE model for Carlingford Lough. B. Updated, finer scale, hydrodynamic model boxes developed by Longline Environment utilising new bathymetric and water current data supplied by AFBI.

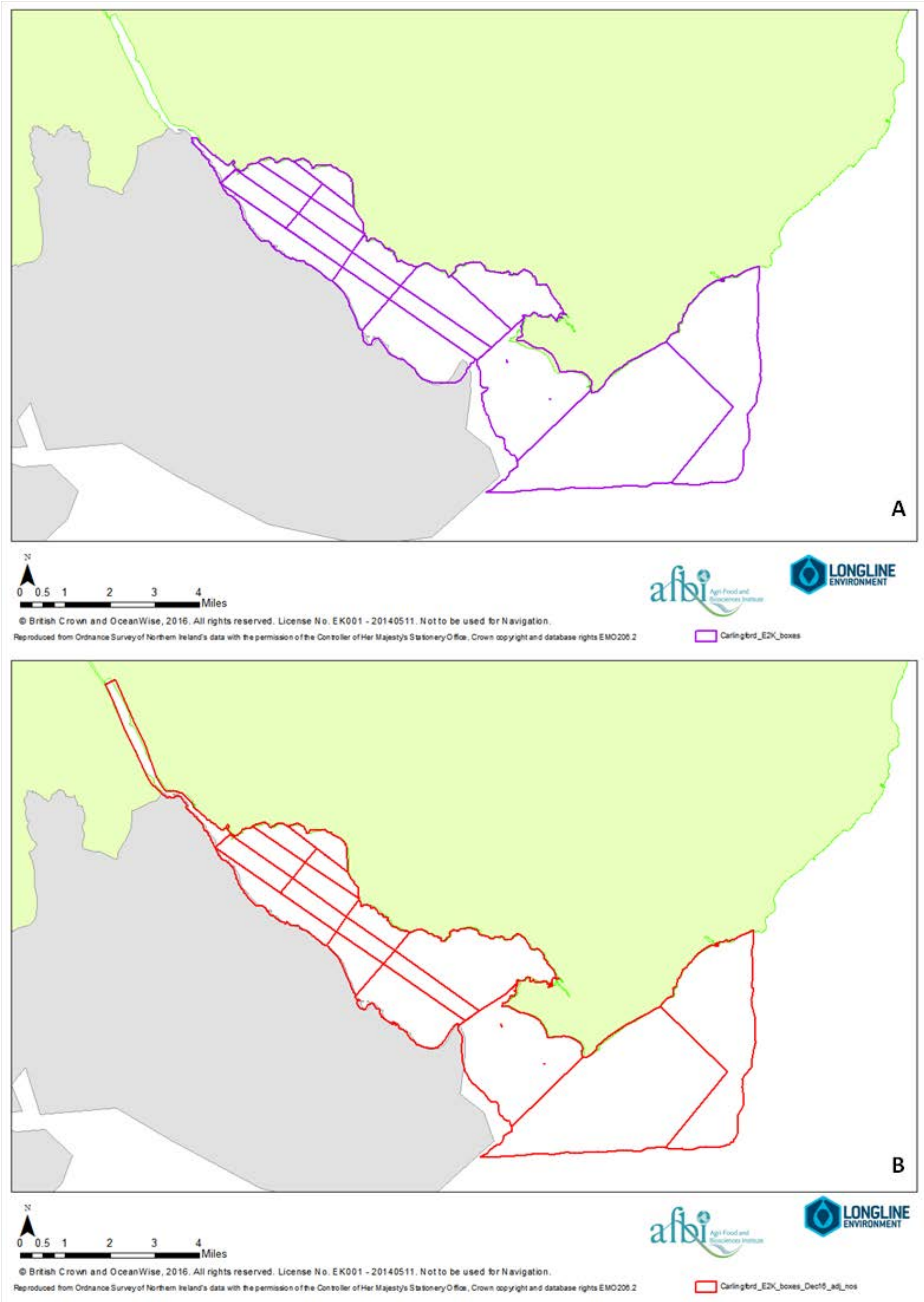


Figure 6.20: A. Ecological model boxes developed for the original SMILE model for Carlingford Lough. B. Updated, Ecological model boxes developed by Longline Environment from the new Hydrodynamic model boxes based on new bathymetric and water current data.

The updated SMILE model for Carlingford Lough has been applied to enable two scenarios, which simulate the impact on the ecosystem of increasing the abundance of filter-feeding organisms in Carlingford Lough to be tested. Chlorophyll a (Chl a) has been used as a proxy for phytoplankton biomass within Carlingford Lough. The two scenarios represent the levels of Chl a present within the Lough if;

a) Run 1 – There was no aquaculture within the Lough (only wild species present). This run is used as a baseline as wild species will always be present.
b) Run 2 – **All** currently licensed aquaculture sites within the Northern area of Carlingford Lough were activated at their rate of production for the year 2014 (as per data supplied by DAERA). Those sites for which there was no production data for 2014 were activated at their rate of production as per data supplied during SMILE development. Current licensed aquaculture sites within the Republic of Ireland area of Carlingford Lough were activated at their rate of production as per data supplied during SMILE development. (As wild species is to be used as a baseline this component was also activated for this run).

Previous analysis of measured data (taken from Taylor *et al* 1999) shows up to -62% annual natural variations within Chl a values in Carlingford Lough (using 90th percentile figures) recorded between sampling years. From this we would recommend that a minimum of 70%, of baseline values, of Chl a remains within the system available for wild species. This therefore implies that aquaculture activities should not reduce Chl a concentrations by greater than 30% of baseline values (Run 1). All boxes with Chl a reduction greater than -30% have been highlighted in Table 3. The location of licensed aquaculture sites in Carlingford Lough in relation to SMILE Ecological model boxes is shown in Figure 6.21.

As can be seen from Table 6.3 and Figure 6.21, impact (in terms of reduction in Chl a values) was observed in model boxes within which no aquaculture is currently undertaken. This is attributed to the effect of aquaculture activities within adjacent boxes resulting from the movement of phytoplankton by water currents and shifts of water between boxes.

The results from these model runs enables us to determine if aquaculture production within Carlingford Lough is at or near the ecological threshold and if there is potential for expansion in some areas (Figure 6.22). From Table 3 it can be seen that the level of aquaculture within Carlingford Lough is currently at its ecological threshold.

It should be noted however that for the purpose of this report (to represent the worst-case scenario) ALL currently licensed aquaculture sites within Carlingford Lough were activated during the SMILE model runs. In reality, this is not the case.

Table 6.3: Simulated Chl a values (90th percentile calculated over index period, April to October). Results from Run 1 were used as a baseline and the % change in Chl a is shown to illustrate the impact when filtration by aquaculture species within current licensed sites is taken into account (Run 2). The turquoise shaded area represents the model boxes with a Chl a reduction greater than 30%.

Box	Species	Run 1	Run 2	% change
Box 36	mussels	11.64	3.20	-72.52
Box 24	mussels	9.27	2.99	-67.71
Box 35	mussels	11.01	3.80	-65.46
Box 34	mussels	10.28	4.83	-53.06
Box 33	mussels	10.00	5.00	-50.00
Box 22	mussels	8.36	4.25	-49.23
Box 32	mussels	9.75	5.22	-46.44
Box 28	mussels	8.99	5.20	-42.19
Box 27	None	9.03	5.35	-40.81
Box 31	None	9.36	5.55	-40.77
Box 29	None	9.53	5.69	-40.29
Box 30	mussels +oysters	9.12	6.00	-34.24
Box 26	None	8.38	5.64	-32.75
Box 21	mussels +oysters	6.86	5.14	-24.99
Box 23	oysters	6.12	4.81	-21.37
Box 25	None	7.16	5.77	-19.40
Box 20	None	4.63	4.34	-6.32
Box 19	None	4.49	4.36	-2.90
Average				**-39.47**

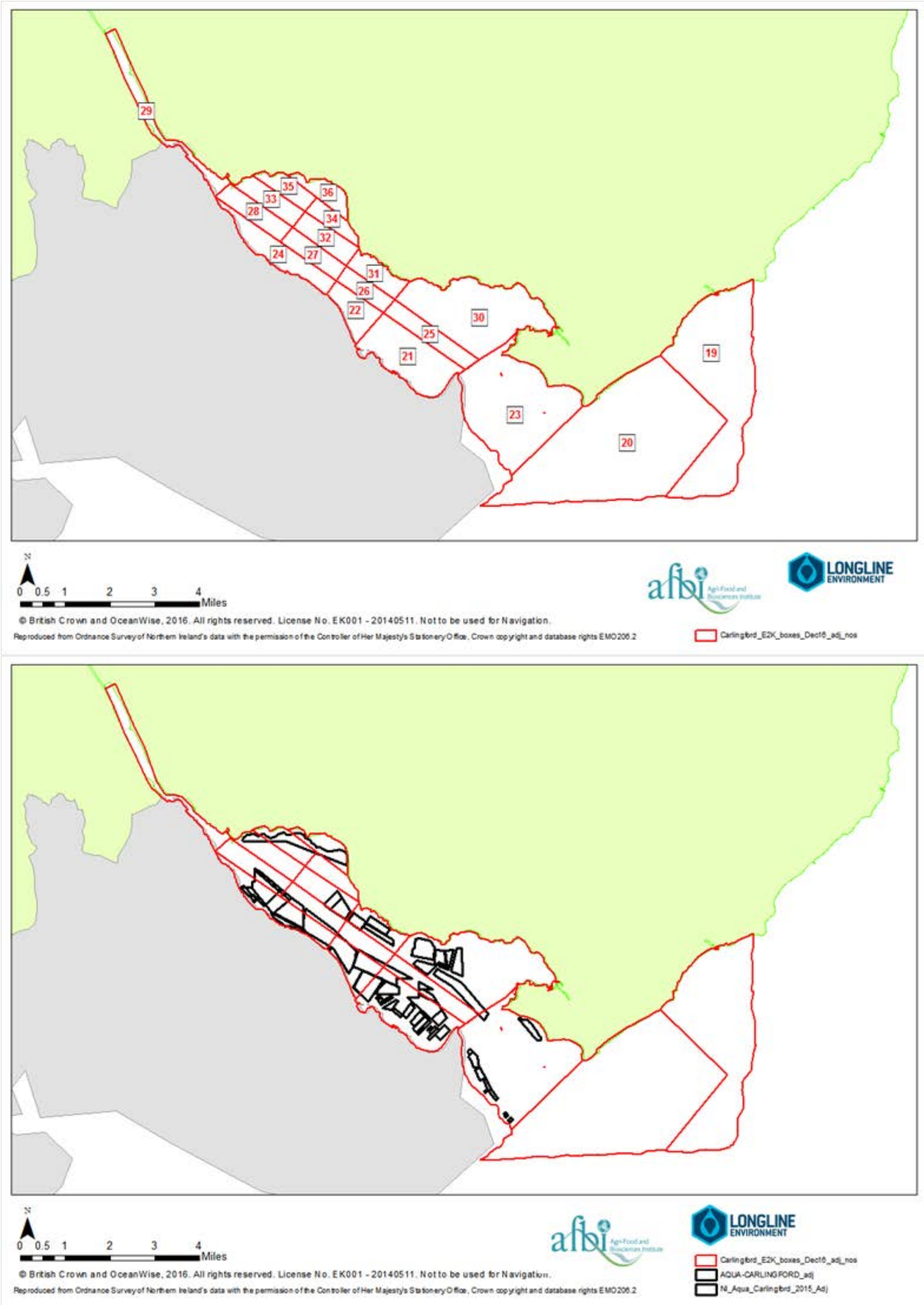


Figure 6.21: Maps showing the location of licensed aquaculture sites within Carlingford Lough in relation to SMILE ecological model boxes.

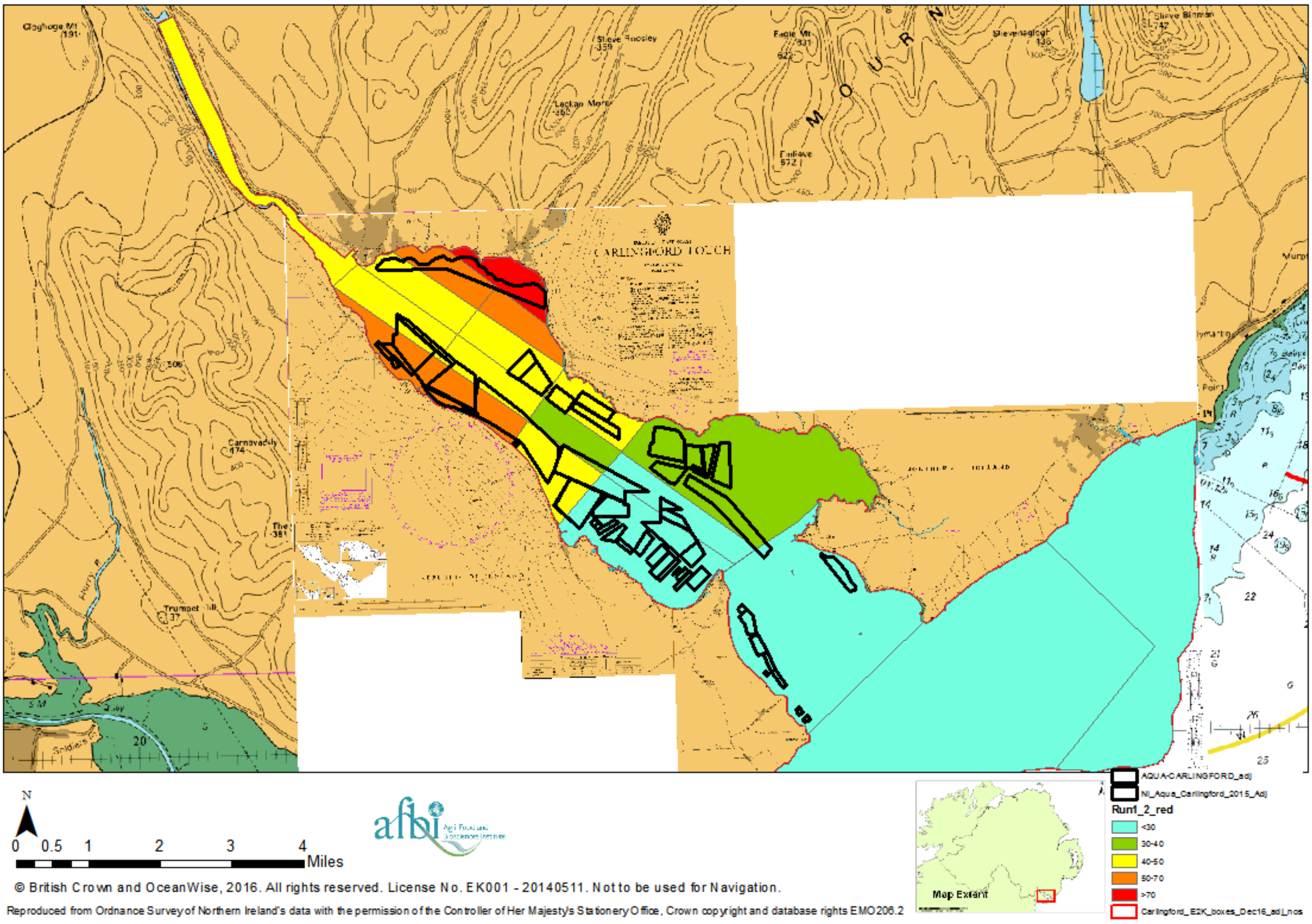


Figure 6.22: Map showing the % Chl a reduction within the SMILE Ecological model boxes within Carlingford Lough resulting from all currently licensed aquaculture sites being activated (results from model Run 1 and 2, see also Table 3). Blue = <30, green = 30-40%, Yellow = 40-50%, orange = 50-70%, red = >70%

Results from previous runs of the SMILE model within Carlingford Lough (before the availability of updated hydrodynamics) can be found within the Cumulative Impact Assessment: Aquaculture activities within and adjacent to Nautra 2000 designated sites in Carlingford Lough (AFBI 2015) (available via the following link https://www.daera-ni.gov.uk/sites/default/files/consultations/dard/cumulative-impact-assessment-carlingford-lough-aquaculture-activities-dec%202015.PDF).

As mentioned previously AFBI have been commissioned by DAERA to produce Habitat Regulations Assessment (HRA) reports for new applications for licensed aquaculture sites within Carlingford Lough. As part of these assessments the newly updated SMILE model for Carlingford Lough will be utilised to determine if the ecosystem of Carlingford Lough can support further aquaculture activities. A further third scenario will be tested to simulate the levels of Chl a within Carlingford Lough if;

Run 3 – Aquaculture activities were increased to include the applications currently in progress on the Northern side of the Lough. As wild species is to be used as a baseline this component was also activated for this run.

This will inform DAERA in their decision regarding the fate of these licence applications.

6.6.3. *AkvaVis*

Through close collaboration between AFBI, CMR and IMR an AkvaVis demonstrator model for Carlingford Lough has been developed. Data layers, which included bathymetry, salinity, nutrients, and marine protected area boundaries, were provided to CMR who undertook the model development.

At the onset of model development discussions, it was hoped to potentially utilise the AkvaVis Carlingford Lough demonstrator model for two purposes;

1. As a risk analysis tool to enable the determination of the optimal location for new aquaculture sites within Carlingford Lough and
2. As a management tool for the operators of currently licensed aquaculture sites.

Within option 1 it was anticipated that factors such as food availability, water temp, distance from nature conservation sites, immersion/emersion times, distance from other users, and distance from discharges, could be considered.

Within option 2 it was hoped that factors such as immersion/emersion times, current flows, water temperature and disease flow, could be considered to enable the optimal citing of trestles within sites and the minimisation of mortality.

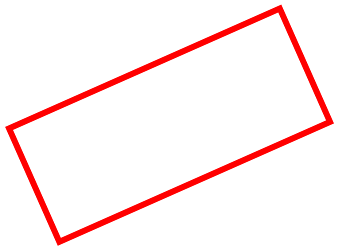
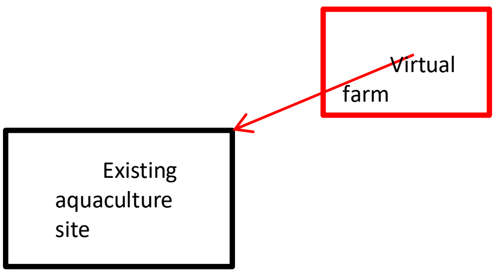
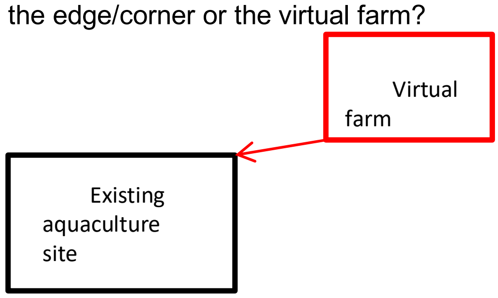
Following several Skype meetings, CMR started construction of the AkvaVis demonstrator model for Carlingford Lough. AFBI provided a short document which outlined the required functionality and the components to be included within the model. It was agreed that the model should include an option for the placement of a virtual farm. Table 6.4 below shows the parameters applied to the placement of virtual farms within the model.

The first version of the model was presented at the 2nd annual meeting of the AquaSpace project partners in Hungary in February 2017 and a live demonstration of the working model was given. Following this, a further meeting was held to discuss amendments/adjustments to the model and AFBI produced Table 6.5 which was circulated to those involved.

Table 6.4: Carlingford Lough AkvaVis Demonstrator Model parameters

Data file	Parameter	Model conditions
Bathymetry	Bottom culture	Max depth must be ≥ 2 m
	Trestle culture	Max depth must be ≤ 0 m
	Suspended culture	Max depth must be ≥ 5 m
Current Aquaculture sites	Current licensed sites	No new aquaculture sites permitted within these areas
Conservation designated areas	Areas within designated area	New aquaculture sites will be required to undergo a Habitats Regulations Assessment before being considered.
	Areas adjacent to designated area	New aquaculture sites will be required to undergo a Habitats Regulations Assessment before being considered.
Sensitive species	Eelgrass beds	No new aquaculture sites permitted within these areas
	Tern nesting sites	No aquaculture permitted within 250 m radius of these sites
	Sea pens	No new bottom culture aquaculture sites permitted. Potential for new suspended culture sites. These will be required to undergo an impact assessment.

Figure 6.5: AFBI suggested model adjustments following Hungary meeting with partners

Model feature	Current output	Preferred output	Priority*
Virtual Farm	When zoomed in on a virtual farm, the appearance is that of a Finfish farm with cages.	Remove the circular cages so that when zoomed in the virtual farm is just an outline. 	**3**
	Currently the virtual farm is a predetermined size.	Is it possible for the user to determine the size of the virtual farm? Perhaps from a choice of three sizes rather than letting the user manipulate the model parameters.	**5**
Results	Current colours; **Red = Not suitable** **Yellow = Suitable but with constraints** **Green = Suitable (no constraints)** On screen it is quite difficult to distinguish between yellow and green.	Suggested colours; **Red = Not suitable** **Orange = Suitable but with constraints** **Green = Suitable (no constraints)**	**1**
Output report	Currently this is in Norwegian and Chinese.	Is it possible to have his output report in English?	**2**
Measured Distances	Distances are calculated from the midpoint of the virtual farm. 	Is it possible to calculate distances from the edge/corner or the virtual farm? 	**4**

***Priorities are cited as 1 – 5, with 1 being the highest priority.**

CMR project partners commenced work on the proposed model adjustments and the model was completed at the end of March 2017 (Figure 23).

Figures 6.24 and 6.25 show some of the functional model layers, Figures 6.26 to 6.28 show the placement of a virtual farm by the user and Figures 6.29 and 6.30 show the resulting model outputs.

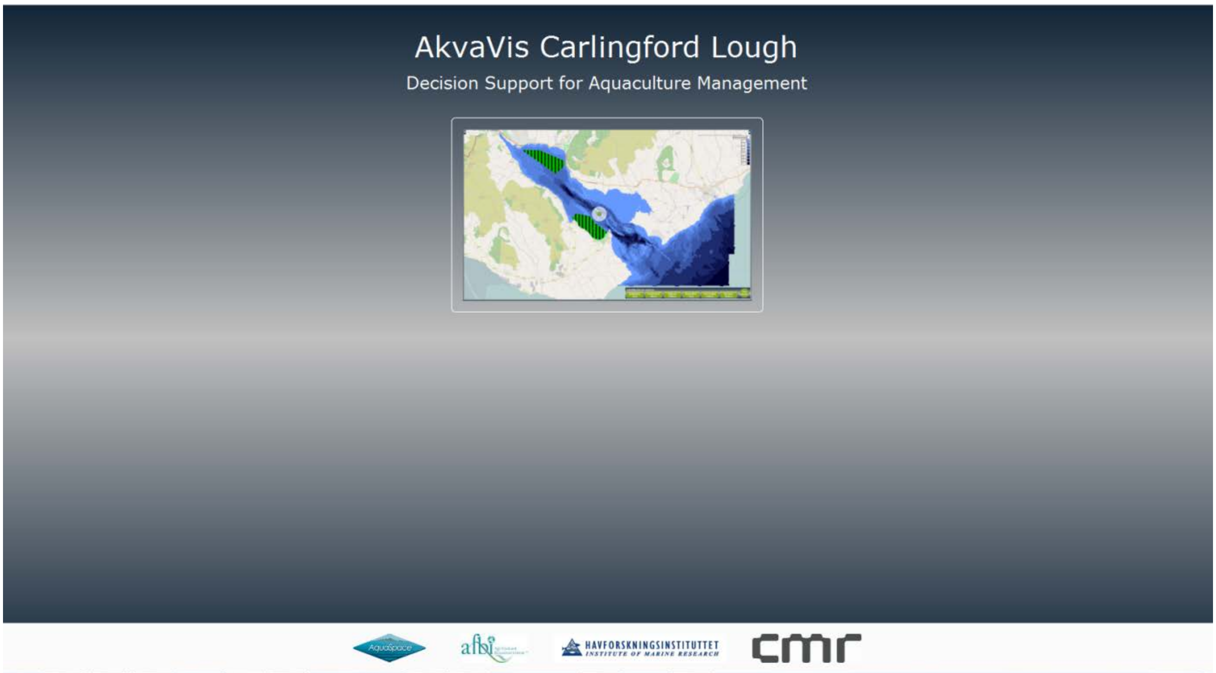


Figure 6.23: Screen shot showing the AkvaVis Carlingford Lough demonstrator model Front page (as developed by CMR).

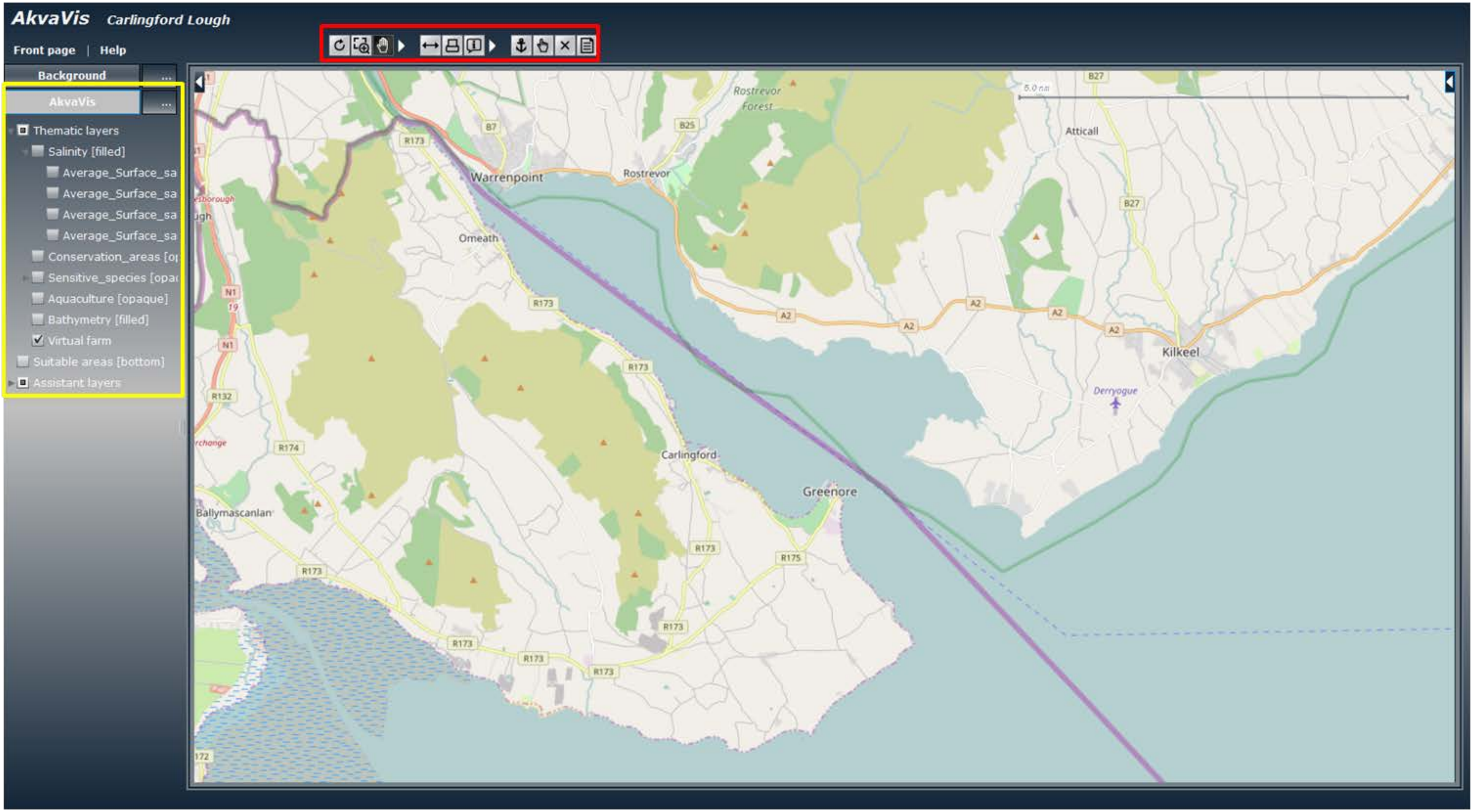


Figure 6.24: AkvaVis Carlingford Lough demonstrator model. Red box shows the function buttons. The Yellow box shows the selectable layers that can be projected on the background map.

Figure 6.25: AkvaVis Carlingford Lough demonstrator model. The green box shows the aquaculture layer selected (ticked). As can be seen above, the user can select how the layer is displayed.

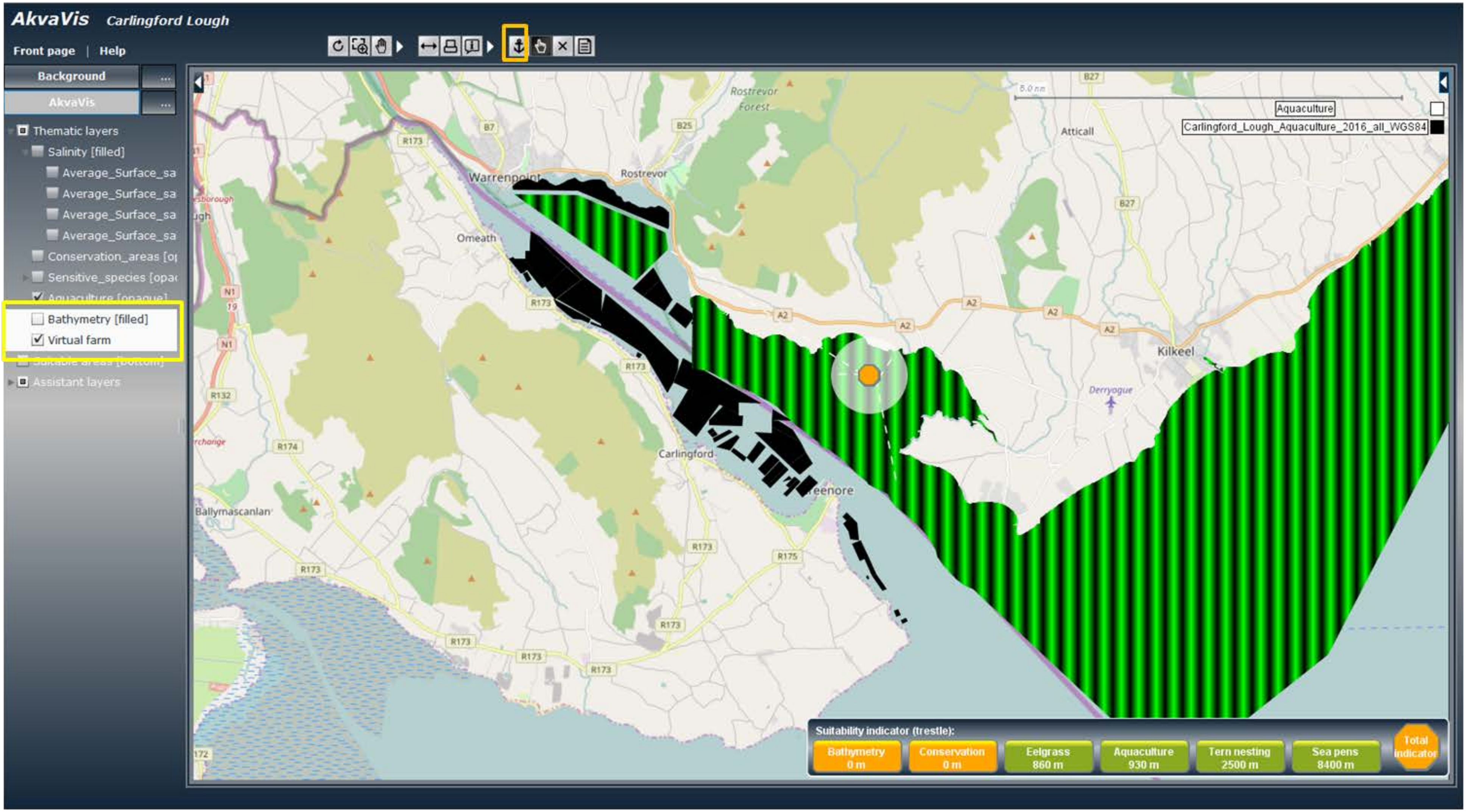


Figure 6.26: AkvaVis Carlingford Lough demonstrator model. The screen shot above shows the placement of a virtual farm within the model. The user firstly selects the virtual farm option (as shown within the yellow box above). The user then selects the anchor icon (as shown within the orange box). The user can then place the new virtual farm wherever they desire within Carlingford Lough (shown as an orange dot on the map).

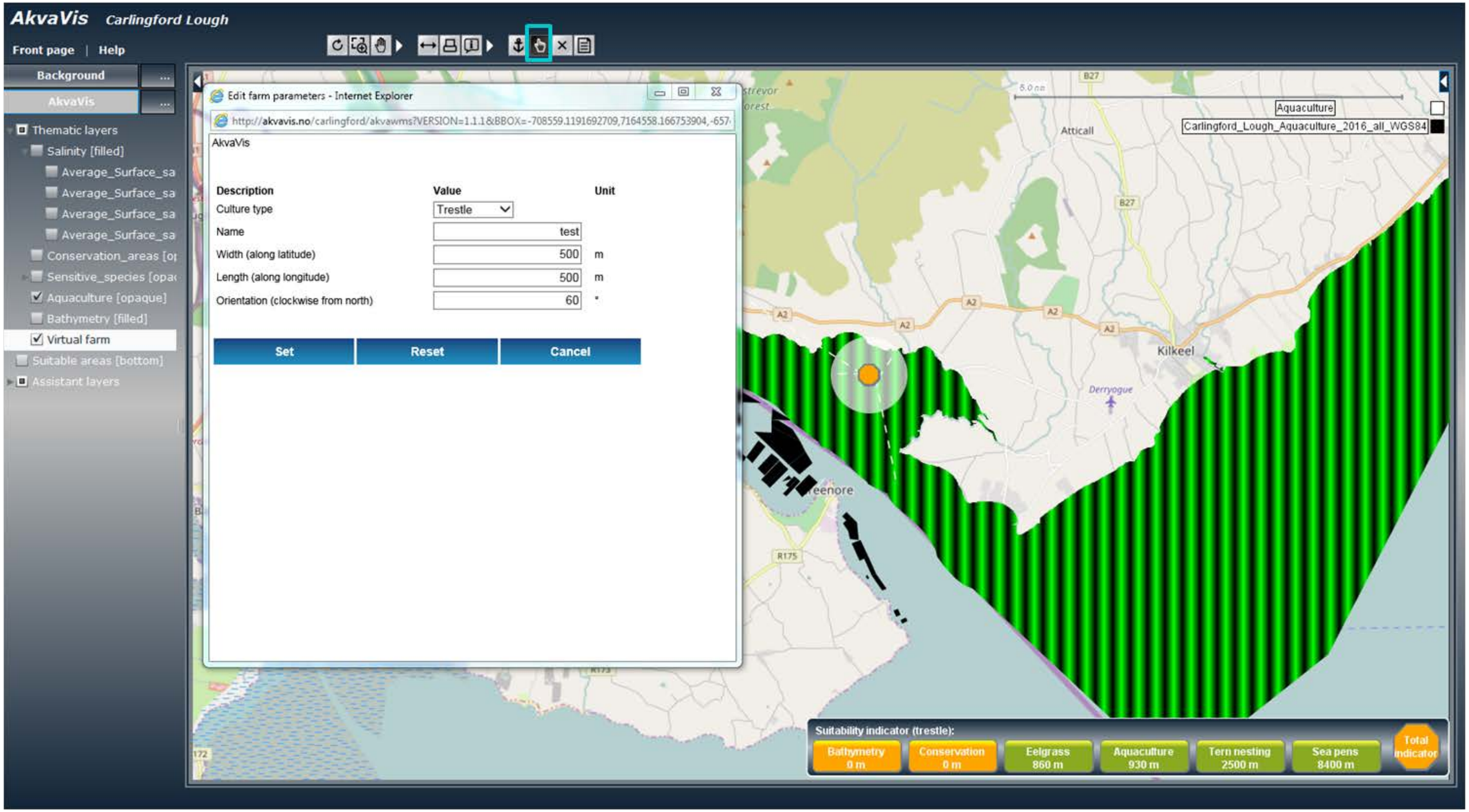


Figure 6.27: AkvaVis Carlingford Lough demonstrator model. By selecting the hand icon (as shown within the blue box) and double clicking on the virtual farm the user can define the culture type and the dimensions of the virtual farm as shown above.

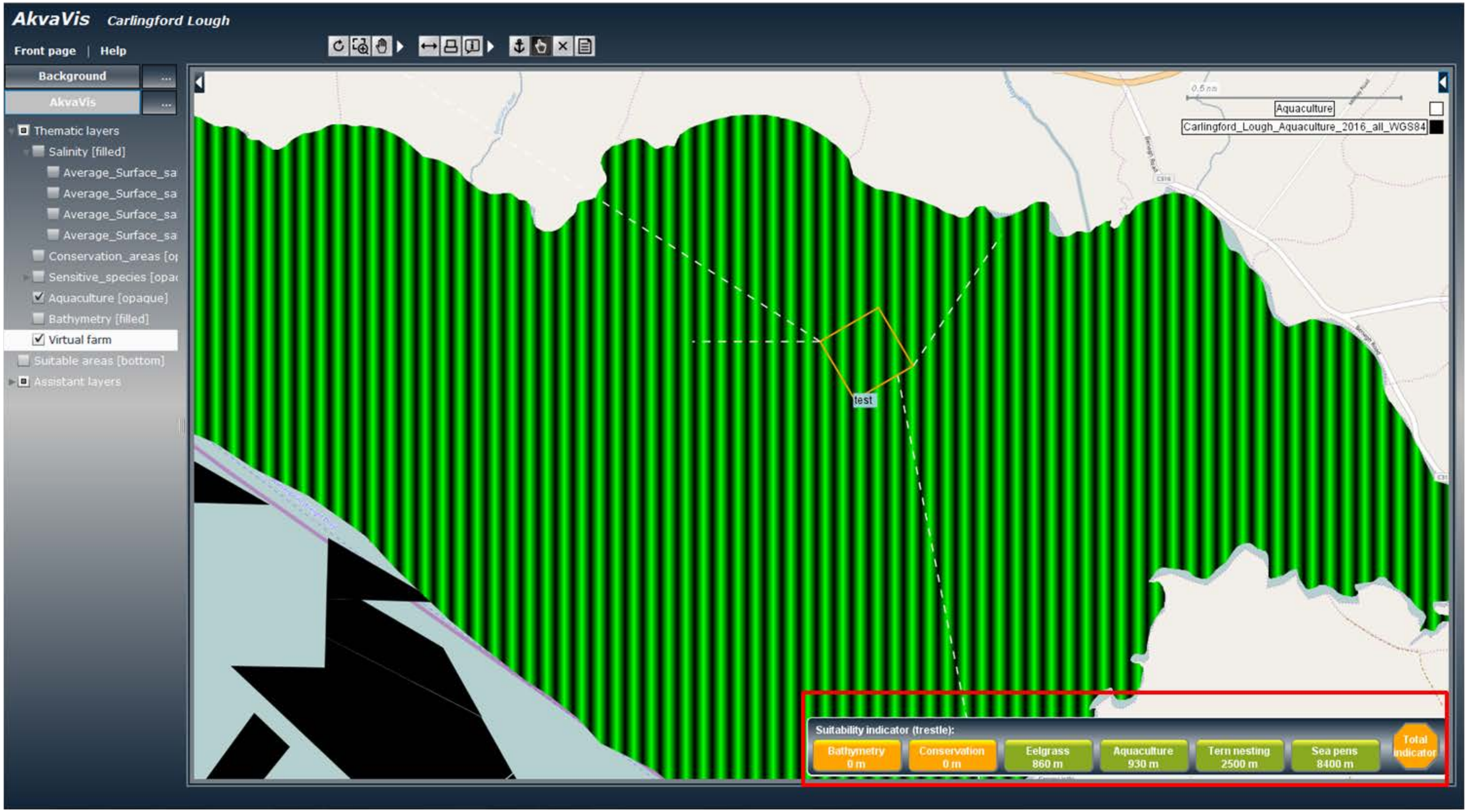


Figure 6.28: AkvaVis Carlingford Lough demonstrator model. The model then calculates the closest distances between the virtual farm and designated features and species as defined in Table 4 and assigns the new farm a Suitability indicator (red box above).

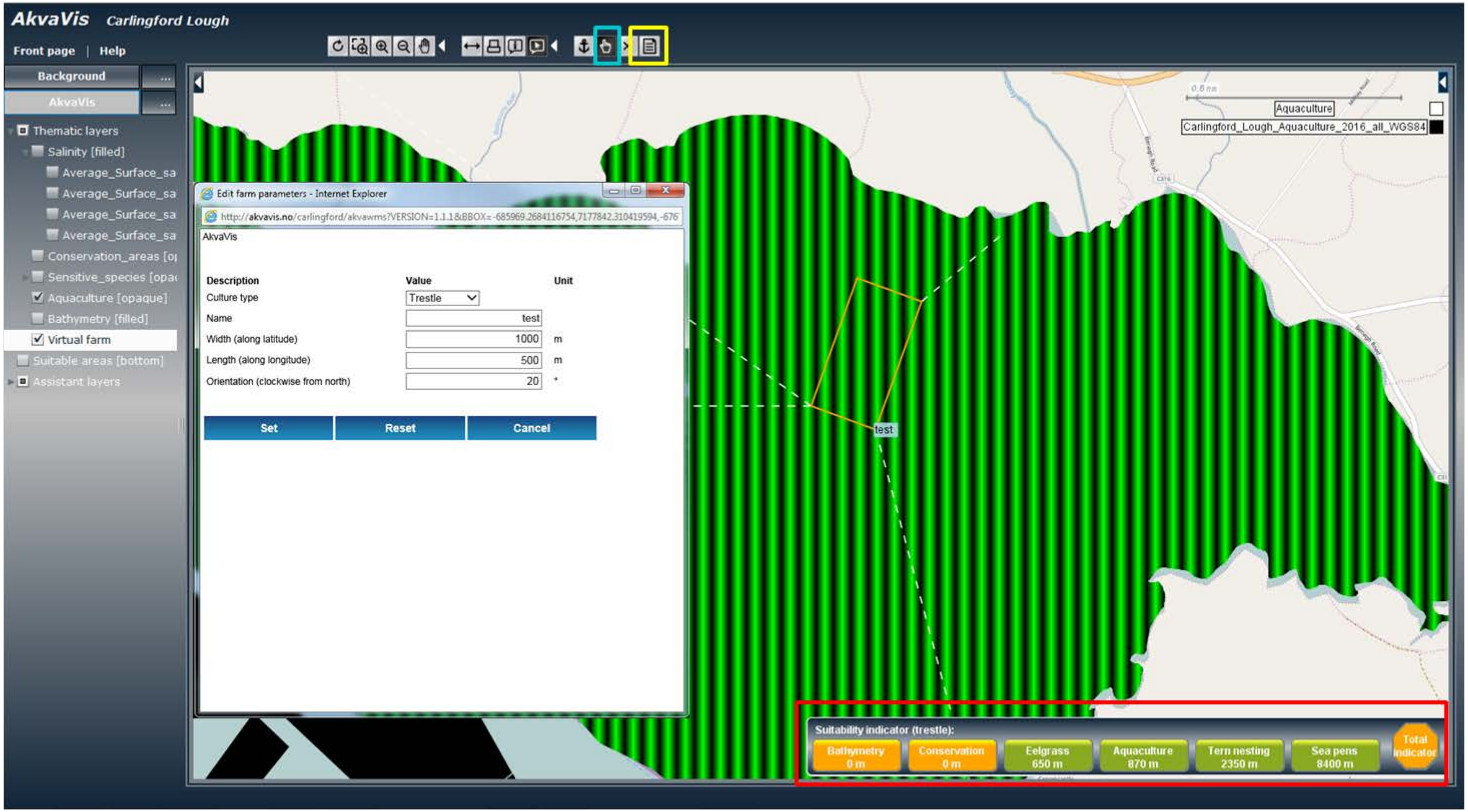


Figure 6.29: AkvaVis Carlingford Lough demonstrator model. By selecting the hand icon (blue box above) and double clicking on the virtual farm the user can redefine the farm parameters and the model then recalculates the suitability indicators accordingly (red box above). The user can then select the report icon (shown in the yellow box above) and the model produces a PDF report of the results.

Report Page 1 of 2

AKVAVIS

Report of new aquaculture site

1 Parameters of the aquaculture site

Parameters	Value
Position	6,118°W 54,057°N
Culture type	trestle
Name	test
Width (along latitude)	1000 m
Length (along longitude)	500 m
Orientation (clockwise from north)	20 °

2 Screenshot

http://akvavis.no/carlingford/akvawms?VERSION=1.1.1&BBOX=-685969.2684116754,71... 11/04/2017

Report Page 2 of 2

3 Suitability description

Suitability indicators	Values	Level	Description
Total indicator		Yellow	Undergo assessment
Bathymetry	0 m	Yellow	Site area partly meets criterion
Conservation	0 m	Yellow	Site area intersects or within conservation areas
Eelgrass	650 m	Green	Site area 650m away Eelgrass beds areas
Aquaculture	870 m	Green	Site area 870m away current aquaculture sites
Tern nesting	2350 m	Green	Site area 2350m(>=250m) away Tern nesting sites
Sea pens	8400 m	Green	Site area 8400m away sea pens

4 Assessment explanations of suitable aquaculture areas

Individual suitability indicators are calculated upon the following table. However, considering the shape of a new virtual farm is rectangle, then:

- Bathymetry: the worst value (i.e., the minimal depth for culture types bottom and suspended, and the maximal depth for trestle) is displayed; indicator in red means not any of the rectangle meets the condition, yellow means partly meets, and green means whole rectangle area meets the condition
- Current Aquaculture sites: the nearest distance between the farm rectangle and current aquaculture sites (in polygon shapes) is displayed, and a line between the nearest points is drawn; indicator in red means either the farm is within a current aquaculture site or vice versa, yellow means the farm intersects a current site, and green means the farm is outside of all current sites
- Conservation designated areas: same as "Current Aquaculture sites"
- Eelgrass beds: same as "Current Aquaculture sites"
- Tern nesting sites: the nearest distance between the farm rectangle and tern nesting sites (in point shapes) is displayed, and a line between the nearest points is drawn; indicator in red means the farm is within 250m radius of these sites, and green means not, no yellow indicator
- Sea pens: same as "Current Aquaculture sites"

Table: Suitability criteria

Data	Parameter	Criteria
Bathymetry	Bottom culture	Max depth must be >= 2 m
	Trestle culture	Max depth must be <= 0 m
	Suspended culture	Max depth must be >= 5 m
Current Aquaculture sites	Current licensed sites	No new aquaculture sites permitted within these areas
Conservation designated areas	Areas within designated area	New aquaculture sites will be required to undergo a Habitats Regulations Assessment before being considered
Sensitive species	Eelgrass beds	No new aquaculture sites permitted within these areas
	Tern nesting sites	No aquaculture permitted within 250 m radius of these sites
	Sea pens	No new bottom culture aquaculture sites permitted; Potential for new suspended culture sites. These will be required to undergo an impact assessment

http://akvavis.no/carlingford/akvawms?VERSION=1.1.1&BBOX=-685969.2684116754,71... 11/04/2017

Figure 6.30: AkvaVis Carlingford Lough demonstrator model results output report.

The previous version of the AkvaVis demonstrator model was presented to local government departments and its potential application to new and currently licensed aquaculture sites within Carlingford Lough, as well as future potential for the Northern Ireland inshore region, was highlighted. The results from the model and any future stakeholder engagement will be reported through AquaSpace.

6.7. *Conclusions and future prospects*

The Key issues identified within Carlingford Lough include conflicts between industry expansion, nature conservation, and the multiple users of Carlingford Lough. These issues are confounded by the existence of a least six different regulatory authorities in two different national jurisdictions. This case study therefore highlights the requirement for regional aquaculture spatial planning tools.

6.7.1. *GIS Assessment*

- Conclusions

Through the Habitats Regulations Assessment process GIS has proven to be an invaluable tool in the assessment of the impacts of current licensed aquaculture sites on nature conservation designations within Carlingford Lough. The Carlingford Lough GIS will be further utilised to help determine the impacts of any newly proposed aquaculture sites on nature conservation features within the Lough.

- Future prospects

The Carlingford Lough GIS project will continue to be updated (once new data sets become available) and utilised when undertaking aquaculture impact assessments.

6.7.2. *Ecological Impact Assessment*

- Conclusions

Updating the hydrodynamic component of the SMILE model, and the resultant changes to the ecological component, has enabled the determination of the ecological carrying capacity (in terms of Chl a availability) of the Lough. This is a valuable tool in the determination of the potential impacts of new aquaculture sites on the natural ecosystem of Carlingford Lough.

- Future prospects

This model will be run annually (utilising actual production figures supplied by DAERA) to determine the ecological impacts (in terms of Chl a availability) of aquaculture operations within Carlingford Lough. The SMILE model will also be utilised for the management of aquaculture sites. The SMILE model will be run to enable the determination of optimal stocking densities for mussels (*Mytilus edulis*) and oysters (*Crassostrea gigas*) within the different model boxes and will also be used to determine the production carrying capacity of Carlingford Lough.

6.7.3. *AkvaVis*

- Conclusions

The development of the AkvaVis demonstrator model for Carlingford Lough provides the user with a quick answer as to the suitability (based on a limited set of predetermined parameters) of potential new areas for aquaculture development. This is a valuable tool that can be utilised within stage 1 (Screening) of the HRA process.

- Future Prospects

The demonstrator model shows how effective a tool such as AKvaVis can be for promoting/assisting aquaculture development within Northern Ireland. It is hoped that a small stakeholder workshop will be held to introduce the demonstrator model to interested parties. It is anticipated that following this further funding will be secured to enable the development of a full version of the AkvaVis model for the Northern Ireland inshore region.

6.8. References

AFBI, 2013. Habitats Regulations Assessment: Aquaculture activities within Carlingford Lough. Report to the Department of Agriculture and Rural Development. pp168

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7. GREAT BAY PISCATAQUA AND LONG ISLAND SOUND, USA.

Suzanne Bricker and Joao Ferreira

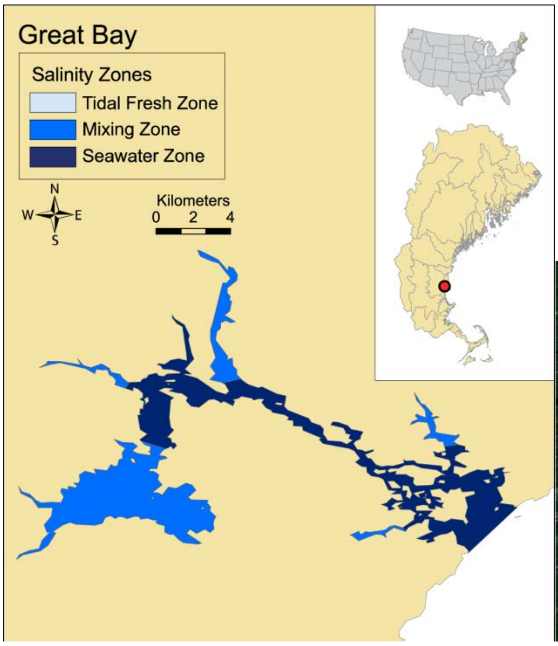
7.1. General characteristics

Eutrophication is among the most serious threats to the function and services supported by coastal ecosystems (Bricker et al. 2007; Bricker and Devlin, 2011). Waterbodies worldwide have experienced nutrient-related degradation (Zaldivar et al. 2008; Xiao et al. 2007) including excessive algal blooms, hypoxia (Diaz and Rosenberg, 2008), and loss of seagrass habitat (Orth and Moore, 1984) that can have cascading effects on fisheries (e.g. Brietburg et al. 2009; Lipton and Hicks 2003; Mistiaen et al. 2003). In the United States (U.S.), 65% of estuaries and coastal bays are moderately to severely degraded by nutrients from agricultural and urban runoff, atmospheric deposition and wastewater treatment plant (WWTP) discharge (Bricker et al. 2008). U.S. and European legislation aimed at mitigating eutrophication is focused mainly on reductions of land-based discharges (U.S. Clean Water Act PUBLIC LAW 92-500-OCT. 18, 1972, E.U. Water Framework Directive, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000). Practical limits on existing point and nonpoint source controls suggest that additional innovative nutrient management measures are needed (Stephenson et al. 2010). The use of shellfish cultivation for nutrient remediation, called 'bio-extraction,' has been proposed in the U.S. and Europe (e.g. Lindahl et al. 2005; Rose et al. 2014; Ferreira and Bricker, 2016; Ferreira et al. 2011). This research is consistent with U.S. policies and aquaculture policies (2011 US NOAA Marine Aquaculture Policy and National Shellfish Initiative, 2015 Obama Administration Ecosystem Services 74 Memorandum).

This chapter describes aquaculture studies in two U.S. estuaries, Long Island Sound (LIS) located in Connecticut, and Great Bay Piscataqua located in New Hampshire. The focus was the potential impact of oyster filtration on the reduction of nitrogen pollution in the estuaries at current and expanded oyster cultivation. There are presently US policies that encourage and promote the expansion of aquaculture in U.S. waters for production of domestic seafood but the benefits to water quality of shellfish aquaculture are also recognised (2011 US NOAA Marine Aquaculture Policy and National Shellfish Initiative, 2015 Obama Administration Ecosystem Services 74 Memorandum). In Long Island Sound an additional study was done to improve an existing GIS aquaculture siting decision support tool.

7.1.1. *Great Bay Piscataqua Regional Estuaries, New Hampshire*

The Great Bay/Piscataqua Region Estuaries (GBP) is a relatively small estuarine system of 54.7 km^2, located between the states of New Hampshire and Maine, United States. Eight major rivers as well as several small creeks and their tributaries drain into the Estuary. It is a tidally dominated, well-mixed estuary due to tidal height (2.4 m) and velocity as well as estuary geometry, though there can be a moderate level of stratification in some areas during high flow periods. Average depth is 3.8 m and the average salinity is 21 psu, with a residence time of about 1 day. The Great Bay National Estuarine Research Reserve (NERR) is part of GBP and includes 21.4 km^2 of tidal waters and mudflats, and 77.2 km of shoreline (GBNERR, 2011). The GBP watershed area covers 2,651 km^2 and includes parts of 57 towns in Maine and New Hampshire. Approximately, 287,700 people lived in the GBP watershed in 2010. The major land use is forestry (70%) with urban uses making up 19% of the watershed area. Population density is 95 persons/km^2. Noted for its valuable water resources, cultural resources, and business and industry, the Piscataqua Region is very important to state and local economies.



The shellfish aquaculture industry in GBP is relatively small, but growing, and is focused on oysters (*Crassostrea virginica*). In 2011 there were five growers with a total of 14.5 licensed acres which grants growers permission (but not exclusive rights) to use public lands (land below the mean high tide line is public trust land in NH). In 2012, there were six growers and 17.5 licensed acres. In early 2013, there were 8 growers and 24.5 acres licensed, with a total of 25.5 acres by the end of 2013 when one of the existing growers was granted a new 1-acre site. Currently, growers are in the third year of culture with about $8,000,000 in oyster sales for the year (2014). No farm is greater than 4.5 acres, and typically oysters are grown in cages or racks and bags. Cage culture produces oysters with thinner shells than bottom grown oysters; a typical harvest size GBP oyster is smaller (~70g) than the ~90g harvestable weight observed in Long Island Sound. For every oyster sold, the grower sends $0.015 to the state which supports the general funds of the New Hampshire Department of Fish and Game. Additionally, aquaculturists pay annual fees for their licenses ($100 license renewal fee) and certifications, as well as a per acre fee for their use of public land ($200 acre^{-1}). While all present operations are subtidal, there is interest in expanding to intertidal areas. *Presently most operations use rack and bag systems which are mesh bags inserted into cages, commonly referred to as 'oyster condominiums' (R. Grizzle, UNH, pers. comm.). While all present operations are subtidal, there is interest in expanding to intertidal areas. There are plans to expand* *aquaculture operations in the future, most likely bottom culture due to concerns (described as 'social carrying capacity,' Angel and Freeman, 2009) by waterfront landowners and boaters who do not want to see floating gear or risk boats getting entangled in culture gear.*

In New Hampshire a few small-scale oyster farmers are experimenting with intensive culture methods. Since wild sets of oyster larvae are sporadic at best, these growers are reliant on hatchery-reared seed which allows these growers to work with lines of oysters that have been selectively bred for fast growth and disease resistance. By utilising the intensive culture methods described above for CT growers (i.e. upwellers, cages, plastic mesh bags), NH growers are able to get a small 3.5 inch thin-shelled 70 g oyster to market in 18-30 months. These growers ask for $0.55-$0.65 wholesale for their oysters which are typically served at high-end restaurants and raw bars.

Intensive growers are able to plant at relatively high densities as long as algal concentrations and current speeds are both high enough to support good growth. Planting densities of 100-200 m^{-2} can be attained under optimal conditions. The oyster aquaculture industry is just getting started in GBP, thus there are few growers who have brought a crop to market. However, the industry is growing and production is expected to continue to grow at double-digit rates as was observed in the adjacent states of Massachusetts and Rhode Island once regulatory obstacles were cleared.

7.1.2. *Long Island Sound, Connecticut*

Long Island Sound is a large estuary (3,259 km^2), located between Connecticut (CT) to the North and Long Island, New York (NY) to the South. Three major tributaries, Connecticut, Thames and Housatonic Rivers, enter from the North and the Sound is connected to the Atlantic Ocean at its Eastern end and connects to the East River and New York Harbour to the west. The tidal height is 1.9 m and the average depth is 20m. Residence time is 2-3 months. The watershed area is 12,773 km^2 and includes parts of Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island and New York. The watershed is highly developed, particularly in the New York City and New Haven, Connecticut metropolitan areas. The watershed population in 2010 was about 8.93 million people with nearly half the population living near the coast. The overall average population density is 121 people per km^2 but locally it is much higher; 2,151 people per km^2 in the New York metropolitan area and 541 people per km^2 in the New Haven, CT metropolitan area. The largest land use is forested (70%) with urban areas making up 16% of the watershed. Activities in the watershed contribute to state and local economies, but they have taken a toll on its environmental health. Severe water quality degradation and critical habitat loss have resulted from a multitude of anthropogenic activities along its coastline.

The shellfish industry in Long Island Sound supports about 45 shellfish growers in Connecticut waters and an unknown number in NY. The industry includes harvest of both Eastern oyster (*Crassostrea virginica*) and hard clam (quahog) (*Mercenaria mercenaria*) from shellfish grounds in the states of CT and NY. Recent cultured and wild caught hard clams and oyster harvests in LIS have provided over 300 jobs and $30 million in revenue annually. Clam and oyster harvests are shown below.

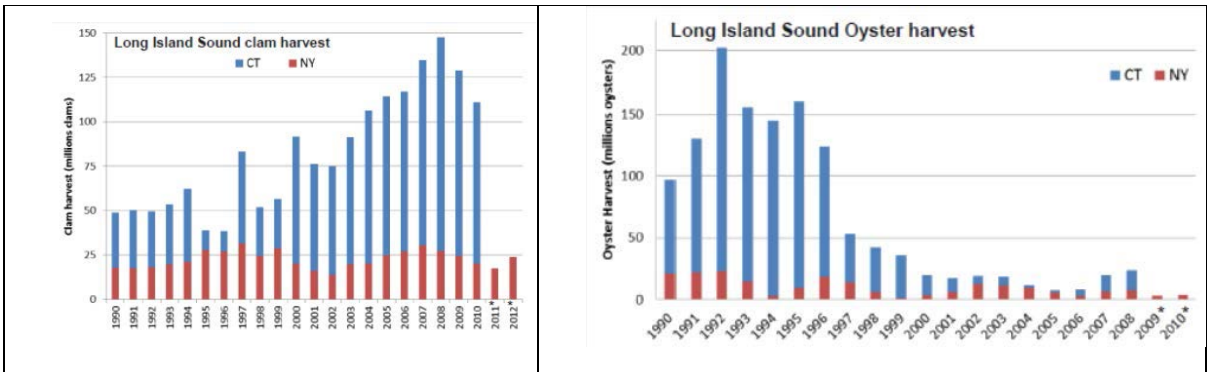


Figure 7.1. Harvest of Clams (left) and Oysters (right) from 1990 in Long Island Sound (Connecticut and New York)

Oyster production grew in the 1980s and 1990s due to successful oyster culture practices which typically grow oysters and clams on the bottom with no gear. A typical harvest size oyster is about 90g at the legal length for harvest of 3 inches (7.62 cm). The large commercial oyster industry peaked in 1992 and declined mainly due to MSX, a parasitic disease. Oyster harvests began to rebound in 2006. Since 2011, CT harvest data has not been available, but resource managers believe that harvests continue to rise. In 2012, there were 127,884 acres of approved oyster harvest areas in CT, 99,132 acres conditionally approved, 138,849 acres restricted and 23,384 acres classified as prohibited from shellfish harvest. In NY, there were 412,018 certified acres (equivalent to approved acres in CT), 1,613 seasonal (harvest allowed only during specific months of the year – similar to conditionally approved in CT), and 75,499 acres where shell fishing was prohibited. Within the approved and conditional acres in the CT side of LIS, there were a total of 66,042 acres of leased shellfish growing area; 49,463 state leased and 16,579 town leased acres.

7.2. *Spatial planning and management issues*

7.2.1. *Environmental concerns*

Great Bay Piscataqua Regional Estuaries

In 2009 – 2011, total nitrogen load to the Great Bay was 1,225 tons, less than the more than 1,200 tonnes discharged to the bay in 2005-2006, the highest loads measured since the first measures in 2003 (PREP, 2013). The higher loads occurred during years of higher rainfall and the decreases are concurrent with drier years of less rainfall. Due to the variability in this data, no long or short term trends can be determined. Non-point sources are the largest portion of the discharge of nitrogen to GBP accounting for 68% of total inputs. Nitrogen from fertilizers from lawns and farms, septic systems, animal wastes, and air deposition onto the watershed is carried into the bay through rain and snowmelt runoff, river flow, and groundwater flow. The balance of nitrogen is discharged to the bay or into tributary rivers from 18 municipal sewage treatment plants (PREP, 2013). The major contributors of nitrogen to the bay are related to population growth and associated building and development patterns within the watershed. Presently, GBP exhibits many of the classic symptoms of eutrophication including low dissolved oxygen in tidal rivers, increased macroalgae growth, and increasing occurrences of nuisance and invasive macroalgal species (PREP, 2013). Of major concern is the loss of eelgrass which has declined by 35% since 1996 (Short 2011).

The observed water quality issues led to the development of nutrient criteria to provide guidance for meeting water quality goals (NH DES, 2009). Additionally, the Piscataqua Region Comprehensive Conservation and Management Plan (CCMP) was updated in 2010 to help address issues impacting the water quality and environmental health of estuaries in the Piscataqua Region (PREP, 2010). Water quality conditions are expected to improve in the future as a result of planned management measures. Restoration of reefs and expansion of oyster aquaculture has been studied as a potential boost to traditional land based nitrogen management measures (Nash and Elliott 2012; Konisky et al. 2014).

Long Island Sound

Hypoxia was used in the 2000 Total Maximum Daily Load analysis (TMDL) to guide a plan for 58.5% N load reduction (by 2017) in order to fulfil water quality objectives (NYSDEC and CTDEP, 2000). Implementation of the TMDL resulted in >40% reductions in N loads by 2012, 83% of final reduction goals, primarily through WWTP upgrades to biological nutrient removal; (LISS, 137 2013). Atmospheric and agricultural loads also decreased (LISS, 2013). While water quality improvements have been documented, they have been slow and masked by weather-driven variability and continued population growth (CT DEEP, 2013). The Assessment of Estuarine Trophic Status (ASSETS) model was applied to average monthly monitoring data from 2008 - 2012 to update the eutrophication status of Long Island Sound and to justify necessary additional nutrient management measures (Bricker et al. 2003, 2008; 2015). Eutrophication conditions improved from High to Moderate High since the early 1990s (Bricker et al. 2007). Improvements resulted from increased bottom water DO concentrations reflecting load reductions from 60.7×10^3 to 50.0×10^3 tonnes y-1 (Latimer et al. 2014). However, chlorophyll *a* concentrations did not change, receiving a rating of High. As nitrogen loads continue to decrease, further improvements are expected but they may be counterbalanced by increasing population. The TMDL analysis concluded that full attainment of desired water quality standards would require additional reductions or increased assimilative capacity. The updated eutrophication assessment results confirm this conclusion. The TMDL identified alternative management methods, such as bioextraction, as potential measures to help achieve DO standards. The well-established Eastern oyster (*Crassostrea virginica*; hereafter 'oyster') industry makes LIS a compelling site to test the potential for N removal through cultivation and harvest. Recent CT shellfish harvests have provided over 300 jobs and $30 million in farmgate revenue annually, with oyster harvest exceeding 200 x 103 bushels (CT Department of Agriculture, 2011).

Local, state, and federal agencies have been exploring the use of shellfish aquaculture as a nutrient management measure in the North-eastern U.S. (Rose et al. 2014; Kellogg et al. 2014; Oyster BMP Panel, 2016). Recent research has shown that the costs and removal efficiencies of nitrogen (N) through shellfish cultivation compare favourably with approved Best Management Practices (BMPs; Stephenson et al. 2010; Rose et al. 2014). Nutrient credit trading has been proposed, and in some states implemented, as a tool to achieve water quality goals (Lal, 2010; Branosky et al. 2011). These programs establish a market-based approach to provide economic incentives for achieving nutrient load reductions to meet pollution reduction targets. They could create new revenue opportunities for farmers, entrepreneurs, and others who are able to reduce discharges below allocated levels at low cost and sell credits received to dischargers facing higher-cost reduction options. The Connecticut Nitrogen Credit Exchange (CT NCE) was created in 2002 to improve nutrient-related hypoxia conditions in Long Island Sound (LIS), providing an alternative compliance mechanism for 79 wastewater treatment plants (WWTPs) throughout the state. During 2002-2009, 15.5 x 10^6 N credits were exchanged at a value of $46 million, with estimated cost savings of $300-400 million (CT DEP, 2010). The CT NCE trading of point sources is active and successful but does not as yet include non-point sources.

7.2.2. *Maritime Spatial Planning and Siting Concerns*

Great Bay Piscataqua Region Estuaries

Great Bay Piscataqua Regional Estuaries have the carrying capacity and zoning requirements to allow for approximately 72 additional acres to be added over time, potentially reaching 97 acres under lease. There are social impediments to expansion however, with landowners and boaters arguing against expanded leases. For this reason, it is likely that any expansion will be in cage culture but on the bottom where they are less obvious to the view scape and to boaters and other users.

Long Island Sound

There are plans to expand Long Island Sound aquaculture operations in the future, and though >90% of current producers are using bottom culture with no gear, future development will likely be floating culture. However, future expansion will be difficult in this highly urban waterbody due to concerns (described as 'social carrying capacity') of waterfront landowners who do not want to see floating bags or working farms in their viewscape, and boaters who do not want to risk boats getting entangled in culture gear. But shellfish aquaculture expansion is being promoted for both increased seafood production and water quality improvement.

Presently there are several state-level, GIS-based shellfish aquaculture site selection tools under development or in use in the United States, including one operating in Long Island Sound, Connecticut (https://www.arcgis.com/home/webmap/viewer.html?webmap=08d223910abd471fb07c120e5511dacb). These GIS based mapping tools allow visualisation of aquaculture within the context of other coastal zone uses to minimize use conflicts and to overlay various datasets to depict potential environmental interactions (e.g. species, habitats, contaminants, food availability). GIS-based tools are successful at minimizing use conflicts for siting operations but mapping alone does not address productivity at these suitable sites (Longdill et al. 2008). Modelling has provided better insight into the potential success of candidate farm locations in terms of biological production and ecological carrying capacity (e.g. Filgueira et al. 2013a, 2013b, 2014a, 2014b; Tissot et al. 2012). Here we refer to ecological carrying capacity as the maximum stocking or farm density that is possible without unacceptable ecological impacts (Inglis et al. 2000). Potential production, socioeconomic outputs, and environmental effects can be estimated through the application of models, including scenarios, without the cost or time required for actual implementation. Site specific environmental data along with typical cultivation practices can be used to predict seed stocking density to determine the optimum long-term production that the area will support. In turn, this allows estimation and maximisation of sustainable harvest of shellfish, as well as an assessment of long-term socio-economic profits and negative and positive environmental externalities (e.g. Bricker et al. 2015; Ferreira et al. 2011; Grant and Filguiera, 2011; Silva et al. 2011).

7.3. Stakeholder engagement and participation

The overall project team included members and stakeholders from federal (National Oceanic and Atmospheric Administration – National Ocean Service and National Marine Fisheries Service; US Environmental Protection Agency; US Army Corp of Engineers), regional (Piscataqua Regional Estuary Partnership), state (Connecticut Bureau of Aquaculture), local (EPA Long Island Sound Office), university (University of Connecticut; University of New Hampshire), private consulting companies (HDR, Inc.; Northern Economics, Inc.), regional trade organisations (East Coast Shellfish Growers Association) and international (New University of Lisbon; Longline Environment, Ltd.) contributors.

The Great Bay Piscataqua Regional Estuaries project had 2 in person workshops and several phone calls with project partners for the nutrient bioextraction modelling project (Bricker et al. 2015).

The Long Island Sound project had 2 in person workshops and several phone calls with project partners for the nutrient bioextraction modelling project (Bricker et al. 2015) and 2 additional meetings with the project team focused on the aquaculture siting project that combined the CT Shellfisheries Atlas tool with results of the FARM model (Bricker et al. 2016). One of the difficulties in the Long Island Sound project was the lack of engagement, interaction and input from shellfish growers in Long Island Sound. This was largely the result of the absence of reporting due to grower disgruntlement with a $1US per bushel tax that was proposed in 2007/2008 at which point growers stopped reporting their harvest. Because our project was funded by the government, the growers were suspicious of our intent and did not freely engage with our group. While this nearly derailed our project, we were able to work with the CT Bureau of Aquaculture to make a calculation of the harvest and mortality from previously reported values.

As an example, although we knew the acres of oyster lease, the growers were not forthcoming with how much of the lease area was being actively cultivated. Additionally, they did not disclose details of their cultivation practices such as seeding density, mortality, and harvest which are critical model inputs and also are used for model validation. Phone calls to specific growers were used to estimate the typical percent of area that was cultivated on a lease. The information from the growers was used to develop a bracketing approach whereby highest and lowest areas of current lease were calculated and the mid-value used to represent current cultivated area. The maximum potential area that could be cultivated (11,116 acres) was determined as one half of all suitable area within the 12 m (40 ft) bottom contour. The spatial distribution of production was estimated by superimposing known harvests from different locations onto these areas.

7.4. *Tools used in the case studies*

The bioextraction studies a combination of local aquaculture models, watershed models, field data and experiments and laboratory experiments to evaluate the impacts of watershed discharges on water quality and the interaction of shellfish aquaculture and water quality. The main models used are the ecosystem-scale EcoWin model (used only in Long Island Sound), the local-scale Farm Aquaculture Resource Management (FARM; Ferreira et al. 2007; www.farmscale.org) aquaculture model and the Estuarine Trophic Status (ASSETS; Bricker et al. 2003; www.eutro.org/register). An avoided costs analysis was conducted for valuation of the removed nutrients. Note that the FARM model was used in combination with an existing GIS aquaculture siting decision support tool in Long Island Sound (https://www.arcgis.com/home/webmap/viewer.html?webmap=08d223910abd471fb07c120e5511dacb) to improve the GIS tool. In both cases, the current acres of oyster cultivation were used in the models to evaluate the current nutrient removal impact. Importantly, in both estuaries an analysis was done to estimate the maximum possible expansion of cultivated acres to evaluate the maximum possible benefit to water quality. In both estuaries there are plans to expand aquaculture lease areas and there are long-term water quality programs in both systems providing data for this study and for any future analyses.:

- The *EcoWin.NET model* (EWN; Ferreira 1995), is a system scale model operating on timeframes of decades which is of interest for aquaculture and economics, it uses a 2 layer, 42 box model grid to simulate system-scale oyster production, and associated drawdown of chlorophyll (Chl), particulate matter (POM), and nitrogen (N) using relevant components of transport biogeochemistry, and shellfish models. The EWN aquaculture model combined hydrodynamic outputs from SWEM as described above, with external nutrient loads representative of the fully implemented 2000 TMDL N and carbon load reductions (HydroQual 2007, 2009). Oyster populations in EWN are modelled using standard population dynamics equations driven by individual scope for growth and mortality (Nunes et al. 2011), using 20 heterogeneous weight classes spanning 0-100 g live weight.

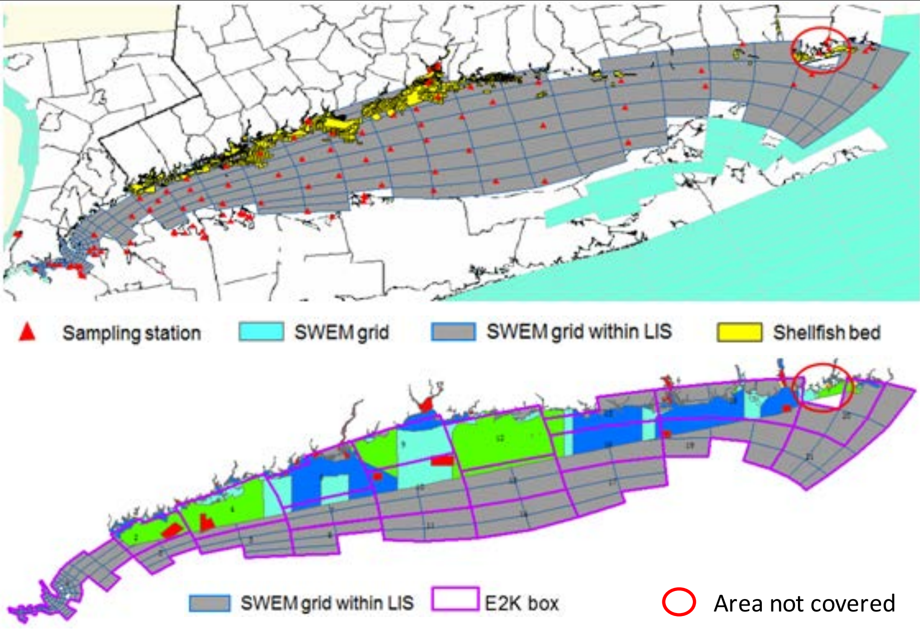
- 

Figure Diagram of SWEM grid coverage in Long Island Sound; a) shellfish beds and sampling stations shown with SWEM grid, and b) SWEM grid boxes and EWN boxes are shown with missing grid area marked in red circle.

- The *Farm Aquaculture Resource Management* model (FARM; www.garmscale.org) is a local scale model that combines physical and biogeochemical models, shellfish growth models, and screening models at the farm scale for the determination of shellfish production and for the assessment of water-quality changes on account of shellfish cultivation. The model has been used previously for decision support for aquaculture siting (e.g. Ferreira et al. 2012; Silva et al. 2011) taking into account food conditions inside a farm, shellfish eco-physiological characteristics, and farming practices. Potential nutrient removal by the farms was estimated and compared to estimates from EWN simulations.

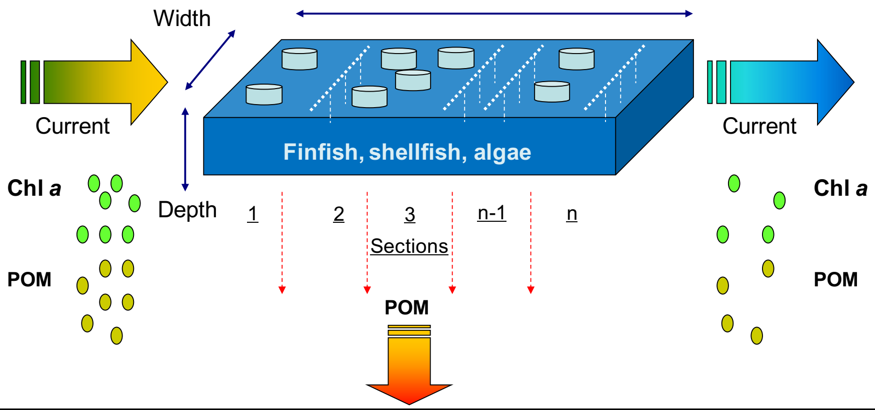
- 

Figure XX Farm layout (rope and bottom culture) used in FARM model (Ferreira et al. 2007, 2009).

- The *Assessment of Estuarine Trophic Status* (ASSETS; www.eutro.org/register) model was designed to address requirements of the different US Acts, such as the Clean Water Act of 1972 and the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998. It is a highly aggregated integrative screening model that includes an assessment of pressure (called Influencing Factors (IF)], state [Eutrophic Condition (EC)], and expected future response [Future Outlook (FO)]) within a water body. The three components are then combined into a single overall score, called ASSETS.

- A *cost-based economic analysis* method used to estimate the value of the N removal service based on costs of avoiding damages due to lost services, replacing services, or providing substitute services (King and Mazzotta, 2000). The avoided costs value of the removed N, estimated by the EWN model application, was calculated as the cost savings from substituting or using bioextraction instead of other nutrient abatement options. The alternate N reduction strategies used to value estimates for removed N were improvements to WWTPs at three different treatment levels, implementation of agricultural BMPs, and urban non-point controls (Evans 2008).

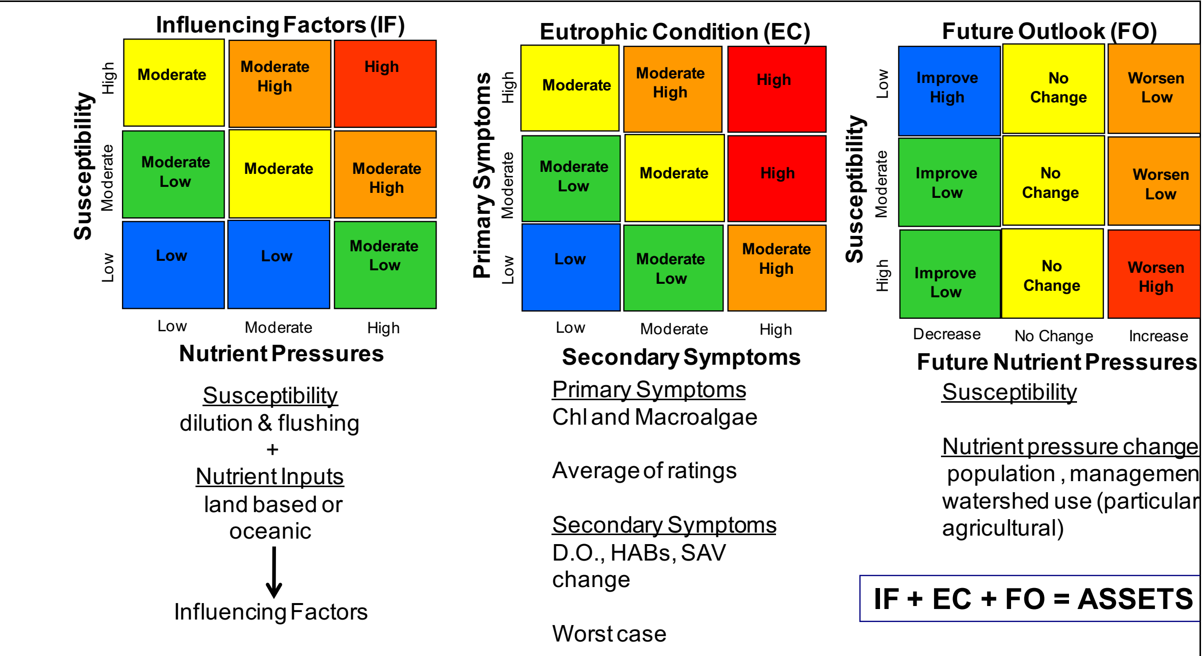


Figure 7.2. Summary of Assessment of Estuarine Trophic Status (ASSETS) method, a Pressure-State-Response framework that uses matrices in each of the three components, Influencing Factors, Eutrophic Condition and Future Outlook. From: Bricker et al. 2003.

We evaluated the success of current aquaculture cultivation and maximum possible expanded acres (harvest), the impact of the farm on water quality (changes in chlorophyll and dissolved oxygen related to aquaculture activity), the potential economic benefit of the water cleaning service provided by the shellfish, and the credit potential for trading carbon and nitrogen in a water quality trading program (value of nutrients removed).

The FARM aquaculture production model (www.farmscale.org) and ASSETS eutrophication assessment model (www.eutro.org/register) are distributed online and are available to regulatory agencies and decision makers to evaluate carrying capacity, social, economic and environmental issues.

7.4.1. *Data used in the case studies*

Great Bay Piscataqua Regional Estuaries

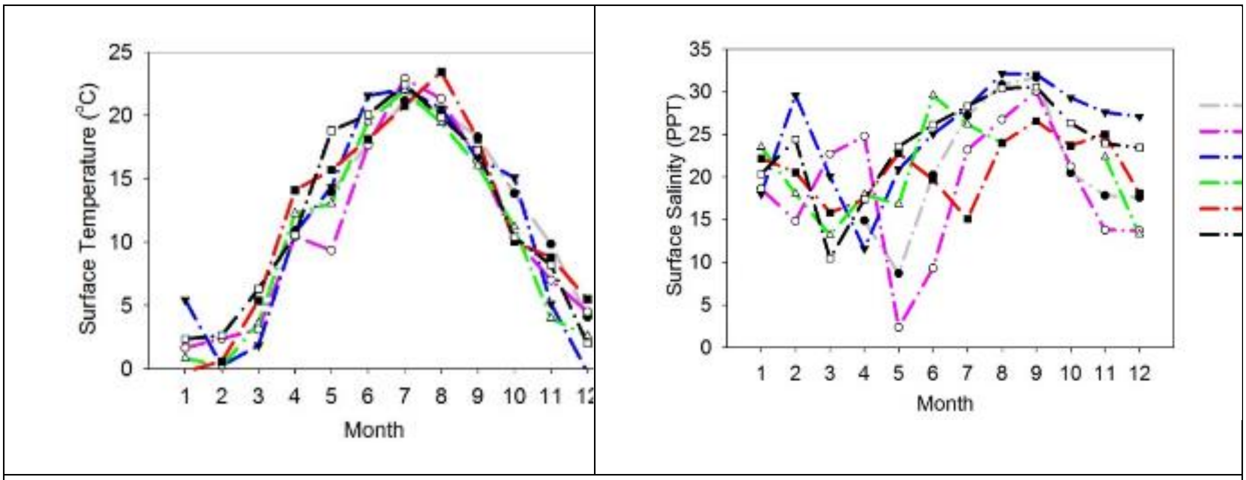


Figure 7.3. Monthly temperature (left) and salinity (right) in Great Bay/Piscataqua Region Estuaries at station BRBAP, located near Adam's Point the only station for which there are data for January - December, 2005 – 2010 (where 1- 12 = Jan - Dec).

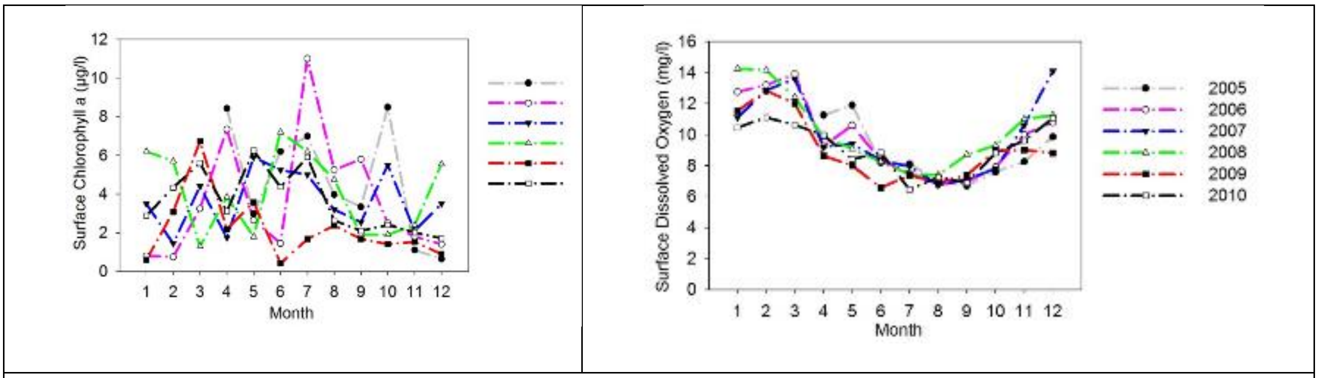


Figure 7.4. Great Bay/Piscataqua Region Estuaries station GRBAP at Adam's Point monthly chlorophyll concentrations (left) and monthly dissolved oxygen concentration, January – December, 2005 – 2010.

7.4.2. *Statistical tests of Great Bay Piscataqua data*

A statistical analysis was performed on the data to rule out any trends in the dataset that might bias results. Jonckheere-Terpstra (JT) tests (Zar, 1999) were performed to detect trends through time for water quality data (temperature, salinity, CHL, and DO) at each station. All data for each station were grouped by year. The null hypothesis for the JT test was that there was no trend through time. A standard α- level of 0.05 was used to define the threshold for acceptance or rejection of the null hypothesis. P-values greater than α- level of 0.05 indicated that there was no trend.

Long Island Sound

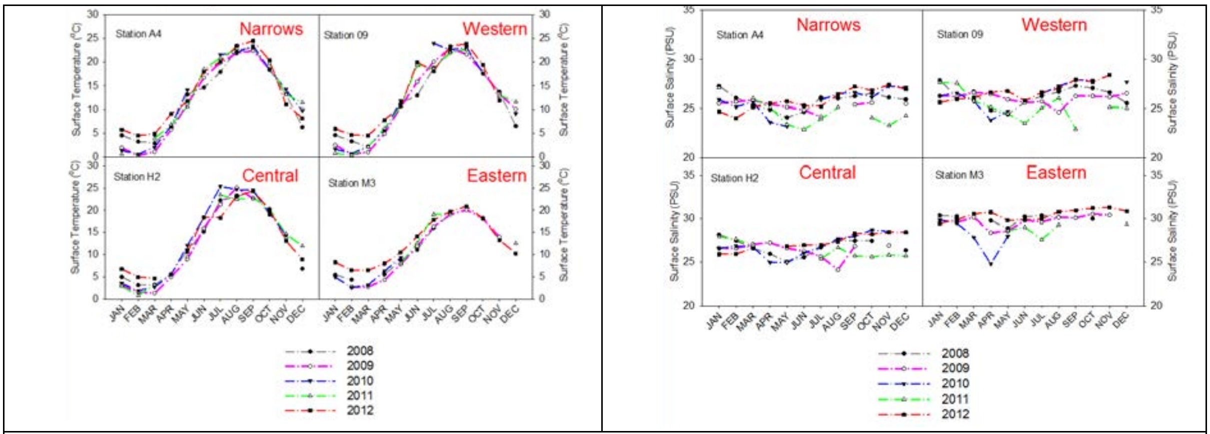


Figure 7.5. Monthly temperature (left) and salinity (right) at 4 LIS stations January - December, 2008 – 2012. (see Figure 1 for locations).

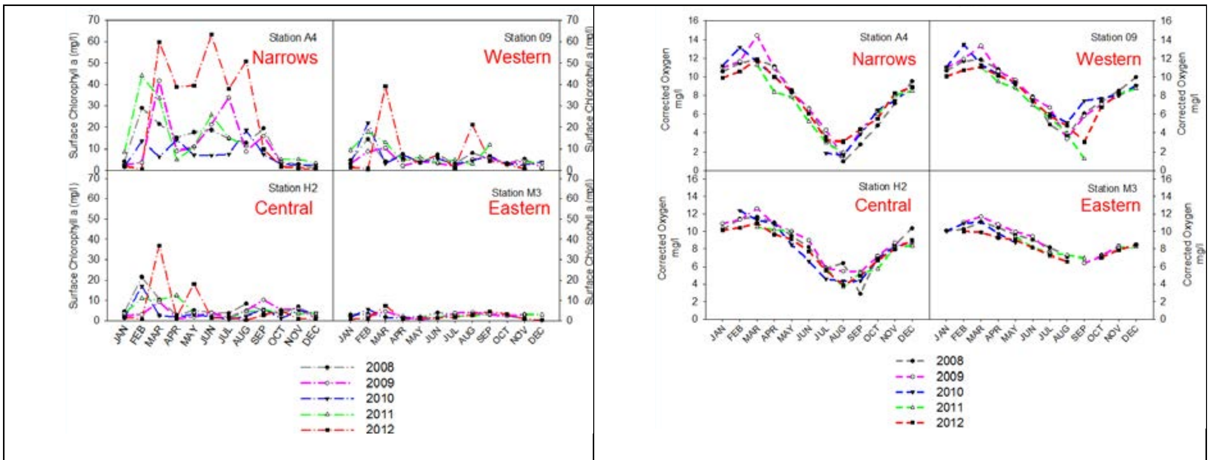


Figure 7.6. Monthly chlorophyll concentrations (left) and monthly bottom water dissolved oxygen concentrations (right), January – December, 2008 – 2012 at 4 Long Island Sound stations (see Figure 1 for locations).

7.4.3. *Statistical tests of Long Island Sound data*

A statistical analysis was performed on the data to rule out any trends in the dataset that might bias results. Jonckheere-Terpstra (JT) tests (Zar 1999) were performed to detect trends through time for water quality data (temperature, salinity, CHL and DO) at each station. All of the data for each station was grouped by year. The null hypothesis for the JT test was that there was no trend through time. A standard α- level of 0.05 was used to define the threshold for acceptance or rejection of the null hypothesis. P-values greater than α- level of 0.05 indicated that there was no trend.

7.5. *Case study results*

7.5.1. *Great Bay Piscataqua Regional Estuaries*

Table 7.1. Results of upscaling farmscale FARM model results to present and potential expanded aquaculture in GBP.

Upscaling N removal in Great Bay/Piscataqua Region Estuaries					
	Acres	N removed (metric tons)	% of total input	People Equivalents	Value of Ecosystem service
Simulated one acre farm	1	0.35	0.03	105	$4,200
Present acres	25.5 (12.8 acres in cultivation)	8.9	0.73	2,678	$107,100
Future acres (minimum = present acres + additional 36 acres)	61.5 (30.8 acres in cultivation)	21.5	1.76	6,458	4258,300
Future acres (maximum = present acres + additional 72 acres)	97.5 (48.8 acres in cultivation)	34.1	2.79	10,238	$409,500

- Bioextractive removal of nitrogen through shellfish aquaculture does not contribute significantly to the removal of nitrogen compared to total inputs.
- Upscaled local scale N removal estimates from the local scale FARM model application at 2 sites in GBP show that oyster aquaculture removes 0.73% of total inputs under current acres. If expanded to the maximum acreage allowable, 2.8% of total N inputs could be removed through oyster bioextraction.
- Expansion of oyster aquaculture would lead to a removal of between 2 and 3% of the total N load in both systems.
- The value of bioextraction estimated through the cost-avoided method for GBP is $1.1 and $1.3 million under the current scenario of 25 acres of shellfish lease area. If production acres were to expand to the potential 97 acres the corresponding range of values is estimated to be $4.3 - $5.0 million.

- The use of shellfish biotechnology as a water quality management tool will require further verifications of actual production and revenues of shellfish harvesters and modifications of existing public cost-share programs or inclusion in economic nutrient trading programs. Regardless of whether shellfish farmers become eligible for nutrient credit trading, the valuation of the ecosystem services associated with shellfish culture will enhance public awareness of water quality issues, and could help shift attitudes to allow increased opportunities for shellfish culture, and stimulate local economies.

Table 7.2. Summary of Nitrogen Removal and Value of Removed N for Great Bay and Piscataqua Regional Estuaries

		Total Value ($/yr)	Nitrogen Removed (lb/yr)	Value ($/lb/yr)
Current	8mg/l	1,278,545	16,525	77.37
	5mg/l	1,116,476	16,525	67.56
	3mg/l	1,152,491	16,525	69.74
	Ag. BMP	-	-	N/A
	Urb. BMP	-	-	N/A
Potential	8mg/l	4,040,201	52,219	77.37
	5mg/l	3,528,063	52,219	67.56
	3mg/l	3,641,871	52,219	69.74
	Ag. BMP	-	-	N/A
	Urb. BMP	-	-	N/A

Source: Northern Economics Analysis 2014

7.5.2. *Long Island Sound*

- Bioextractive removal of nitrogen through shellfish aquaculture does not contribute significantly to the removal of nitrogen compared to total inputs.
- In LIS, the EcoWin simulation showed bioextraction of N by oyster aquaculture ranging from 0.11 to 1.88% of total N inputs, with an increase to almost 3% of total N inputs in an expansion scenario. Results that include oyster and clam cultivation are more promising, with a removal ranging from 0.58– 10% under low and high values for acres currently in cultivation, and up to about 14% if cultivation is expanded. However, the quahog removal was not included in the model explicitly, only as a wild species with no natural mortalities

and without a calibrated and validated growth model. Thus, we only use the oyster values for discussion.

- Nitrogen removal estimates based on the local scale FARM model applied to 4 areas in LIS (0.09 – 1.6% total input) compare well to the removal estimated from system scale EcoWin results (0.11– 1.88% total N input). This suggests that in places where there is no system scale hydrodynamic model, upscaled local scale results can provide a reasonable estimate of removal, dependent on caveats and assumptions.
- Based on a costs avoided method of estimation, the value of the N removed through oyster cultivation and harvest in LIS ranges from \$8.5 to \$230.3 million under the current acreage scenario. If LIS were to expand aquaculture production, the potential value could range between \$17.4 and \$469.3 million, depending on the alternative abatement approach considered.
- The use of shellfish biotechnology as a water quality management tool will require further verifications of actual production and revenues of shellfish harvesters, and modifications of existing public cost-share programs, or inclusion in economic nutrient trading programs. Regardless of whether shellfish farmers become eligible for nutrient credit trading, the valuation of the ecosystem services associated with shellfish culture will enhance the public awareness of water quality issues, and could help shift attitudes to allow for increased opportunities for shellfish aquaculture, and stimulate local economies.

Table 7.3. Summary of Nitrogen Removal and Value of Removed N for Long Island Sound

		Long Island Sound		
Scenario	Abatement Source	Total Value ($/yr)	Nitrogen Removed (lb/yr)	Value per Acre Cost ($/lb/yr)
Current	8mg/l	21,148,285	1,445,764	14.63
	5mg/l	24,318,909	1,445,764	16.82
	3mg/l	64,782,727	1,445,764	44.81
	Ag. BMP	8,535,842	1,445,764	5.90
	Urb. BMP	230,277,273	1,445,764	159.28
Potential	8mg/l	43,099,893	2,946,387	14.63
	5mg/l	49,561,577	2,946,387	16.82
	3mg/l	132,026,242	2,946,387	44.81
	Ag. BMP	17,395,919	2,946,387	5.90
	Urb. BMP	469,301,681	2,946,387	159.28

Source: Northern Economics Analysis 2014

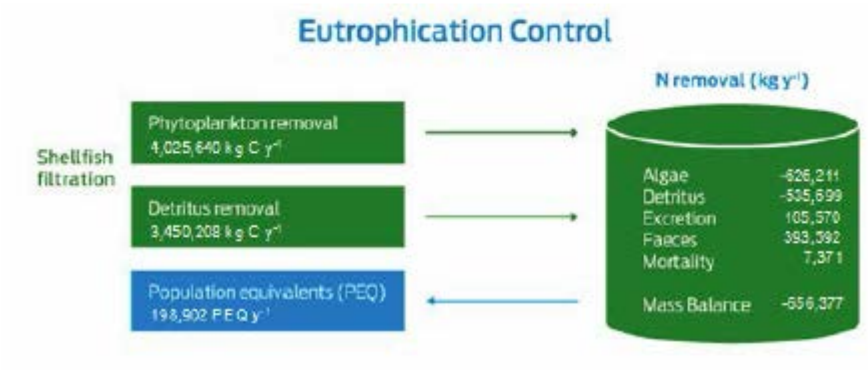


Figure 7.7. Mass balance for the total cultivated area of oysters in Long Island Sound, based on results from EcoWIn.NET.

7.5.3. *Improving an aquaculture siting tool to help the success of Maritime Spatial Planning*

In Long Island Sound, Connecticut, we combined 2 tools, the Aquaculture Mapping Atlas (https://www.arcgis.com/home/webmap/viewer.html?webmap=08d223910abd471fb07c120e5511dacb) and the local scale Farm Aquaculture Resource Management model (FARM; Ferreira et al. 2007a, 2007b, 2009, 2012; www.farmscale.org), to provide an improved GIS-based decision support tool to identify suitable areas for siting aquaculture that will minimize use conflict and assess the potential for successful growth (Bricker et al. 2016). The combined tool is intended to help streamline and facilitate permitting, giving regulators, who have responsibility to prevent adverse impacts to habitat and to avoid use conflicts, the necessary information to evaluate grower requests. Thus it should facilitate the integration of social, environmental and economic factors in the decision- making process. The combined tool will assist informed and smart growth of aquaculture with expansion into areas best suited for shellfish production.

In general terms, the CT Shellfisheries Atlas tool combines various layers of geospatial information to depict the location of restricted or potentially problematic areas, which provides a method to identify those areas that have limited regulatory constraints and suitable water quality to allow oyster aquaculture. The Farm Aquaculture Resource Management (FARM) model was used to estimate potential production in areas deemed 'suitable' for commercial shellfish activities without the cost and time required for implementation. For this pilot study, all stations were included in the modelling, regardless of suitability determination. The model was applied to data from each station within the three nearshore study areas (Westport, Milford, Mystic) and from two sites in Connecticut waters of Long Island Sound. The model output used to evaluate site suitability was the estimated time for *C. virginica* seed (one inch, 2.54 cm) to reach harvestable size (three inch, 7.62 cm).

The three nearshore study areas, Mystic, Milford, and Westport, are small (5–30 km^2 area), shallow (~3m average depth) and support a variety of marine based activities (e.g. recreational and commercial boating, fishing, aquaculture, and shipping). The Long Island Sound stations are located in water depths of about 10m and are adjacent to or overlapping with shellfish lease areas. The base map, used to locate and identify these areas of interest, could be a street map, aerial imagery, topographic map or navigational chart. Once determined, geospatial data layers were used to depict unsuitable areas sequentially and the areas that remained were considered suitable for siting of aquaculture activities.

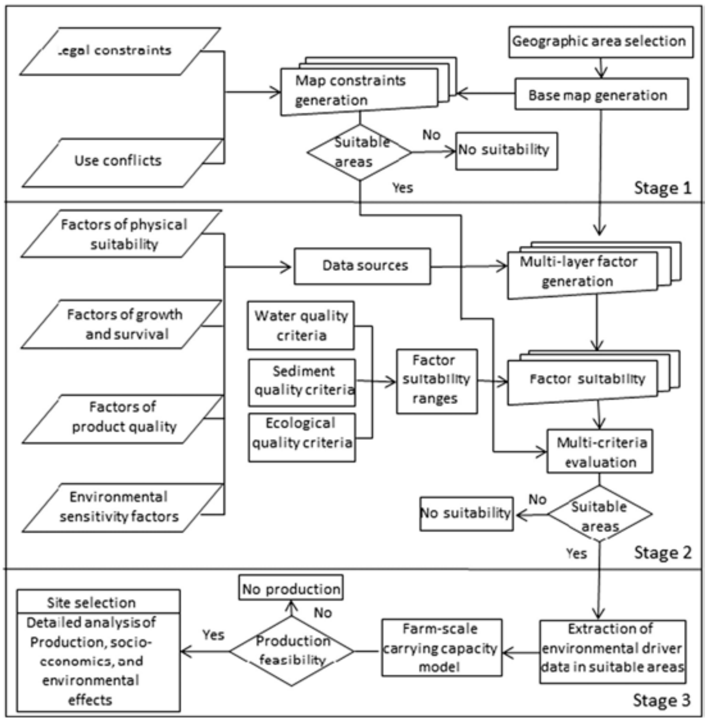


Figure 7.8. *Flow process and considerations for selection of shellfish aquaculture sites adapted from the framework of Silva et al. (2011) for this study. Here stages 1 and 2 represent steps taken in the CT Aquaculture Mapping Atlas for determination of suitability, stage 3 represents application of FARM model results to areas deemed suitable in stages 1 and 2. Production, specifically time to reach harvest size as the key indicator in Bricker et al. (2016).*

- All stations, both nearshore and offshore, are considered suitable for aquaculture with demonstrated Moderate to High growth potential based on results of FARM model simulations. The results will be added as a GIS layer (dark green to indicate High growth and light green for Moderate growth potential) to the existing Connecticut Aquaculture Mapping Atlas.
- It is worth noting that the results of this pilot study did not differentiate among locations in Connecticut (i.e., all stations were in the Moderate and High growth categories). This tool is likely to be most useful in locations with limited existing aquaculture or new industry, rather than distinguishing among locations in a waterbody already known to support good shellfish growth.
- This tool provides useful information to aid growers in the selection of an aquaculture site from those deemed suitable by the mapping tool, and for resource managers and regulators who are charged with permitting oyster lease areas.
- Where measured data are not available for a full year, particularly when winter data are missing and not data typical of the major growing season, model data can be used as inputs if an ecosystem scale model, such as EcoWin, with monthly data output is available.

- It is important when comparing among suitable sites to use data from the same year due to large inter-annual variability in many locations. Comparison of data from different sites and different years may give an incorrect determination of the most desirable site.

- Analysis of FARM results at two long-term monitoring sites in Long Island Sound showed that there was specific chlorophyll *a* thresholds that were reasonable predictors of ‘good’ and ‘bad’ years for potential oyster growth. These results indicate a threshold of annual average chlorophyll *a* concentrations of 4.50 μg L^{-1} above which growth is considered ‘good’ while an analysis of variation 2.69 μg L^{-1}. It is possible that these thresholds would be a useful screening tool, though further research should confirm these threshold values.

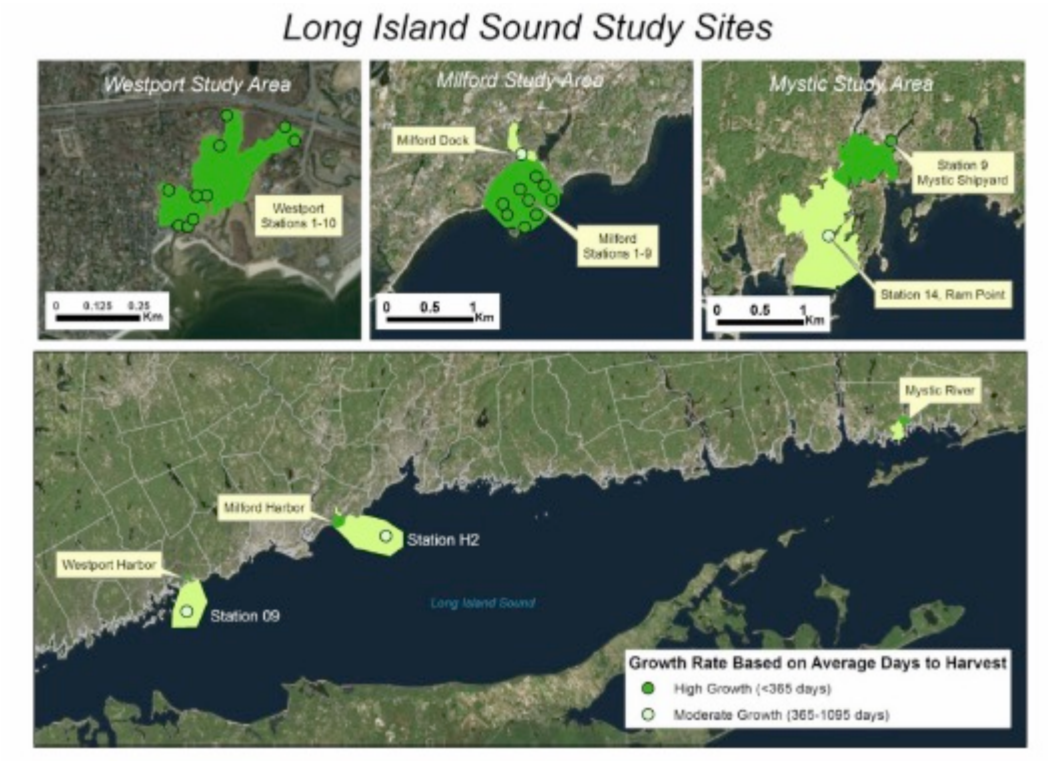


Figure 7.9. GIS layers to be added to the Connecticut Aquaculture Mapping Atlas. The layers depict areas of High and Moderate ‘potential oyster growth’ based on FARM model results as they would be applied to areas deemed suitable by the CT Shellfisheries Atlas.

7.6. Relevance of the case studies within AquaSpace

7.6.1. *Great Bay Piscataqua Regional Estuaries and Long Island Sound, USA*

These case studies in two U.S. estuaries are designed to address U.S. and European legislation aimed at mitigating eutrophication (U.S. Clean Water Act PUBLIC LAW 92-500-OCT. 18, 1972, E.U. Water Framework Directive, Directive 2000/60/EC of the European Parliament and of the Council of

23 October 2000). The use of shellfish cultivation for nutrient remediation, called 'bioextraction,' has been proposed in the U.S. and Europe (e.g. Lindahl et al. 2005; Rose et al. 2014; Ferreira and Bricker, 2016; Ferreira et al. 2011) and the bioextraction project results confirm the usefulness of aquaculture for nutrient removal but also to stimulate coastal economies. This in turn supports the use of coastal areas for multiple uses, incorporating shellfish aquaculture into the list of uses and promoting expansion not only as a means of sustainable seafood but also for water quality improvement. This research is consistent with U.S. policies promoting shellfish aquaculture for both seafood production and for the ecosystem service value of water quality improvement (2011 US NOAA Marine Aquaculture Policy and National Shellfish Initiative, 2015 Obama Administration Ecosystem Services 74 Memorandum).

Through the maintenance of current production and expansion into additional bottom and cage culture in both estuaries, seafood will be provided but also water quality improvements. While not unique to these waterbodies, this research adds to the body of work contributing to the development of shellfish as a best management practices (BMP) for nutrients. This also supports the potential inclusion of shellfish growers in nutrient credit trading programs – this has still not happened since most programs are trading only point sources but the body of work did inspire the Chesapeake Bay Program to convene a panel to determine the process and protocols for crediting oysters with nutrient removal. That panel has released its first recommendations for crediting of harvested oyster tissue with nitrogen and phosphorus removal on December 19, 2016 (see http://www.chesapeakebay.net/calendar/event/24330/, https://coastalscience.noaa.gov/news/ecosystem-management/environmental-effects-of-aquaculture/panel-releases-first-recommendations-oyster-aquaculture-practices-reduce-nutrients-chesapeake-bay/).

The bioextraction and siting studies detailed in this case study address the objectives of the AquaSpace project to assess current status, processes and practices for aquaculture siting, site selection and area management. The aquaculture in Long Island Sound is presently conducted in a traditional fashion where by more than 90% of aquaculturists harvest seed oysters from restricted areas and relay them for grow out on bottom with no gear in approved areas. The future growth of aquaculture in Long Island Sound includes some floating and cage culture but is still primarily bottom culture with no gear. In Great Bay Piscataqua Regional Estuaries expansion will likely occur as bottom cage culture since there is social impediments to expansion of floating cages as there are in Long Island Sound and many other estuaries in the U.S. and around the globe.

7.7. Conclusions and future prospects

(i) Regarding to the participation and perspectives from stakeholders

The bioextraction project would have been more successful if growers had been engaged and involved in the project. Despite their knowledge that we were doing the work in part for the potential payment to them for the ecosystem service provided by their oysters, as a government funded project they were unwilling to join the team. We must work harder to include growers as project partners.

(ii) Regarding to the implementation of the Aquaspace tool (or the ones implemented in the CS)

The bioextraction modelling framework is useful for determining carrying capacity of a waterbody and estimating current and possible nutrient removal as well as current and potential harvest. This and the improvement of the GIS based siting tool will provide much use in the sustainable and smart siting and expansion of shellfish aquaculture as well as in the improvement of nutrient management in coastal waterbodies that support shellfish.

(iii) What new knowledge has AquaSpace provided to the case study?

These studies were done in US estuary and thus the AquaSpace project has knowledge of how things are done on a broader geographic scale with examples in the Long Island Sound, a major oyster producer in the US and in Great Bay Piscataqua Estuaries, a smaller industry that is relatively new.

(iv) Is it expected that the approach and concepts developed in AquaSpace are going to be implemented or considered by managers or decision-makers?

Since the use of shellfish aquaculture as a nutrient management measure is now being evaluated in earnest by the Chesapeake Bay Program (e.g. http://www.chesapeakebay.net/calendar/event/24330/), it is likely that maritime spatial planning to make room for aquaculture as well as programs to evaluate the nutrient removal will go forward in many states. In the US they are already close to becoming operational, it is good for AquaSpace to be able to represent the spectrum of operability in the EU as well as elsewhere and how these tools might be used.

(v) How can the Aquaspace tool support the aquaculture activity? Licensing, minimizing conflicts of use, suitability analysis, site selection.

Our GIS + FARM model aquaculture siting decision support tool is meant to streamline the permitting process, the tools will minimize conflicts in multi-user locations leading to shorter time to permit approval and more successful site selection and thus more successful aquaculture operations.

(vi) What other functionalities might be interesting to develop in the future?

(vii) Which are our perspectives on the measures or strategies that should be adopted to “increase space for aquaculture” at your national level? (then, we can collate all the ideas and include it in the Synthesis document. This could be an important outcome from the project)

The GIS decision support tool combined with the local scale FARM model aquaculture model showing where aquaculture will be successful could lead to greater success in siting and may be useful if aquaculture use zones are implemented in a water body.

(viii) What is going to be the role of the outcomes from AquaSpace and aquaculture activity in general, in the development of national MSP?

The outcomes will be useful to inform local, state, regional and national legislative mandates in the US about how to go forward with respect to increasing aquaculture by new siting and/or expansion of existing operations.

(ix) The benefits that can be derived using the spatial planning tools to address the national issues

More successful siting through an improved decisions support tool, which will support increased and sustainable domestic seafood production in addition to helping to improve coastal water quality.

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8. HOUTMAN ABROLHOS ARCHIPELAGO - WESTERN AUSTRALIA

Ana Martins Sequeira and Callum Donohue

8.1. General characteristics

The geographical extent of Western Australia (WA) offers great potential for aquaculture. Currently, the aquaculture sector generates high quality seafood products valued at around $90 million annually (The Department of Fisheries, 2016). Production is mostly from South Sea pearls but also barramundi, mussels, marron, silver perch, rainbow trout, and yabbies. The state government has established two new aquaculture development zones situated between the Easter and Pelsaert island groups of the Houtman Abrolhos Archipelago. These zones will contain open water finfish cages where Yellowtail Kingfish (*Seriola lalandi*) will be cultured.

The Houtman Abrolhos study site shares commonalities with another AquaSpace case study region at the Algarve Coast, in Portugal, where offshore aquaculture is being developed in both locations, and similar modelling tools are to be applied. However, the Houtman Abrolhos site brings uniqueness to AquaSpace as this region of WA encompasses a large and diverse range of tropical and temperature species. Such unique biodiversity has led to the application of strict management protocols, including a status of fish habitat protected area which surrounds the islands, and the development of four reef observation areas to restrict fishing (Figure 8.1). With the multiple uses occurring in the region, including commercial and recreational fishing, and tourism, the region is an ideal case study for the application of the Ecosystem Approach to Aquaculture (EAA) and Maritime Spatial Planning (MSP).

The Houtman Abrolhos Archipelago is comprised of 122 coral reef-fringed islands extending across 100km of ocean about 65km from shore. The islands are clustered into three groups: Wallabi, Easter and Pelsaert (Figure 1). These clusters form a unique marine area where tropical and temperate species co-exist including a diversity of seagrass and seaweed communities, tropical and temperate corals, crustaceans, molluscs, echinoderms, sponges, almost 400 finfish species and up to 20 sharks and rays (The Department of Fisheries 2012a). The WA Department of Fisheries (DoF) is the governmental body responsible for the conservation of fauna and flora of the region, as well as the management of all recreational and industrial activities, including fishing and aquaculture. The region has the status of Fish Habitat Protection Area, which serves to protect fish (and other organisms, excluding sea birds and mammals) and their habitats through regulation of anthropogenic activities that may impact the health of the ecosystem (e.g. dredging, and waste management) (Department of Fisheries 2001).

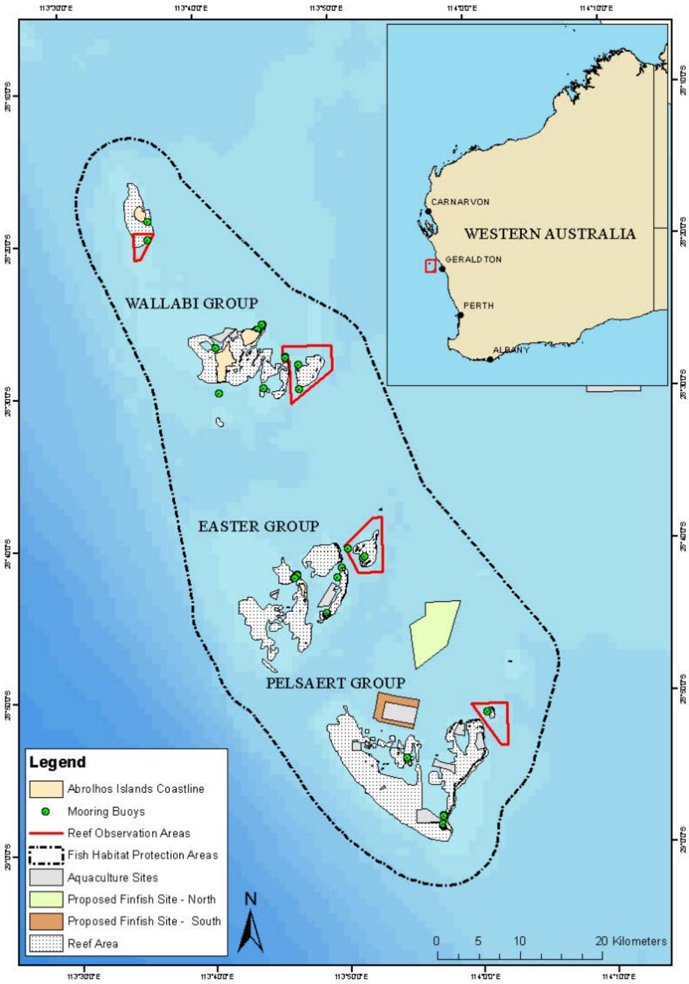

Figure 8.1 Left: Aerial photograph of the Houtman Abrolhos Archipelago (picture from australianexplorer.com); Right: Depiction of some marine uses within the Houtman Abrolhos Archipelago, including mooring buoys, reef observation areas, current aquaculture sites and the Fish Habitat Protected Area.

8.2. Spatial planning and management issues

Production of the Yellowtail Kingfish (*Seriola lalandi)* is just beginning, and no statistics are available. The aquaculture system is open water cages, and it is estimated that 3,000 hectares are available for farming.

The main management issue is to streamline licensing approvals and the ongoing management of activities, develop governmental policy to expand aquaculture on conditions of sustainable production, assessment of site suitability and carrying capacity to reduce compliance costs.

The spatial planning must be improved to enable better targeting and monitoring requirements in order to ensure sound environmental protection.

While no spatial management plans have been implemented at the case study region specifically, spatial management has been implemented at the state level

At the state level, aquaculture is considered a valuable and growing industry: The Western Australian (WA) government released a Statement of commitments in 2015 which recognises aquaculture as a legitimate user of WA land and resources (Statement of Commitment 2015). The above is in addition to, ensuring that fishing activities are managed consistent with an ecosystem-based approach and that the ecological and cultural heritage values of the Houtman Abrolhos Archipelago are maintained.

8.3. Stakeholder engagement and participation

UWA has had six meetings in person with the aquaculture manager at the WA Department of Fisheries regarding the exchange of data and information related to the case study region.

UWA had three meetings with the director of the TAFE (International agency associated with UWA https://www.tafeinternational.wa.edu.au) and their principal research scientist. They provided advice on Yellowtail Kingfish physiology and growth. Two meetings have taken place at the University of Western Australia, and one meeting at the South Metropolitan TAFE in Freemantle, Western Australia.

One meeting between UWA and the Aquaculture Council of Western Australia (ACWA) was held to discuss the possibility of collaboration in one of the projects and obtaining funding (however, the application was unsuccessful).

Together with major aquaculture stakeholders in western Australia and Australia in general, UWA attended a state forum on aquaculture which took place in Perth, WA. on May 25th 2016.

Three meetings took place in person, and five meetings via Skype, with BMT Oceania and UWA, respectively. The skype meetings were also attended by the AquaSpace partner Longline Environment Ltd (LLE). The meetings discussed potential collaboration through the contribution of BMT Oceania's hydrodynamic modelling results. We were unable to move this collaboration forward, as BMT Oceania needed payment and UWA had no funds from AquaSpace to buy the existing hydrodynamic modelling tools from Longline Environment Ltd.

In general, the meetings recommended to concentrate on the modelling of the release of biochemicals into water column, i.e. nitrates and phosphates. UWA provided data from the Houtman Abrolhos Archipelago, including oceanographic data (wave height and speed, tidal patterns and bathymetry), water quality data (temperature, dissolved oxygen, pH), sediment quality data (phosphorus, nitrogen, trace metals, particle size distribution) and benthic habitat descriptions.

Furthermore, the current state of the aquaculture industry has been discussed, and the networking (enabled through those discussions) will assist in targeting future avenues for knowledge exchange and discussions regarding the impact of the AquaSpace outcomes.

8.4. Tools used in the case study

The tools currently in use in the Houtman Abrolhos case includes:

A hydrodynamic model – TUFLOW FV (BMT WBN) modelling hydrodynamic offshore, providing results intended for aquaculture users.

At a regional scale ROMS (Regional Ocean Modelling System) is applied by UWA.

At a farm scale, a sediment diagenesis model FABM-AED, by UWA, is applied.

Finally, at site level GIS-based mapping of bathymetry and multiple uses is carried out.

8.5. Case study results

Application of different new modelling tools is now in the early stages as UWA is trying to get access to existing hydrodynamic models crucial for the implementation of the ecosystem model provided by LLE (i.e., SMILE model).

8.6. Relevance of the case study within AquaSpace

The uniqueness of the Houtman Abrolhos Archipelago arises from the mix of tropical and temperate environments that occur in the region. This is mostly due to the effect of the Leewin current, a warm ocean current which flows southward along WA's coast and is stronger in La Ninã years (Feng et al. 2009). Such an environment provides a home to a huge diversity of life, with the islands being fringed by corals and the waters being protected under a Fish Habitat Protected Area status. Due to the clean and relatively deep (35-45 m) surrounding water, the Houtman Abrolhos Archipelago is considered to have high potential for aquaculture. Combined with the unique ecosystem qualities, protected areas and multiple uses (e.g. commercial fisheries, recreational fishing and tourism), such suitability for aquaculture makes this location an ideal study site to apply and develop an Ecosystem Approach to Aquaculture and Maritime Spatial Planning.

Australia is a non-EU/EEA partner without AquaSpace funding, and this case is relatively early in its development, compared to the others.

8.7. Conclusions and future prospects

A collaboration has been established between UWA and the DoF. DoF have provided the necessary data to start the process of defining aggregated boundaries for extraction of the hydrodynamic modelling results. Involvement with other stakeholders has also occurred, for example, The WA Department of Transport (DoT) has shared detailed bathymetry data and there might be an interest in pursuing a collaboration, e.g., in case vessel traffic is relevant for inclusion in modelling scenarios. UWA will also be aiming to establish collaborations with the company Indian Ocean Fresh Australia (IOFA) who are directly involved in trials of Yellowtail Kingfish growth and condition in aquaculture environments. Contact with the Aquaculture Council of Western Australia (ACWA) has also been established in the early stages of the AquaSpace project, and greater involvement is expected in the forthcoming months and years.

Ecosystem modelling is to be developed at the Houtman Abrolhos study site to produce a model similar to SMILE (Ferreira et al. 2008) from which informed management scenarios at the ecosystem scale can be obtained. The approach used in the SMILE model requires the integration of results from multiple modelling tools, and UWA is currently in the process of obtaining aggregated results from a hydrodynamic model (Regional Ocean Modelling System; ROMS). Success in obtaining such results will be crucial for implementation of a SMILE-like model. Additionally, the ecosystem model will require the integration of outputs from a physiological model describing the energy budget and growth of the target species.

So far, knowledge exchange with DoF, the major stakeholder in WA, has provided an informed account of the issues restricting the development of aquaculture on a global level, and also information on how to better tackle such issues.

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9. MEDITERRANEAN SEA, MULTIPLE EEZ

Nafsika Papageorgiou, Panagiotis Dimitriou and Ioannis Karakassis

9.1. General characteristics

The Mediterranean Sea, an intercontinental sea that stretches from the Atlantic Ocean on the west to Asia on the east and separates Europe from Africa. It is circa 3,900km long with a maximum width of 1,600km; its greatest depth is about 400m. It connects with the Atlantic Ocean through the Straits of Gibraltar; with the Black Sea through the Dardanelles, the Sea of Marmara, and the Bosporus; and with the Red Sea through the Suez Canal. The 21 countries with coastlines along the Mediterranean Sea create a patchwork of different cultures, constitutions and economies.

Despite all the differences, in the last few decades aquaculture production in the most of the Mediterranean countries shows an increasing trend. In particular fish cage farming represents the sector with the fastest growth in the region. The expansion of aquaculture in the Mediterranean has, however, brought with it several environmental and socio-economic issues, which influence the sustainability of the sector and compromise its further development.

In order to establish sustainable development, the Mediterranean aquaculture sector benefited from several research projects and adopted proposed decision-making schemes related to territorial management of activities and competing uses. Thus, aquaculture in the Mediterranean has managed to overcome difficulties concerning, among other aspects, aquaculture sustainability, environmental and aquaculture interactions and to establish, in a number of countries, guidelines for Environmental Impact Assessment (EIA) and carrying capacity. In this context, the first part of this study introduces the Mediterranean experience as an example of successful implementation of policy and management and may be used as a basis for establishing good practice principles and adopting common standards for environmental sustainability in other parts of the world as well.

Although the already established guidelines and recommendations form a good basis for establishing good practice principles, an analysis of aquaculture production in the EU, based on FAO Fisheries Information system (FIGIS), shows that aquaculture production in the EU has fallen by approximately 8% since 2000, from 1.4 million tonnes in 2000, to 1.28 million tonnes in 2013. As stated in the *AquaSpace deliverable D2.1-2* (WP2), the fall results from significant drops in three of the top five major producing countries (France, Italy, Spain), with all of them be involved in marine finfish cage farming production in the Mediterranean. In addition, the recent economic crisis in the countries of southern Europe could also affect the growth of marine cage farming in the Mediterranean. From the above it becomes apparent that there is a need to evaluate the current state of Mediterranean marine culture in order to recognise the problems and establish new guidelines that follow the evolving needs of the stakeholders within the context of changing markets and social constraints.

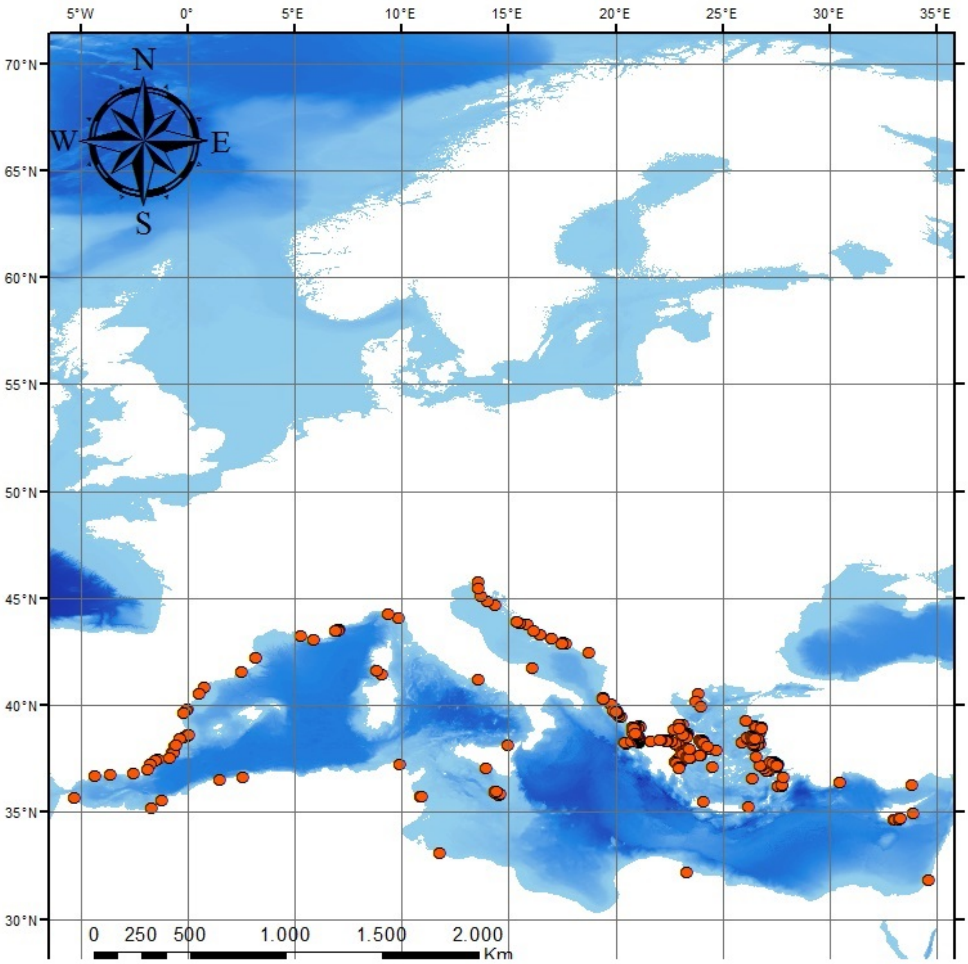

Figure 9.1. Map of fish farming locations in the Mediterranean area

9.1.1. *Description of the geographical and biological context*

Mediterranean marine ecosystems present an idiosyncratic combination of characteristics which make them very different from northern European conditions. These affect both the fish farming industry and the ecological processes determining the fate of aquaculture wastes (Karakassis 2001):

i. High temperatures (annual minimum of 12^oC, reaching up to 25^oC during summer); high metabolic rates, affecting both the production of the farmed fish and the activity of microbial communities.

ii. The microtidal regime (tidal range is typically less than 50 cm) reduces the potential for dilution and dispersion of solute and particulate wastes particularly in enclosed bays were wind driven currents are relatively weak.

iii. Oligotrophy: low nutrient content, low primary production, and low phytoplankton biomass. Low phytoplankton biomass induces high transparency of the water and light penetration deeper in the water column thus allowing photosynthesis at a greater depth.

iv. Primary production is considered to be phosphorus limited as opposed to nitrogen limitation in the Atlantic and in most of the world's Oceans. In this context, eutrophication could be expected only when phosphate is released in adequate quantities.

v. The biotic component of the ecosystem, i.e. the fauna and flora, is highly diverse particularly in the coastal zone and consists of a large proportion of endemic species as a result of the dynamic geological past of the Mediterranean. It is typically of low abundance and biomass as a result of the prevailing oligotrophic conditions.

9.1.2. *Socio Economic context*

The Mediterranean can be considered as a microcosm of the world: it includes countries and regions with different cultures, levels of economic growth, administrative styles, economic priorities and technical capabilities. At the same time, they all share the same volume of water, a common history and the need to feed a growing population. Aquaculture again has to play a role in providing high quality food but also employment for the years to come. This development needs to be sustainable and therefore it has to respect a series of boundary conditions set by the society.

9.1.3. *Issues confronted within the Mediterranean Case Study*

Although the already established guidelines and recommendations from previous projects and initiatives (IUCN, FAO-GFCM; see section below, *Guidelines and recommendations on Aquaculture site selection*) set a good basis for establishing good practice principles, harmonisation and a review of the efficiency of the framework is needed.

More specifically the issues listed below are experience within this CS:

- Follow up and evaluation of IUCN, ICZM and AZA (as proposed by FAO GFCM) as applied in different Mediterranean Countries.
- Evaluating methods, indicators, and environmental standards used in the frames of the EU Directives (Water Framework Directive-WFD and Marine Strategy Framework Directive-MSFD) for monitoring aquaculture activities in different countries.
- Evaluation of methods for resolving competition for space with new (e.g. offshore wind farms) and traditional (e.g. fisheries) stakeholders.
- Other factors (economic depression, civil unrest and conflicts etc.) preventing the expansion of Mediterranean aquaculture.

9.2. Spatial planning and management issues

MSP implementation varies in content and in administrative authorities between the different EU Mediterranean Member States. As shown in Table 9.1 (modified by the original Table 7 of *AquaSpace deliverable D2.1-2* - p. 43), it is apparent that most Member States are very much in the process of beginning to implement the Directive.

Table 9.1. Implementation of the MSP Directive in Mediterranean EU member states (*modified by AquaSpace deliverable D2.1-2*)

Member State	Transposing Mechanism	Competent Authority
Croatia	Physical Planning Act 2013, as amended.	Ministry of Construction and Physical Planning
Cyprus	No information submitted to EC as yet.	Ministry of Transport, Communications and Works - Department of Merchant Shipping
France	LOI n° 2016-1087 du 8 août 2016 pour la reconquête de la biodiversité, de la nature et des paysages (article 123) [Law on the re-conquest of biodiversity, nature and landscapes].	Decentralised structure
Greece	No information submitted to EC as yet.	Ministry of the Environment and Energy
Italy	Attuazione della direttiva 2014/89/UE che istituisce un quadro per la pianificazione dello spazio marittimo [implementation of Directive 2014/89/EU on MSP].	Cross-departmental remit / undecided
Malta	Marine Spatial Planning Regulations, 2016 - Development Planning Act (Cap. 552 of the Laws of Malta) 18/10/2016.	Malta Environment and Planning Authority (MEPA)
Slovenia	Spatial Planning Act 2007. Law Amending the Law on Spatial Planning, 27/07/12 and earlier legislation.	Slovenian Ministry of the Environment and Spatial Planning
Spain	No information submitted to EC as yet.	Ministry of Agriculture, Food and Environment

Although MSP implementation could be useful for offshore aquaculture planning, it is not expected to resolve a number of issues related to coastal aquaculture. Since most Mediterranean marine aquaculture currently takes place in coastal waters (less than 1 nautical mile from the shore), which usually come under a country's terrestrial planning system, the MSP Directive does not apply to those areas. Apparently, the WFD is the Directive that presently covers planning of Mediterranean aquaculture. Of course, MSP should include aquaculture as a potential future stakeholder, because once technical challenges are resolved it is likely to move further offshore.

9.2.1. *Management and environment issues*

The growth of fish farming and its future role as a food supplier to human society has environmental, social and economic limitations and affects marine ecosystems and socio-economic scales locally and globally (Duarte et al.2009). Aquaculture affects the marine environment through the release of dissolved nutrients (organic and inorganic compounds of P and N), particulate material (fish faeces, fish feed) as well as chemotherapeutants and antifouling chemicals (Sarà 2007;Holmer 2010). In addition, floating aquaculture structures impose changes in water circulation to a certain extent (Iwama, 1991) and cause direct shading of the seabed (Holmer et al.2008). The impact on the sediment and the water column depends on the distance from aquaculture facilities, the productivity of the farm and the hydrodynamic regime of the area (Kalantzi and Karakassis, 2006).

In addition to the impact of aquaculture on the marine environment, there are other kinds of negative and positive interactions between other coastal stakeholders and the aquaculture industry. The interactions relate not only to additional environmental impacts from other sources but also conflicts relating to the usage of coastal space. All the factors which interact with marine aquaculture must be considered and taken into account in future growth scenarios for aquaculture production.

In an enclosed sea like the Mediterranean it is natural to see competition for space among different uses of the coastal zone. Traditional activities like fisheries, tourism, boat and ship mooring (marinas and ports) as well as the recent appearance of offshore energy generation (wind farms, oil rigs) are setting a very complex and challenging context for aquaculture spatial planning. Hofherr et al (2015) suggested that as little as 630 ha are used for the production of 95% of European marine aquaculture and that the amount of coastline impacted by marine aquaculture ranges between only 0.5% and 3.0% of national coastlines. Given the fact that all these activities will increase significantly over the next 20 years little space is left for aquaculture expansion. The competition for space problem is confounded for countries with limited coastline (Slovenia, Montenegro etc.).

In addition, because marine aquaculture requires coastal waters with good or high environmental quality characteristics, the suitable coastal areas for aquaculture are limited due to the impacts on the environment of other human pressures. Indicative is that 30% of international sea-borne cargo originates from or is directed towards the 300 ports in the Mediterranean Sea. It is logical that there are various maritime-associated impacts in a number of coastal areas in the Mediterranean Sea.

To have a sustainable growth of marine aquaculture capable of feeding humanity, a series of regulations must be adopted and implemented in order to minimise environmental impacts and conflicts with other users of the coastal zone.

The Mediterranean aquaculture sector has successfully faced many of the above-mentioned issues and can be seen as an example of successful implementation of policy and management. The experience gained so far needs to be reported in order to be available as a basis for establishing good practice principles and adopting common standards for environmental sustainability in other parts of the world.

Even though there have been positive results to date from Mediterranean aquaculture policy and management, new challenges are rising due to the need for further expansion of the aquaculture sector and the application of MSP in the different European countries. In addition, the global economic depression affecting largely the leading Mediterranean countries in farmed fish production poses new issues regarding the management and expansion of Mediterranean aquaculture.

9.2.2. *Aquaculture species, types and systems*

The main type of aquaculture in the Mediterranean is marine finfish cage farming, followed by shellfish farming (mainly Mediterranean mussel - *Mytilus galloprovincialis*, oysters - *Ostrea edulis* and *Crassostrea gigas* etc.). The 95% of total production of marine finfish cage farming is based on European Seabass (*Dicentrarchus labrax*) and Gilthead seabream (*Sparus aurata*) but the cultivation of new similar species (meagre, dentex, red porgy, sharpsnout seabream) is increasing.

9.2.3. *Production and aquaculture development trends*

According to the information provided by the FAO, until 2000 there were 21,000 farms along the coasts of the Mediterranean and the average finfish production reached 200,000 t, while the trend seemed to be increasing for the leading countries in the Mediterranean (Spain, Greece and Turkey). In the following years, however, aquaculture production in the EU Mediterranean countries fell by approximately 16%, from 900 million tonnes in 2000, to 756 million tonnes in 2013. According to *AquaSpace deliverable D2.1-2*, the fall results from significant drops in three of the top five major producing countries (France, Italy, Spain). Greece is an exception with an increase of seabass and sea bream production. Smaller producer Member States have generally increased production, but not sufficiently to offset the fall in production in France, Italy, and Spain (Table 9.2).

Table 9.2. Mediterranean EU aquaculture production in 2000 and 2013 for EU Member States (Source: FAO and *AquaSpace deliverable D2.1-2*). * countries having part of their production in the Mediterranean

Country	Production in 2000 (tonnes)	Production in 2013 (tonnes)	Change (%)
Spain*	309,229	223,700	-27.7
France*	266,802	202,210	-24.2
Italy*	216,525	162,620	-24.9
Greece*	95,418	144,595	51.5
Croatia*	6,876	12,019	74.8
Cyprus*	1,878	5,340	184.3
Malta*	1,746	3,939	125.6
Slovenia8	1,181	1,226	3.8
Total	**899,655**	**755,649**	**-16.0**

Unfortunately, no more recent data, or data from non-EU countries, were available but the current report is expected to shed light on the expansion of Mediterranean finfish cage farming during the last 5 years.

Because of the economic depression, it is likely that the production rates have fallen, especially in countries like Greece where the impacts of the economic crisis were severe. Increased tax rates for aquaculture companies combined with higher market prices for petrol (offshore farms) and commercial fish feed affected and modified the cultured fish and seafood market.

In addition, in non-EU countries (e.g. Turkey, Tunisia) where regime problems or war and unrest lead to a great decrease in tourism rates, the demand for cultured fish also declined, limiting the market to only local consumption requirements.

9.2.4. *National and EU policies*

There are no common criteria and standards for all countries but there is a trend from most Mediterranean countries to follow the ICZM guidelines for aquaculture placement (see section below, *Guidelines and recommendations on Aquaculture site selection*). In addition, zoning of aquaculture areas is the most applied spatial planning approach (*AquaSpace deliverable D2.1-2*).

Furthermore, all EU countries are now required to achieve and maintain Good Environmental Status as set by the WFD and MSFD Directives, but other non-EU Mediterranean countries adopt similar frameworks for aquaculture planning and management (e.g. Turkey, Tunisia). Another important aspect for spatial planning of aquaculture within the EU will be the implementation of the MSP Directive.

9.3. Stakeholder engagement and participation

To evaluate the current state of Mediterranean aquaculture after the recommendations proposed by SHoCMed project ("Developing site selection and carrying capacity for the Mediterranean aquaculture within aquaculture appropriate areas") of the General Fishery Commission for the Mediterranean (GFCM), a stakeholder meeting was held "back to back" with a meeting of the GFCM Scientific Advisory Committee on Aquaculture (wrap-up workshop for the SHoCMed project) in Cattolica, Italy on 27 November 2015. A questionnaire was prepared and distributed to a Mediterranean stakeholder group that included scientists, regulators/planners and industry members from a wide range of Mediterranean countries (Spain, Greece, Cyprus, Turkey, Malta, Croatia, Morocco, Tunisia, Montenegro, Albania, Italy, Israel). The questionnaire covered a variety of issues concerning the main bottlenecks of aquaculture sector in the Mediterranean (e.g. MSP implementation, national regulation, conflict with other users).

The stakeholder feedback provided important information concerning:

1) MSP frameworks at national level are not yet implemented.

2) ınternational Union for Conservation of Nature (IUCN) and ICZM concepts are implemented in most countries

3) Allocated Zones for Aquaculture (AZA) adopted in a number of countries

4) Aside from spatial reasons, a number of policy and economic factors limit aquaculture expansion.

9.4. Tools used in the case study

To evaluate the current state of Mediterranean aquaculture, to update the existing data and to understand the existing trends in the industry development we used the approach described by Trujillo et al. (2012). Existing and historical fish cage locations were extracted from Google Earth and combined with existing information for aquaculture sites and their characteristics at an administrative level for the respective countries as provided by the National Aquaculture Sector Overview (NASO) maps collection (NASO-maps) along with depth data collected from the Emodnet portal (EMODNET). ArcGis was used to extract values from a GRID file to point locations and assigned depth values from the nearest cage where there was no satellite information. Data processing and map projection was carried out using the packages "maps", "marmaps" and "shape", implemented in R program language (R Core Team 2017). All these data were combined in a GIS-model system with ground-truthing data from other human activities (e.g. offshore platforms; marine traffic) and important ecosystem data (e.g. seagrass beds) to map the current spatial range of human activities on Mediterranean marine ecosystems. Where human activities and/or ecosystem data overlap, a weighting variable is applied and all weighted layers are summed to create a cumulative map. It is important to mention that there are still some issues regarding the varying resolution of the satellite imagery provided by Google Earth (lack or low resolution quality of satellite photographs in some countries), but still the provided images have been updated and improved in comparison with the study of Trujillo et al. (2012).

9.5. Case study results

9.5.1. Review and Recommendation Framework of Mediterranean aquaculture

In the last few decades, aquaculture production in the Mediterranean has increased, mainly resulting from technological developments for the two finfish species European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*). In 1995 the GFCM, in recognition of the increasing importance of the aquaculture sector, established a Committee on Aquaculture (CAQ) to promote sustainable development and responsible management of marine and brackish-water aquaculture in the region. The efforts of GFCM/CAQ and the associated working groups and projects aimed at improving the level of understanding of the ecological and social issues related to the development of aquaculture in the Mediterranean and the Black Sea.

In 2007 CAQ, in order to identify priority issues, created three working groups for the different aquaculture issues in the Mediterranean: one on site selection and carrying capacity (WGSC), one on sustainability (WGSA) and one on marketing (WGMA). These three groups liaise closely with each other to address the identified fundamental issues with Mediterranean aquaculture. Under the framework of the WSGSC working group, the SHoCMed project (“Developing site selection and carrying capacity for the Mediterranean aquaculture within aquaculture appropriate areas”) was developed. The SHoCMed project’s main goal was to develop site selection and carrying capacity guidelines for Mediterranean aquaculture. It involved experts from different Mediterranean countries, with various complementary backgrounds. During meetings on specific topics (site selection, carrying capacity etc.) the experts discussed with producers, consultants, regulators and scientists’ aspects of the key issues associated with aquaculture in the GFCM region.

In order to ensure appropriate site selection and management in the Mediterranean a strategic plan for site selection was developed (Allocated Zones for Aquaculture - AZA). The AZA concept sets standards and a homogenous methodology as a harmonisation measure for sustainable development of the aquaculture across the Mediterranean. Furthermore, the SHoCMed project recommended a full environmental management system that included a corresponding Allowable Zone of Effect (AZE), an Aquaculture Management Area (AMA) but it also included a full set of criteria for application in the environmental monitoring programmes as well as potential environmental quality standards. The methodology and information about the AZA-concept is described in detail by Sanchez-Jerez et al. (2016).

All findings and recommendations produced by the SHoCMed project were reviewed as part of the case study description. The summary of the main outcomes of the review is presented below:

9.5.2. *Main issues of Mediterranean aquaculture confronted by the SHoCMed project*

1. *Environmental Issues:*
   - Need for meta-analysis of scientific data about aquaculture-environment interactions focused on the oligotrophic Mediterranean environment that will provide important input for monitoring and policy making in the Mediterranean;
   - Need for identification of the pressures from aquaculture activities in the different sensitive habitats of the Mediterranean;
   - Lack of common indicators and thresholds that can be used to monitor the effects of aquaculture on environmental quality;
2. *Policy issues:*
   - Licensing processes are very complex and time consuming involving a large number of administration agencies;
   - Legal frameworks lack an understanding of aquaculture operations, which should not only consider the activity itself but also the categories involved with respect to location (offshore, inshore, etc.) production (intensive, extensive, etc.) and other relevant criteria;
   - Aquaculture site selection is generally focused on administrative criteria (areas where there are no conflicts of use with other activities) or environmental criteria (protected or sensitive areas), and do not generally consider the suitability of the aquaculture site for sustainable production or income generation;
   - Social and economic studies are not normally included as tools for aquaculture planning. These should include prospective market analysis (matching supply to demand) and use in conjunction biological, environmental and other technical studies to formulate aquaculture plans;

- No stakeholder participation mechanisms are required to ensure proactive input and accountability of the actors involved;
- No common criteria and standards (monitoring, carrying capacity, EIA) for all countries and even between the different regions of some countries;

9.5.3. *Modes for sustainable operation of aquaculture in the Mediterranean*

This section summarises the main findings of the SHoCMed project with relevance to the known impacts of aquaculture activities in the Mediterranean marine environment and the thresholds and methods to optimise monitoring and thus ensure the sustainable operation of aquaculture in the Mediterranean.

a. Aquaculture-environmental interactions in Mediterranean marine ecosystems

The effects of aquaculture vary in terms of spatial and temporal scales as well as in terms of the time needed for recovery of the part of the ecosystem affected. The water column variables in exposed marine sites are impacts for up to a few hundred metres but this effect is temporally limited, whereas the benthic effects are quite local (<50m from the edge of the farm) but more persistent in time. An extensive list of the effects of aquaculture on marine communities compiled by Milewski (2001) and updated by Karakassis and Angel (2011) is available in the SHocMed - GFCM report "Site selection and carrying capacity in Mediterranean marine aquaculture: key issues".

Sensitive habitats such as seagrasses and particularly *Posidonia oceanica* meadows, or biogenic sediments, are affected up to a distance of 400m and their recovery takes several decades. A modified version (Karakassis and Angel 2011) of Huntington et al.'s (2006) analysis of the sensitivity of key habitats and species to various sources of pressures due to aquaculture operations focusing only on those of Mediterranean importance is shown in a summary table (not presented here due to space limitations).

b. Thresholds and Monitoring around aquaculture facilities

In order to ensure sustainable use of the natural environment, the effects of aquaculture activities must be kept within tolerable levels - i.e. within the assimilative capacity of the site or water body. By doing this we end up with environmental quality standards (EQSs) which should be respected by the fish farming industry but also by the other stakeholders. The thresholds used for regulation and monitoring marine aquaculture are probably substantially lower than the ones applied to large water bodies or allegedly pristine areas.

According to Karakassis and Sanchez-Jerez (2011), when considering thresholds, it is important to keep in mind that the aquaculture-environment interactions operate at various spatio-temporal scales and therefore the indicators of impact should be assessed/monitored at the proper scales. In weighing the interaction of aquaculture with the surrounding marine environment, the Allowable Zone of Effect (AZE) concept must be taken into account. This concept establishes that it is impossible to have "pristine conditions" in the immediate vicinity of the aquaculture site, but that beyond the AZE environmental impacts from aquaculture should be minimal to non-existent.

In the context of the SHoCMed project, given the environmental peculiarities of the Mediterranean, the distinct characteristics of the fish farming industry in the GFCM area and the need to achieve agreement by a multinational set of stakeholders, a new set of EQSs was derived (Karakassis and Sanchez-Jerez, 2011).

A table with the most commonly used indicators for monitoring the effects of aquaculture on environmental quality was subsequently prepared (not presented here due to space limitations). The safe/critical thresholds are identified for each indicator and set within the SHoCMed project. Also, some details on the sampling frequency, the requirements and the costs/benefits for each method applied were presented in the table. Most of the methods are straightforward and may be used by personnel with a reasonable amount of training. The exception is the CHN analyser which needs specially trained and dedicated staff as well as macro-faunal variables including taxonomy (species number, AMBI, Shannon diversity etc.).

For the set of 21 EQSs, nine of them were ranked as the most appropriate for monitoring purposes taking into account their costs/benefits impact as well as their importance as indicators. The chosen set of EQSs may be seen as a starting point but also as a yardstick. A starting point because it helps to coordinate monitoring among different countries, institutes and companies, to bring together data and to assess how these EQSs match the real picture of environmental interactions in the Mediterranean. They can also be used as a yardstick because they provide values against which producers but also other stakeholders may evaluate the results of monitoring. This set of EQSs should by no means be seen as the end of the discussion on environmental interactions of fish farming in the Mediterranean. A period of application with a pilot set of farms in different regions covering different depths, background environmental conditions, farming practices and farmed species and a meta-analysis of existing data sets are likely to provide a better understanding of the interactions under all these sources of variability.

9.5.4. *Aquaculture site selection and expansion*

According to Freeman and Angel (2011) there are five types of bottlenecks for the Mediterranean aquaculture:

1. Site selection and licensing;
2. Market issues (no institutional support for market stability, lack of diversification in cultured finfish, consumer perceptions and acceptance of aquaculture products);
3. Conflict with other stakeholders and social acceptability problems;
4. Environmental issues mainly regarding sensitive habitats (e.g. seagrass meadows); and
5. Potential impact on wild fish stocks because of capture-based mullet culture and capture-based tuna fattening.

According to Sanchez-Jerez (2011) studies dealing with site selection can be developed at different spatial scales; at the national level (hundreds of km), down to the regional level (tens of km) or even further down to the local (km) level. Additionally, it is important to differentiate between site selection procedures for defining new sites in pristine areas (development of aquaculture in pristine localities) and site selection within an area already used for production (new facilities within a region with aquaculture facilities). Also, because of the lack of dedicate aquaculture planning in recent decades, it may be necessary to reallocate farms already in production to avoid environmental problems and/or social tensions. In such cases, additional consideration should be taken into account, such as the capacity of recovery of the ecosystem, the cost of reallocation and social cost for local population.

This section summarises the main findings of the SHoCMed project with respect to issues relating to site selection and licensing of aquaculture in the Mediterranean. Furthermore, the section includes information on the interaction of coastal uses/stakeholders with each other and with the environmental properties of the marine ecosystem as recognised for the GFCM region.

9.5.5. *Existing regulatory schemes, site selection, and EIA procedures in the Mediterranean*

The information presented below is based mainly on the findings of Chapela and Ballesteros (2011) and focuses on summarising the current state of regulatory schemes in the GFCM area, based on two major sources of information, an analysis of laws, decrees and aquaculture and fisheries policies currently in existence in the target countries but also data obtained from questionnaires sent to all Mediterranean countries.

Generally, in the Mediterranean, the legal framework for aquaculture is predominantly under the umbrella of a fisheries and aquaculture law (79%), and only Cyprus has developed an exclusive law for aquaculture. The major legal constraint for aquaculture development is related to cumbersome and overlapping norms and administrative procedures. In the Mediterranean basin, 40% of the studied countries have more than seven bodies/authorities that need to be consulted or informed during the licensing process. For instance: Turkey (15), France (12), Greece (11), and Spain (10) are the leading countries in this respect. On the other hand, Albania and Morocco declare to have only three bodies/authorities involved. Coordination is directly related to effectiveness of the licensing process and it appears that the higher the number of bodies involved, the more intricate the process.

According to the survey of Chapela and Ballesteros (2011) within the SHocMed project the main problems related to licensing are the complex, lengthy processes, the multiplicity of agencies involved and the absence of zones designated for aquaculture. Generally, the average time taken to obtain a licence in a Mediterranean country has been estimated to take around 14 months and the time taken from application to first sale can take between 2.5 to 3.5 years. This is a very long period when considering changing market scenarios and global competition that restricts aquaculture development and expansion in the Mediterranean.

Site selection processes in the GFCM area are based on already established criteria or guidelines (79% of the studied countries). Forty percent of the countries surveyed declared to have some sort of specific planning for aquaculture (Chapela and Ballesteros, 2011).

Regarding EIA and monitoring, according to the data presented by Chapela and Ballesteros (2011), the EIA process is operative in all the countries surveyed, being mandatory in 79% of them (all but Albania, Egypt and Montenegro). In addition, monitoring programmes are extensively implemented in the GFCM area and thus almost 70% of the countries use some tools to monitor and control the impact of aquaculture activities. Only Egypt, Montenegro, Lebanon and Albania lack monitoring programmes (no information was provided for Slovenia).

9.5.6. *Interaction of aquaculture with other coastal uses in the Mediterranean*

Site selection for aquaculture should take into account a series of basic requirements which are related to the interests of the farmer but also to those of society. These may be economic in nature but should also reflect environmental, social and political considerations. Sanchez-Jerez (2011) summarised the different interactions between other coastal uses.

The interaction of aquaculture with other uses of the coastal zone can be classified according to three different categories (Angel and Freeman 2011).

1. The first category groups the interactions according to different stakeholders in the coastal areas

- Capture fisheries sector
- Fish farmers
- Local communities and/or businesses reliant on processing, marketing, transport and other activities associated with fisheries and aquaculture
- Authorities (local, regional, national, other)
- Tourism (may need to treat local and international as distinct)
- Environment
- Home owners
- Recreational users
- Other enterprises directly using the coast or marine body (marinas, ports, shipping, wind farms)
- Other enterprises indirectly using the coast or marine body (urban and industrial consumers of water, polluters, etc.)
- Food and health authorities
- Scientific community
- Relevant authorities with jurisdiction over aquaculture (e.g. ministries of agriculture, natural resources and environment, local planning authorities etc.).

The Chapela and Ballesteros (2011) survey showed that, in the Mediterranean, problems and conflicts arise mainly with tourism (93% of the countries studied), and to a lesser extent with fisheries (60%), urban development (40%) and environmental issues and protected areas (40% respectively). Conflicts with other users such as industry and navigation (14%) are in the minority, and there seems to be no problem at all with ports except in Israel (although in the other countries conflicts with yachting facilities are probably considered within the 'tourism' category).

2. The second category is grouped according to spatial scale and the distances of aquaculture sites from other activities in the coastal zone. The key stakeholders will vary from zone to zone, as will the nature of the interactions. In some cases, it is possible that interactions between identical stakeholders will be synergistic in one zone and competitive in another. In general, most aquaculture site selection focuses on Zone A issues.

> **Zone A** – the area immediately around the farm; the main stakeholder interactions here are those related to direct competition for space. This would include competition between adjacent farms, and between farms and capture fisheries, shipping lanes and recreational uses of the site.
>
> **Zone B** - the scale of small water bodies, the main stakeholder interactions of concern are those stemming from spill overs among different uses (but not necessarily direct competition for space). Areas corresponding to zone B include those in which nutrient enrichment stemming from fish farm effluent could lead to a reduction in water quality that affects recreational users. Similarly, industrial pollution or accidental spills in the same zone could have negative spill overs that impact upon local fish farms.
>
> **Zone C** - regional scale; at this scale, effects are potentially long term and stem from complex ecosystem processes which change 'background' conditions. Spill overs in Zone C include changes in wild fish stocks and capture fishery landings.

3. The third category is defined according to the geographical location within the Mediterranean basin. Different regions have different types of aquaculture, as well as different policy priorities, and these determine key stakeholders and their interactions. Table 9.3 (modified from Angel and Freeman 2011) shows the main policy issues and major stakeholders in four geographic sectors (North West, North East, South East and South West) of the Mediterranean basin. Countries on the Mediterranean's northern coast have more aquaculture than those on the southern coast and more stakeholder conflicts have been observed in this part of the region.

Table 9.3. Aquaculture sector and stakeholders by sector. **NW:** Spain, France, Italy, Monaco, Malta, Slovenia, Croatia, Bosnia-Herzegovina, Montenegro, Albania; **NE:** Greece, Turkey, Cyprus, Lebanon; **SE:** Israel, Palestinian Authority, Egypt, Libya; **SW:** Tunisia, Algeria, Morocco

Geographical Sector	Costal Aquaculture activity	Key stakeholders	Aquaculture policy priorities
Northwest (NW)	HIGH	CAPTURE FISHERIES; SHIPPING; URBAN/INDUSTRIAL; TOURISM; RECREATION; CONSERVATION	EXPANSION/MAINTENANCE OF SECTOR; FOOD SAFETY; MARKETING AND DISTRIBUTION; LOCAL COMMUNITIES
Northeast (NE)	MODERATE (EXCEPT FOR TURKEY AND GREECE)		EXPANSION OF SECTOR; FOOD SAFETY; MARKETING AND DISTRIBUTION; LOCAL COMMUNITIES
Southeast (SW)	LOW (EXCEPT FOR EGYPT)	CAPTURE FISHERIES; URBAN/INDUSTRIAL SECTORS; (TOURISM & RECREATION); ENVIRONMENTAL QUALITY	INTRODUCTION OF AQUACULTURE; LOCAL FOOD SECURITY; TRADE; LOCAL COMMUNITIES
Southwest (SE)	LOW		

9.5.7. *Guidelines and recommendations on Aquaculture site selection*

IUCN and FAO have made a series of recommendations regarding aquaculture site selection and monitoring (IUCN 2009; Ross et al.2013). In the Mediterranean region some of these recommendations (AZA selection, effluent monitoring and production process) are included in the Mediterranean Integrated Coastal Zone Management strategy plan (ICZM, EU Official Journal L34/19, 4 Feb 2009). This protocol is the only legal instrument on ICZM in the entire international community and could serve as a model for other regional seas (IUCN, 2009). From the Mediterranean countries, Croatia, Italy, Spain and Tunisia have already incorporated the IUCN code for site selection and site management into their own legal systems. The implementation of the AZA concept within the ICZM Protocol in the Mediterranean countries as well as in other parts of the world is reviewed by Sanchez-Jerez et al. (2016).

Furthermore, according to the seventh session of the Sub-Committee on Aquaculture (SCA) of the FAO Committee on Fisheries, MSP must ensure the allocation of space for aquaculture growth. The SCA acknowledged that spatial planning needs to follow an ecosystem-based approach and to define socio-economic, environmental and governance objectives that result in the integrated management of land, water and living resources for the development and expansion of the sector in a sustainable and equitable way (FAO 2013).

9.5.8. *General aspects of aquaculture site selection in the frames of ICZM and MSP*

Aquaculture, like any other human activity, influences the environment. Favourable physical, environmental and water quality conditions are imperative for the successful performance of aquaculture. However, as has already been stated, anthropogenic forcing has a major influence on coasts and oceans, contributing greatly to ecosystem changes, many of which are regularly viewed as degradation of the marine environment. Since the ability to maximise economic benefits derived from the intelligent use of marine ecosystem and its resources was thought to be limited by an inadequate understanding of the human influences on the environment and vice versa, a framework was developed for collecting basic information on this interrelationship. This was presented with the form of a table (HOTO-module) which gives a general characterisation of the relationships between marine resource use of socioeconomic benefits and certain analytes indicative of environmental health.

Table 9.4. Modified version of the table provided by HOTO in 2001. As in the original table, numbers "3", "2", "1" denote increasing importance and the arrows signify the direction of impact. New relationships are indicated using red fonts, while changes in the strength or direction of the relationship are indicated with blue fonts.

	SEAFOOD				WASTE DISPOSSAL			TOURISM	MARITIME OPERATIONS	FISHING	OIL/GAS EXTRACTION	MINERAL EXTRACTION	COASTAL AREA DEVELOPMENT	HYDROLOGICAL CYCLE ALTERATIONS	RECREATION WATER
VARIABLES	*Finfish*	*Shellfish*	*Fish culture*	*Shellfish culture*	*Municipal*	*Industrial*	*Agroforestry*								
Algal toxins	↑1	↑1	↑1	↑1				↑1							↑2
Artificial radionuclides	↑3	↑3	↑3	↑3		←1			←3						
Dissolved oxygen	↑1	↑1	←3 ↑1	←3 ↑1	←1	←1	←2	←3 ↑3	←3		←3		←2	←3	
Herbicides/Pesticides/Biocides	↑2	↑2	←3 ↑2	←3 ↑2	←2	←3	←1	←2	←3				←2		
Human pathogens	↑1	↑1	←3 ↑1	←3 ↑1	←1	←3		←2 ↑1	←3				←2		↑1
Litter/plastics	↑3	↑3	←3	←3	←1	←1	←3	←2 ↑1	←2	←3			←2		↑2
Metals and organometals	↑2	↑1	←3 ↑3	↑3	←2	←1	←2		←3			←1	←2		
Nutrients			←2 ↑3	←3 ↑3	←1	←1	←1	←2 ↑3	←3				←3	←1	
PAHs	↑3	↑2	↑3	↑2	←2	←2	←3		←3		←1		←3		
Petroleum Hydrocarbon/ Oil	↑3	↑1	↑3	↑1	←1	←2	←3	↑1	←1		←1				↑2
Phytoplankton abundance/diversity	↑1	↑1	↑2	←3 ↑1	←2	←2	←1	←2 ↑3					←3	←1	
Pharmaceuticals	↑3	↑3	←2 ↑3	←3 ↑3	←3	←2	←3								
Suspended particulate matter		↑2	↑2	←3 ↑2	←1	←2	←1	←3 ↑2	←1	←3	←3	←2	←2	←1	↑3
Synthetic Organics/POPs	↑3	↑2	↑3	↑2	←3	←1	←2		←3				←3		
Exotic species	↑2	↑2	←2 ↑3	←2 ↑3					←1						
Habitat destruction			←2	←2	←3	←3	←3	←2	←3	←1	←1	←1	←1	←1	
Predators	↑2	↑2	←3 ↑1	←3 ↑1				←2	←1	←1	←1		←2		
wind			↑1	↑1					↑3	↑3					
light conditions	↑3	↑3	↑3	↑3											
water temperature	↑2	↑2	↑2	↑2		←1								←3	
salinity	↑3	↑3	↑3	↑3		←2								←1	
turbidity	↑2	↑2	←3 ↑2	←3 ↑2	←1	←2	←1	←3	←1	←3	←3	←2	←2	←1	
pH	↑3	↑3	←2 ↑3	←2 ↑3	←2	←2	←2								
benthic effects			←2	←2						←1	←1	←1		←3	
Genetic pollution			←3	←3											

One of the main goals and contribution of the HOTO module was the understanding of trends in, and conservation of, global ocean health with a view to contribute to the sustainable development of marine environment. However, as the original HOTO table was not created specifically for aquaculture, certain variables that could be important for aquaculture development were not considered, and the differential effect the selected variables could have on each of the major aquaculture types, finfish and shellfish, was not addressed separately. Therefore, it was essential to modify the table in order to include environmental issues that are reported or expected to be significant for aquaculture (i.e. light conditions, turbidity, exotic species), and distinguish between shellfish and finfish production, as they are activities which have different environmental demands and therefore, are practiced in environments with different characteristics. Furthermore, interactions that have not been considered in detail in the original table were revisited. This was achieved through considerable efforts to review existing published information, as well as via discussions with the experienced partners of ECASA project team. Table 4 is a modified version of the original table provided by HOTO module of GOOS-IOC, (IOC 2001) produced in the ECASA project and shows the impact different anthropogenic activities may have on aquaculture.

As shown in Table 4, there are complex interactions among users of coastal areas that leave little space for aquaculture, particularly since it requires coastal waters with high water quality and specific environmental characteristics. In this context, aquaculture production is incompatible with certain other coastal zone activities, such as waste disposal. The result is that suitable coastal areas for aquaculture are severely limited in many areas and this has become a major barrier to expansion. This inevitably implies that a process of multi-criteria decision making must be applied.

9.5.9. *Updated information from stakeholder feedback*

The results of the questionnaire are summarised below:

- MSP is not implemented at national level in the most of the Mediterranean countries (Montenegro and Albania are in the processes of developing new MSP regulations). For Croatia, Italy and Spain different regulations are applied regionally. Some of these regions have already implemented MSP;
- IUCN and ICZM concepts are embedded in the legal framework of Croatia, Italy, Turkey and Tunisia;
- The concept of AZA has been adopted by most of the GFCM participating countries. Although it has been used under different names and with various ways of implementation in different Mediterranean countries (e.g. “poligonos” in Spain, “POAY” in Greece, designated offshore sites in Turkey, Malta, Cyprus, etc.). Also, Tunisia, Montenegro, Italy and Croatia use the AZA concept for site selection;
- The main reason for rejecting a new aquaculture plan is conflict with other stakeholders (mainly tourism) but also in countries with narrow coastlines the lack of available free space.
- Conflicts with other stakeholders have been decreased in Mediterranean countries that adopted the EIA in their aquaculture regulations.
- The main factors limiting aquaculture expansion are:
    - availability of space,
    - increased costs due to stricter regulations on monitoring, hygiene and safety,
    - lack of industrial investors (possibly due to long and complex licensing periods and other administrative constraints),
    - no or low support from the government/state,
    - quality of juveniles and the quality of fish feed prohibit performance improvement,
    - specifically, for shellfish (in the Adriatic) problems with faecal contamination and bio-toxins;
    - a last factor that affected aquaculture expansion in the Mediterranean is the economic crisis that most countries in the area are experiencing. Higher taxes, in combination with increased prices of petrol, fish feed and declining market prices is a new problem that Mediterranean countries are dealing with.

9.5.10. ***Mapping of present and historical data on fish cage farms in the Mediterranean***

The aim of this analysis was to highlight the existing diversity among Mediterranean countries in terms of aquaculture regulatory frameworks, production policies and technologies used.

In the entire Mediterranean area (Figure 9.1), 428 fish farming locations (stations) were examined in three different time periods (Period 1: 2006-2009, Period 2: 2010-2013, Period 3: 2014-2017). In every station, the distance from shore (metres), depth (metres), distance between fish farms (metres – fish farm clusters) and fish cage size (meters) and number were recorded.

Figure 9.2. Measured parameters: Period (yellow arrow), distance from the shore (red arrow), distance between fish farms (green arrow), cage size (orange arrow).

9.5.11. *Historical and current state of Mediterranean marine fish farming*

Currently in the entire Mediterranean area there are 15,902 cages, with an average depth of 28 metres and with an average distance from shore of 900m. For Period I, small cages (<20m) totalled 14,380 with a decreasing number over the years, while large cages (>20m) showed an increasing trend and currently amount to 2,548 (Figure 9.3).

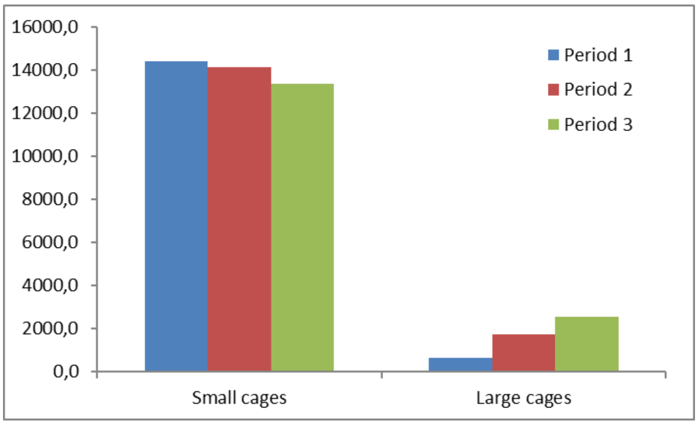

Figure 9.3. Number of small and large cages in the three periods

In the Mediterranean 46.5% of the fish farms are part of a larger fish farm cluster (distance between two stations <1km), with Albania and Turkey having more than 60% of their farms aggregated in clusters.

The percentage of small and large fish cages is different between countries. Greece is the leading country with more than 50% of the total number of cages in all time periods. The highest number of small cages are found in Greece representing more than 50% of their total number, while in Turkey the number of small cages decreased significantly after Period 1 (Figure 9.4).

Conversely, the percentage contribution of large cages in the Mediterranean decreased significantly for Spain, while in Greece it remained stable. In Turkey, the percentage of large cages showed a significant increasing trend between the three periods and is currently the leading country with almost 50% of the total number of large fish cages (Figure 9.5).

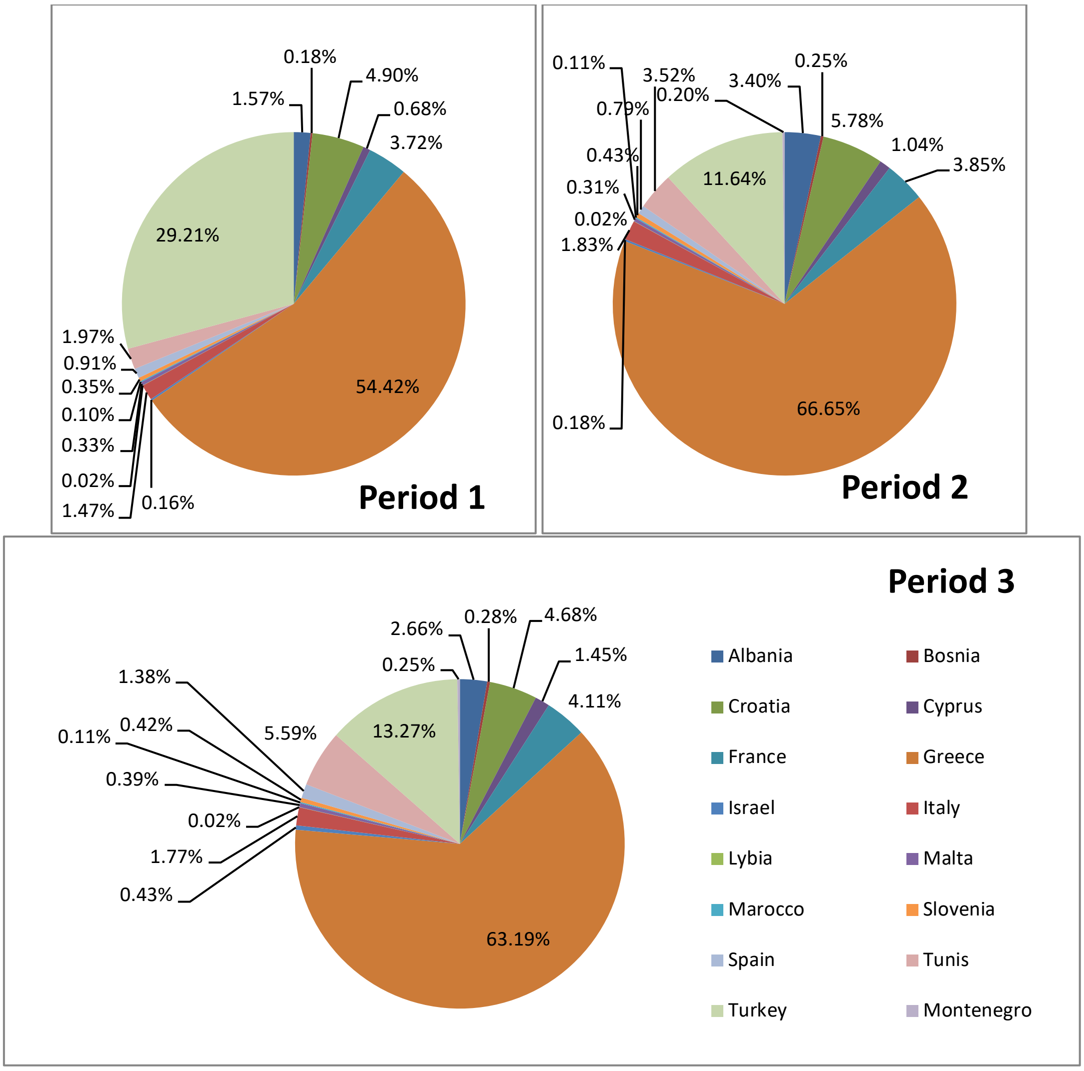

Figure 9.4. Percentage of small cages in the different Mediterranean countries for the three time periods.

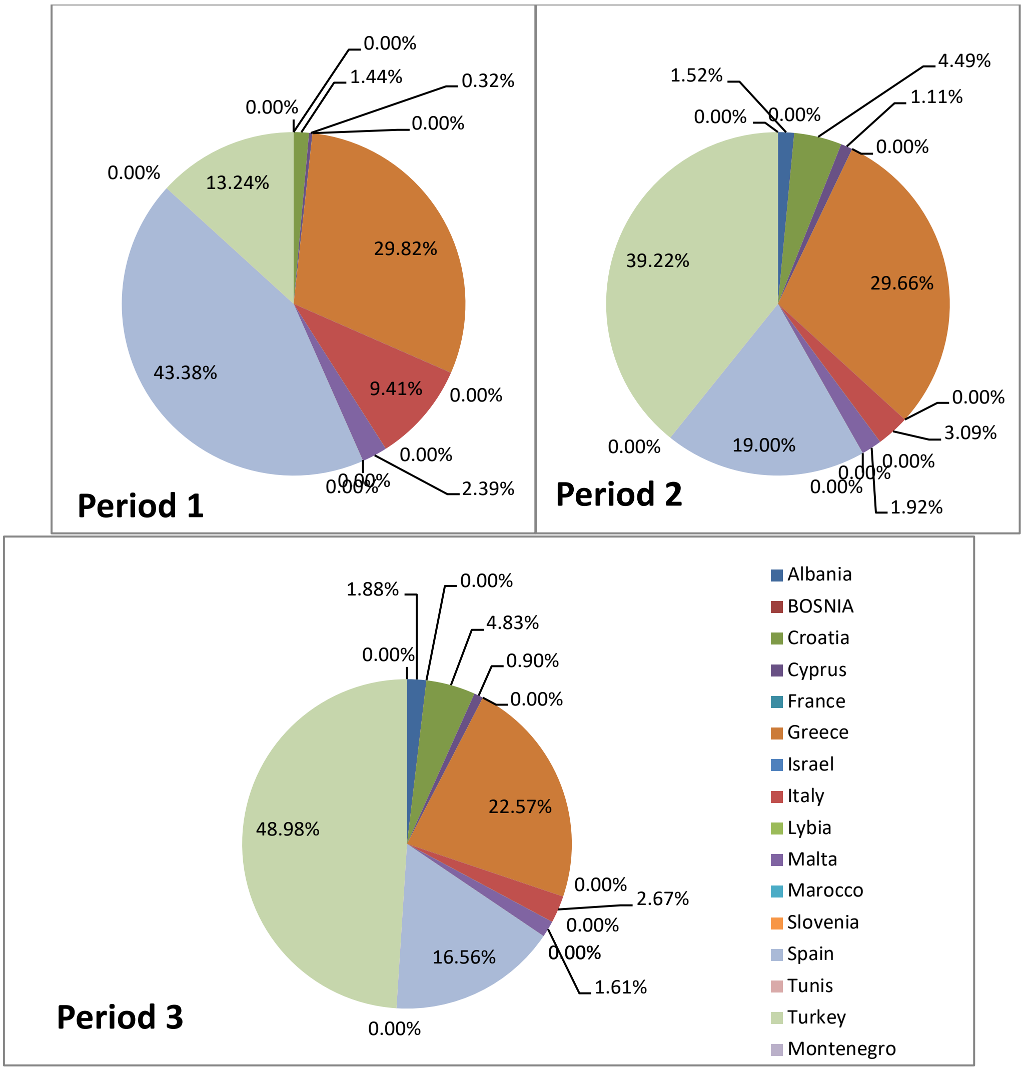

Figure 9.5. Percentage of large cages in the different Mediterranean countries for the three time periods

9.5.12. *Current state of marine fish farms in Mediterranean countries with the highest production (Greece vs Turkey)*

The adoption of the AZA concept into the regulations was made differently in the two countries ("POAY" in Greece, designated offshore sites in Turkey). Fish farm locations in both countries are shown in Figure 6. In Turkey aquaculture zones are concentrated in only a small part of the coastline to protect the tourism industry and others had to move offshore. This requirement specifies that fish farms move a minimum distance of 0.6 miles from the land and be located in a minimum water depth of 30 m.

For Greece, aquaculture zones are distributed along the coastline. Spatial planning of the fish farms is based on the carrying capacity of the installation area, determined by parameters such as distance from shore, depth and currents.

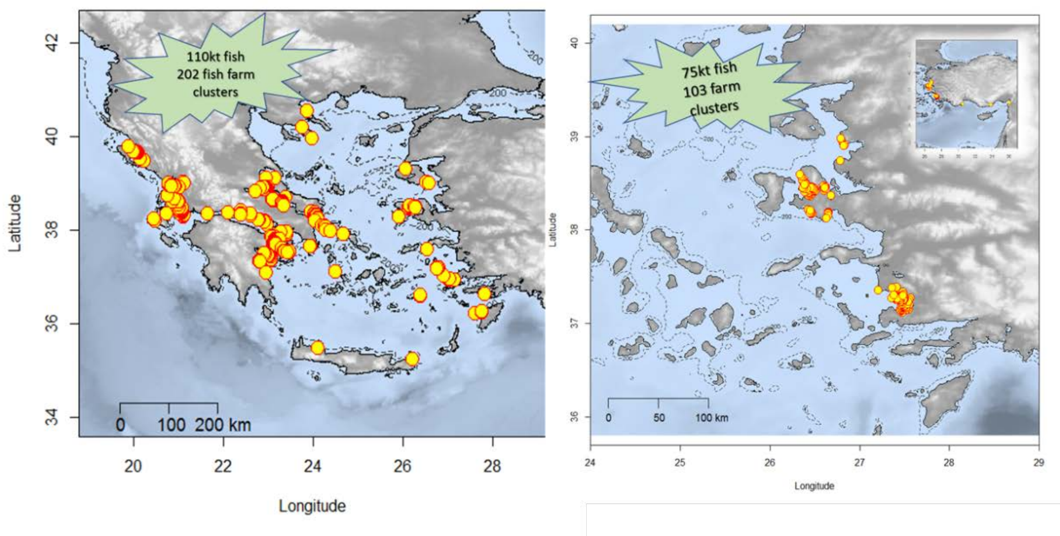

Figure 9.6. Fish farming locations in Greece and Turkey

In the evaluation of the adoption of the AZA concept in Greece and Turkey, spatial distribution data (Figure 9.7) showed that in Greece the distance from the shore has not changed significantly between periods, while in Turkey the distance from the shore increased in accordance with the new regulations. The pattern is the same for depth. In addition, fish farms tend to be aggregated in clusters in Turkey, whereas in Greece the distribution of the fish farms is much scarcer and only 40% of fish farms is aggregated in larger clusters.

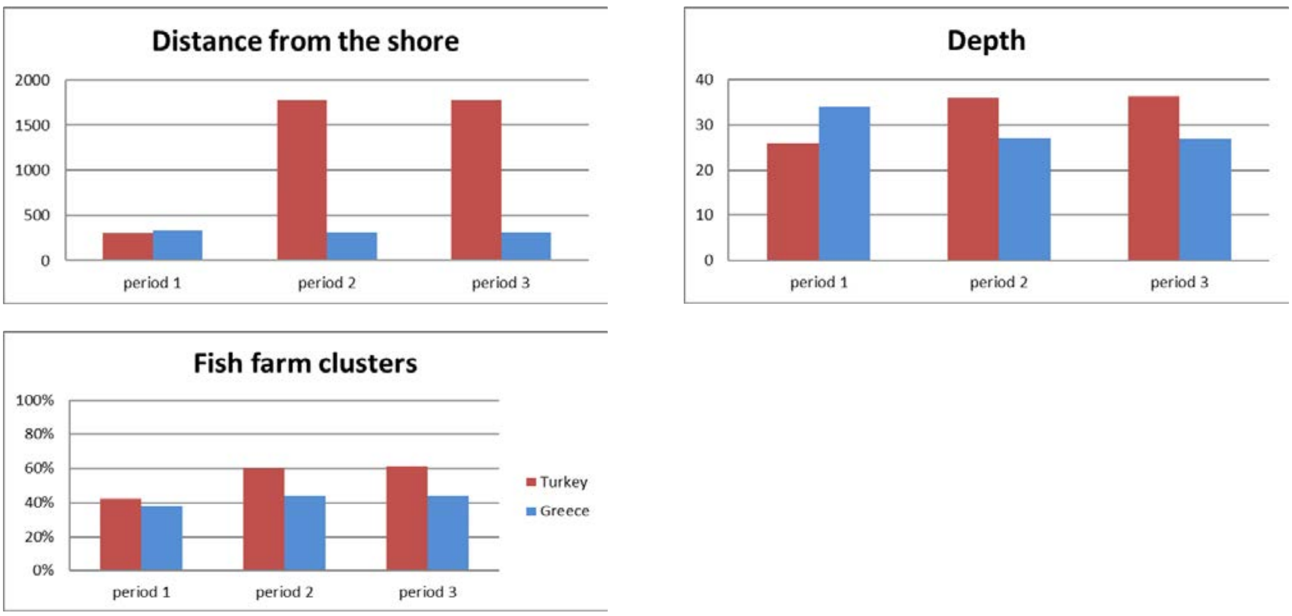

Figure 9.7. Evaluation of the adoption of the AZA concept in Greece and Turkey: spatial distribution

Considering the production and performance (Figure 9.8) of the studied fish farms, in Greece the cage numbers have not changed significantly between periods 2 and 3. There is a small decrease in the number of small cages for Period 3. The number of the large cages has changed significantly between periods 1 and 2 which coincides with the adoption of the new aquaculture regulation (increase in the carrying capacity for total fish production in many areas). In period 3 no increase was recorded, possibly due to other external factors like the economic situation or declining market prices. In Turkey, the usage of small cages was replaced by larger cages. This is related to the movement of fish farms to deeper and more exposed areas but can also be caused by another factor: small fish farm owners could not cope with the demands of the new regulations (new technologies, new location and finding/economic/ support) and as a result 166 farms were closed and only large companies could successfully transfer and adapt to the new regulatory regime.

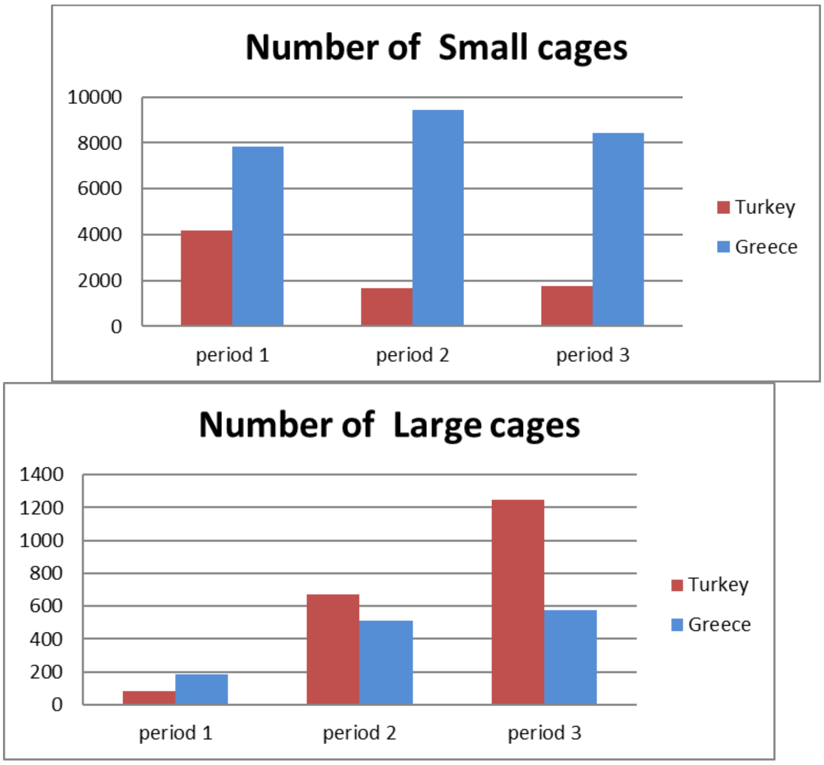

Figure 9.8. Evaluation of the AZA concept adoption in Greece and Turkey: production and performance

In summary, the adoption of AZA concept in Greece provided the industry with a boost in production but the expansion of the industry is currently hindered due to other factors, while in Turkey the adoption of the AZA concept provided the industry with a sufficient boost and it seems that expansion will continue but the largest part of the market is occupied by the bigger companies.

9.5.13. *Aquaculture (finfish and shellfish) monitoring indicators*

The aim of this analysis was to investigate the existing monitoring regulations pertaining to the seabed. The analysis focused on the top ten world aquaculture producers (not only EU Member

States) in order to detect their strengths and weaknesses in implementing the Ecosystem Approach to Aquaculture (EAA). The review of the different benthic monitoring indicators is not finalised but it has already revealed serious gaps in the monitoring requirement. The main problems detected were:

- In a number of countries although monitoring is incorporated in the regulations no specific monitoring guidelines are given,
- There is a lack of a uniform monitoring system, with thresholds calibrated for the different areas,
- Benthic monitoring, as conducted, is costly and time consuming and consequently is not done very often (normally once every three years).

In addition, the information collected on impacts of aquaculture on the seabed for different groups of cultured species will be used within the frames of Aquaspace to analyse and compare the environmental impacts of different marine cultures (fish, molluscs, crustacea and algae) on the seabed, focusing on the increase of the footprint of each cultured group.

9.6. Relevance of the case study within Aquaspace

As mentioned above the Mediterranean can be considered as a microcosm of the world with countries that have different priorities but they all share the need to feed a growing population. In this respect, aquaculture can have an important role in providing high quality food but also employment for the years to come. The further development of Mediterranean aquaculture needs to be sustainable and take into account the different environmental peculiarities and needs. However, harmonisation is an essential step to ensure both protection of the environment and fair competition. If this exercise is successful in the politically, economically, socially and culturally diverse situation of the Mediterranean, there is hope that it could be implemented in other parts of the world as well.

In this Case Study, the following issues were explored:

a. the existing diversity among Mediterranean countries in terms of the regulatory frameworks and environmental/production priorities for aquaculture;

b. evaluating methods, indicators, environmental standards and tools used in the EU Directives (WFD and MSFD) for monitoring aquaculture activities and/or the regulatory framework for AZA-AZE concepts, Environmental Monitoring Programme (EMP) and preliminary selection of variables;

c. the importance of EIA studies based specific to different types of aquaculture and the general concept of MSP and mandatorily implementing these before the establishment of new aquaculture farms;

d. Mapping the current spatial extent of Mediterranean aquaculture and future growth options.

9.7. Conclusions and future prospects

The Mediterranean paradigm has important experience to offer with respect to successful implementation of aquaculture policy and management in a multinational area. Although the already established guidelines and recommendations from previous projects and initiatives (IUCN, FAO-GFCM) set a solid basis for establishing good practice principles, harmonisation and review of the efficiency of these frameworks are needed. The process of establishing new guidelines is dynamic and must follow the evolving needs of the stakeholders in the context of changing market and social conditions. To this end, the Mediterranean Sea (Multiple EEZ) case study offered an important update on the current status and prospects of the Mediterranean aquaculture sector. The main outcomes of this study can be divided into three parts. The first one is a review of the current state of policy and environmental issues based on previous initiatives combined with updated information provided by stakeholders. The most important outcomes from this part of the study is that, according to stakeholder feedback, MSP at national level is not yet implemented but IUCN, ICZM and/or AZA concepts have been embedded into aquaculture planning. The second part of the study focuses on meta-analyses of data in order to evaluate the current state and the future prospects of Mediterranean aquaculture. To this end, GIS-mapping tools were used to imprint the current interactions with other human activities as well as with important sensitive habitats providing information about potential future aquaculture expansion in multiple EEZs. In addition, a meta-analysis from environmental data will test (within the frames of Aquaspace) existing thresholds and evaluate aquaculture interaction with the major ecological status descriptors of the EU Marine Strategy Framework Directive.

The updated outcomes of this case study together with the Mediterranean-SHoCMed project experience can be used as an example of adopting a common framework in a multi-national context by using (a) scientific expertise, (b) stakeholder involvement and (c) political decisions. The main processes followed can be used as a tool and guide for aquaculture policy making in other regions of world. The key steps of the procedure are presented below as a successful example of sustainable aquaculture planning:

1. Establishment of a Mediterranean network of experts with various complementary backgrounds, working closely together, interacting and learning from each other.
2. Thematic meetings and workshops with multi-country participation to discuss with producers, consultants, regulators and scientists, issues identified by the network such as site selection, MSP and carrying capacity.
3. Interaction with political levels (official representatives of Member States).

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10. NORMANDY AND CANCALE, FRANCE

A. Gagnery, C. Bacher, M. Callier, JP Blancheton, M. Ropert, J. Meillon, C. Satra Le Bris, E. Roque d'Orbcastel

10.1. General characteristics

This case study is located in the North-Western part of France and includes the bay of Mont Saint-Michel, which is listed by UNESCO as a world heritage site, and Cancale bay, which does not belong to the Normandy Region per se, but is in the same ecoregion. The whole length of the coastline is about 450 km (Figure 10.4), and the total area is around 20 000 km^2 (including terrestrial and marine zones). The maintenance of existing aquaculture (mainly shellfish culture) and the sustainable development of new aquaculture activities (fish farming) coexisting with other uses are dominant issues within this case study.

Figure 10.4. Map of the Normandy Case Study with geographical limits of the region and main biological & geographical entities (OpenStreetMap).

10.1.1. Application of EU policy on MSP in France

The framework developed by the French government in response to the EU Directive (2014/89/EU) on Maritime Spatial Planning (MSP) is managed by the Inter-Regional Directions of the Sea (DIRM) at the scale of the four maritime regions. The French decree 2012-219 (https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000025372075&categorieLien=id) from the 16th February 2012 describes the creation and the implementation of the National Strategy for the Sea and the Coastline (SNML), which contains Strategic Documents for each Façade (DSF). The major issue of SNML is the successful colocation of traditional uses of the sea with more recent activities but also to be aware of the necessity to preserve and increase knowledge of marine ecosystems. The objective of the SNML is to coordinate all sectoral policies acting on the coast or in the sea by covering the six following themes:

1. Protection of ecosystems, resources, biological and ecological equilibriums, preservation of sites, landscapes and heritages,
2. Prevention of risks and management of the coastline (in terms of erosion/submersion),
3. Knowledge, research and innovation, education and training to maritime jobs,
4. Sustainable development of economic, maritime and coastal activities and promotion of mineral, biological and natural resources,
5. French contribution to the development and application of international and European policies,
6. Providing this strategy with the adequate governance system, means of achievement, monitoring system and evaluation.

DSF specify and complete the guidance given by SNML and focus on the four first themes cited above. They represent the concrete way to implement maritime spatial planning in France and include among others a presentation of the existing situation given through the Action Plans for the Marine Environment (PAMM) developed within the Marine Strategy Framework Directive (MSFD).

The Normandy case study belongs to the maritime region: East Channel – North Sea.

10.1.2. *Geographical and biological context*

The Normandy case study contains two main geographical and biological entities: a part of the Gulf Normand Breton (GNB) located on the Western part of the Cotentin peninsula and the Bay of Seine (BS) located on the Eastern part (Figure 10.4).

Both entities are characterised by a macro tidal regime. Amplitude of tides can reach 15 m in the Bay of Mont Saint Michel and tides here are among the highest reported in the world. In the GNB, hydrological circulation is complex because of the presence of numerous islands and archipelagos creating gyres whereas in BS, circulation is more straightforward (Figure 10.5). Bathymetry is relatively low creating large intertidal areas particularly in the GNB (Figure 10.6). Influence of river inputs is more intense in BS with the Seine estuary.

Both entities are characterised by different levels of primary production: BS presents higher levels of chlorophyll *a* concentrations (Figure 10.7).

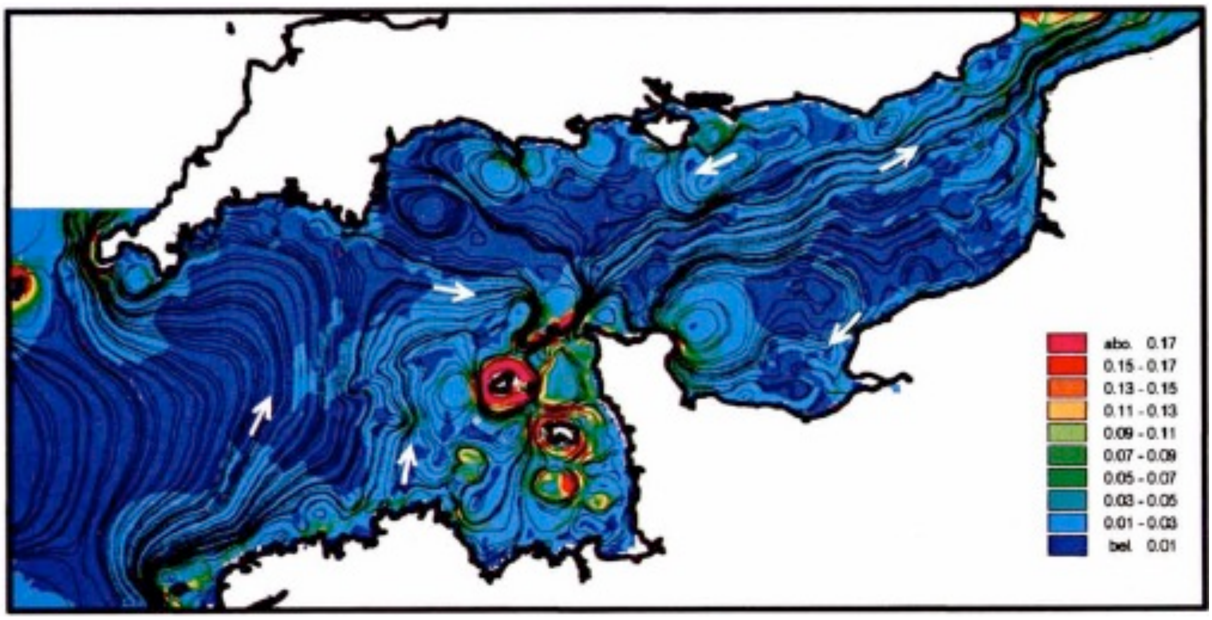


Figure 10.5: Long term trajectories and current intensities in Channel in the situation of a mean tide with no wind (Salomon & Breton, 1993).

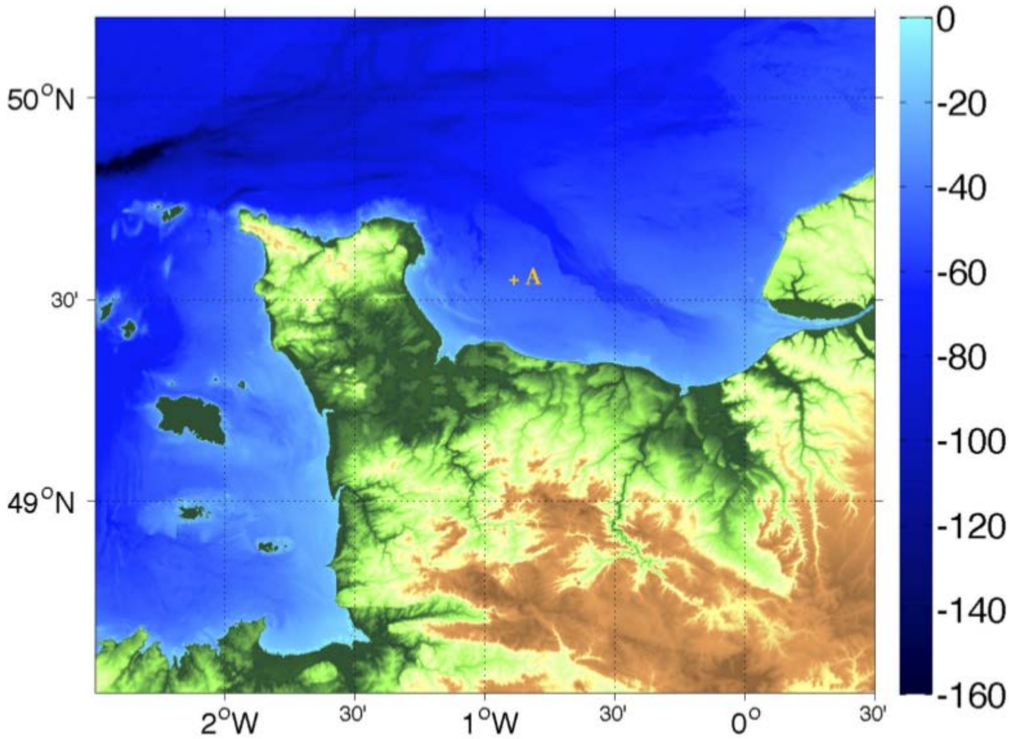


Figure 10.6. Bathymetry (Le Gendre et al.2014).

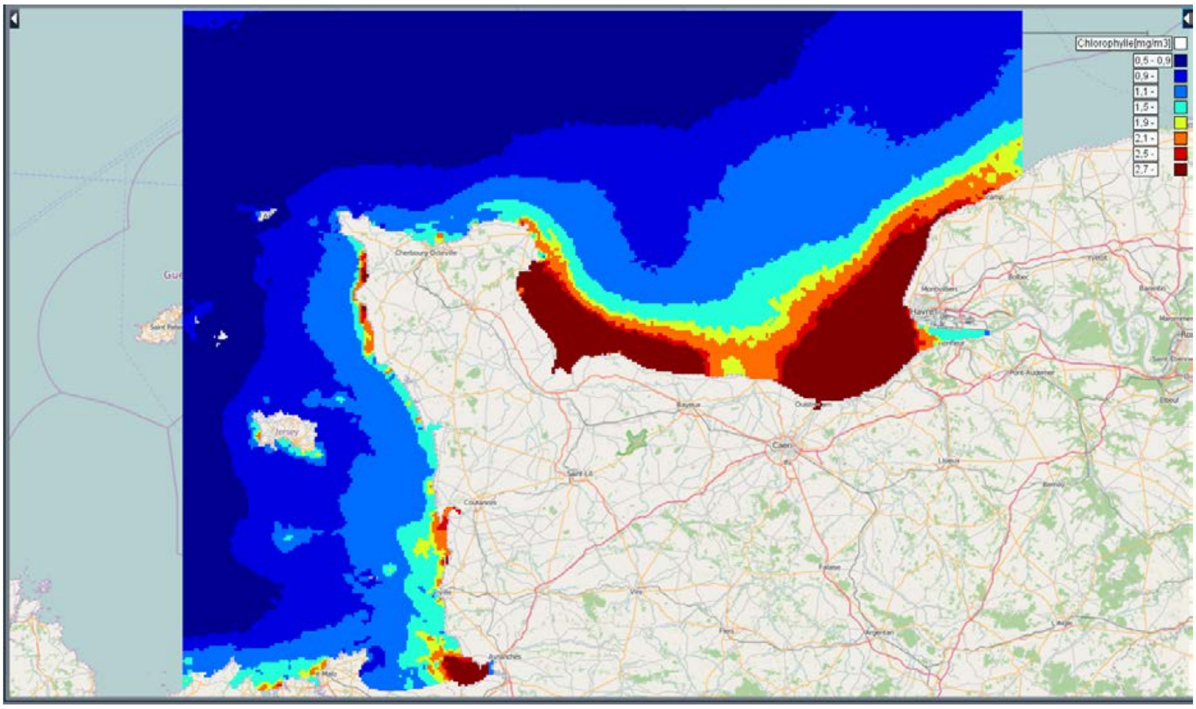


Figure 10.7. Mean chlorophyll *a* concentration over the period 1998-2012 as measured by satellite MODIS/Aqua-MERIS/SeaWiFS (http://sisaqua.ifremer.fr).

10.1.3. *Socio Economic context*

There are numerous economic and social activities in the Normandy Region, which can have an impact on the coastline/maritime space potentially leading to conflicts of use:

- Aquaculture (mainly shellfish and a few marine fish aquaculture - see following section and Figure 10.8),
- Fisheries (professional, recreational - several species of fish and an important population of wild scallops in the bay of Seine),
- Tourism (including a diverse range of nautical activities),
- Agriculture (vegetable and meat production),
- Urbanisation (presence of the Seine estuary),
- Nuclear power plants (3 sites: Flamanville, Paluel, Penly),
- Fuel processing industry,
- Sand gravel extraction and reject of sediments dredged in the main commercial harbours (Le Havre, Rouen),
- Offshore renewable energy projects.

The area also has a high patrimonial value for remarkable landscapes and species implying different levels of environmental protections (Figure 10.9).

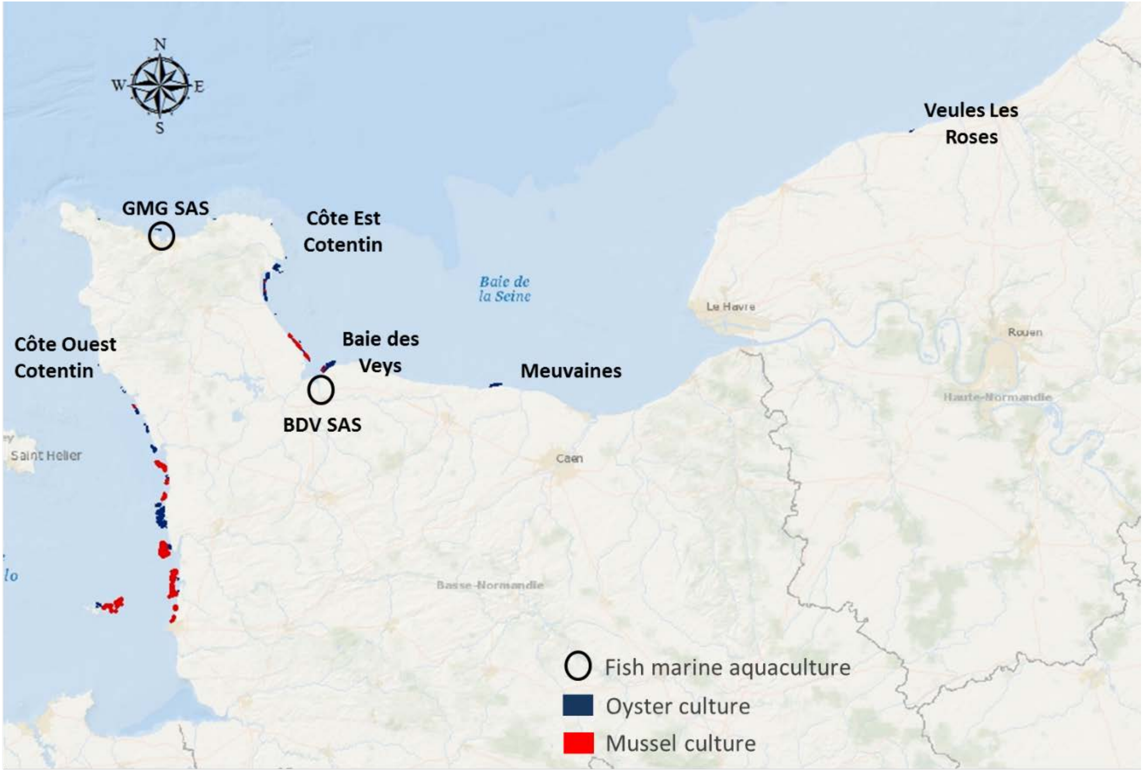


Figure 10.8. Map of aquaculture activities in Normandy.

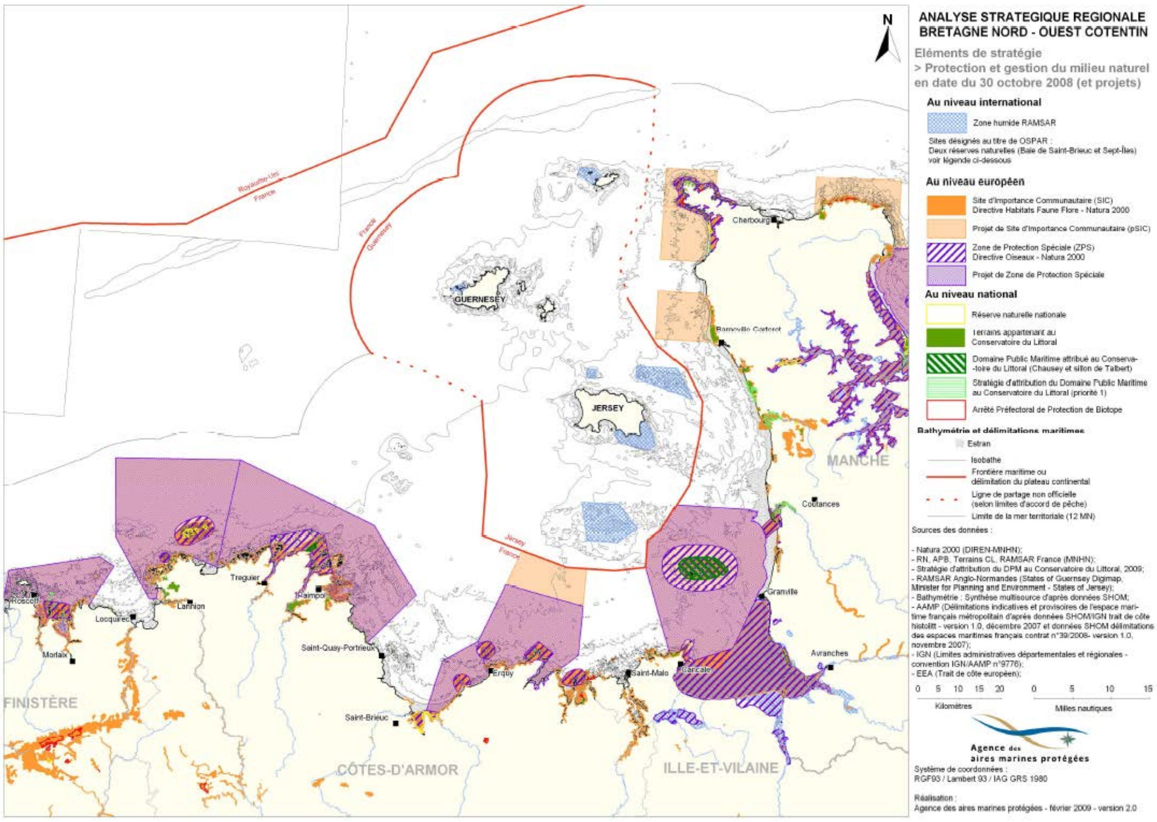


Figure 10.9. Synthesis map of environmental protection in the Gulf Normand Breton (AAMP, 2009).

10.2. Spatial planning and management issues

10.2.1. *Management and environmental issues*

Regarding the socio economic context on the area, different issues have been identified (AAMP, 2009):

- Protect key marine habitats
- Understand and preserve coastal ecosystems in relation to ecosystem functions and land/sea interactions
- Maintain seabirds and marine mammals' diversity
- Improve water quality and maintain primary productivity of the coastal zones
- Invasive species (*e.g.* limpet *Crepidula fornicata*) which affects coastal biodiversity and productivity
- Improve the coherency and transparency of decision-making process regarding coastal zone management, including a better integration with the Channel Islands
- Develop new uses in the coastal zone
- Promote sustainable activity, including aquaculture and fisheries

10.2.2. *Aquaculture species, types and systems*

Shellfish aquaculture occurs in several locations along the Normandy coast, mostly in sheltered areas (bays, estuaries). Two species are cultivated: The Pacific oyster, *Crassostrea gigas*, and the blue mussel *Mytilus edulis*. Oysters are placed in plastic bags fixed on metallic tables moored in the sediment (Figure 10.10). The tables are about 70 cm above the sediment. Mussels are generally cultivated on wooden poles. For the whole area (Normandy including bays of Mont Saint Michel & Cancale), annual oyster production is around 34,000 tonnes and annual mussel production averages 29,000 tonnes.

Figure 10.10. Left - Oyster culture on tables in Chausey archipelago; right - Mussel culture on poles in West Cotentin.

Marine fish aquaculture is only represented in Normandy through 2 salmon farms (*Salmo salar*). One farm is located in the harbour of Cherbourg in the northern part of Cotentin, where salmons are bred in cages. The second one is a land-based farm located in the eastern part of Cotentin, where salmon is produced in a sea water recirculation system. The total annual salmon production is 2,000 tonnes.

10.2.3. *Statistics for production and aquaculture development trend*

Two reports of French shellfish production have been conducted in 2001 and 2012. Between these two periods, results showed a decrease of 26 % for oyster production and an increase of 8% for blue mussel production (Agreste 2014). For oysters, this decrease can be related to high mortalities of spat observed since 2008. For mussels, despite the production increase, the volume is not sufficient to satisfy the demand of French consumers. The total number of companies (n=2900) commercialising shellfish products in France has also decreased by 24% between 2001 and 2012 as well as the total area exploited with a reduction of 22%. Even if oyster culture remains dominant, the area dedicated to this type of culture decreased whereas the area dedicated to mussel culture increased. Total revenues of shellfish companies reached 876 million euro in 2012. The majority of revenue is represented by shellfish production itself (89%, 781 million euro).

In France, the production of marine fish coming from aquaculture is relatively stable and represents about 5,000 tonnes and 78 million of larvae (CIPA/SFAM, 2012). A total of 39 companies exploit an area of 15 ha.

10.2.4. *French policy for aquaculture spatial planning*

In France, marine aquaculture is regulated by the Decree 83-228 establishing the authorisation system for marine aquaculture. There are 2 types of concessions: one for establishing an aquaculture facility on the maritime public domain and one for using sea water allowing the operation of an aquaculture facility located on the private domain. Development of fish aquaculture is subject to an Installation Classified for the Protection of the Environment (ICPE= impact analysis), which is not the case for shellfish culture. For shellfish, rules regarding the activities are driven by Departmental Structure Plans (SDS). Four departments cover the coastline of our case study: Côtes d'Armor (North Brittany region), Manche, Calvados and Seine-Maritime (Normandy region). More recently, Regional Plans for Marine Aquaculture Development (SRDAM) were set up. These plans aim to identify existing aquaculture areas and new potential areas for aquaculture development and include both shellfish culture and marine fish aquaculture. However, SRDAM do not enforce on licensing aquaculture farming

10.3. *Stakeholder engagement and participation*

The French AquaSpace team held the first stakeholder workshop on March 2nd 2016 (10:00-16:00), in Caen. The workshop was co-organised with the national authorities (French Ministry of Environment, Energy and Sea), more specifically the Inter-Regional Direction of the Sea (DIRM) and the Departmental Directions of Territory and Sea (DDTM). The workshop was held at DDTM of Calvados Department and was specifically dedicated to the AquaSpace project.

A total of 28 people from 18 organisations participated in the workshop which was managed by the Ifremer AquaSpace team (M. Callier, A. Gangnery, J-P. Blancheton and C. Bacher).

Type of structure	**Name**
National Authorities (Decentralised services)	Inter-Regional Direction of the Sea (DIRM - French Ministry of Environment, Energy and Sea, MEDDE)
	Departmental Directions of Territory and Sea (DDTM - French Ministry of Environment, Energy and Sea, MEDDE)
	Regional Direction of Environment, Development and Housing (DREAL - French Ministry of Environment, Energy and Sea, MEDDE)
	French Marine Agency for Protected Areas (AAMP)
	French Water Agency Seine-Normandy (AESN)
Regional/Local Authorities	Regional Council of Normandy (CRN)
	Departmental Councils of Manche and Calvados (CD)
Industry and representatives (marine fish and shellfish culture)	Regional Committee of Shellfish Culture (CRC)
	Regional Committee of Fisheries (CRPEM)
	Interprofessional Committee of Aquaculture Products (CIPA)
	French Syndicate of Marine Aquaculture (SFAM)
	Fish farmer, GMG SAS (salmon)
	Fish farmer, BDV SAS (salmon)
Technical centers (shellfish, fish) / Applied research	Technical Institute of poultry farming (including fish farming) (ITAVI)
	Synergy Sea and Coastline (SMEL)
	Study Group on Estuarine and Coastal Ecosystems (GEMEL)
Non governmental organisations	International Union for Conservation of Nature (IUCN)

	Regional Group of Environmental Protection Associations from Normandy (GRAPE)
Public institutions	Center for Studies and Expertise on Risks, Environment, Mobility and Planning (CEREMA)
	University of Caen (UMR Spaces and Society)
	French Research Institute for Exploitation of the Sea (Ifremer, Organization of the workshop)

The workshop started in the morning with several presentations:

- ⇨ Introduction to the European Directive for Maritime Spatial Planning (MSP), application in France and in the Eastern Channel – North Sea facade, step report – DIRM.
- ⇨ Presentation of the AquaSpace project (objectives, methods) and SISAQUA application – IFREMER.
- ⇨ What is the administrative procedure applied to project development in aquaculture? – DDTM.

During the afternoon, exchanges with stakeholders were organised with the objectives of i) identifying & ranking the data needed to implement spatial planning for aquaculture in the area, ii) verifying the existence & availability of this data and specify its format. Two working groups were set up, each of them managed by 2 Ifremer participants. The results of the working groups were disseminated immediately and an open discussion about the issues of aquaculture development in the area took place in the second part of the afternoon.

During the meeting, we identified CEREMA as an important participant because they manage data required to implement MSP in the case study area. They are also in charge of providing technical support to authorities for the development of DSF (see section 1). A first technical meeting between Ifremer and CEREMA was organized on May 10th 2016. At this meeting, all the data managed by CEREMA was listed. Based on this list, we classified data according to the degree of priority for our purpose and a second technical meeting was organised on December 16th 2016 to discuss priority data and examine their availability. In March 2017, we received data from CEREMA that will be included in the tool used in the case study (see section 4).

10.4. Tools used in the case study

This section discusses the SISAQUA application, (Information Spatial System for Aquaculture) which is directly derived from the AkvaVis tool developed in Norway. The demonstrator SISAQUA has been developed under the cooperative project SISQUONOR (2013-2015) joining the Institute of Marine Research and CMR Computing (Bergen) with Ifremer. Like AkvaVis, SISAQUA is a dynamic web application based on a Geographic Information System (GIS) and provides a user interface. AkvaVis was originally developed for salmon but a module was also constructed for the blue mussel. For more information on AKvaVis, see the sections dedicated to the case studies in Norway, China and Northern-Ireland (UK).

SISAQUA focuses essentially on shellfish culture and relies on two types of data:

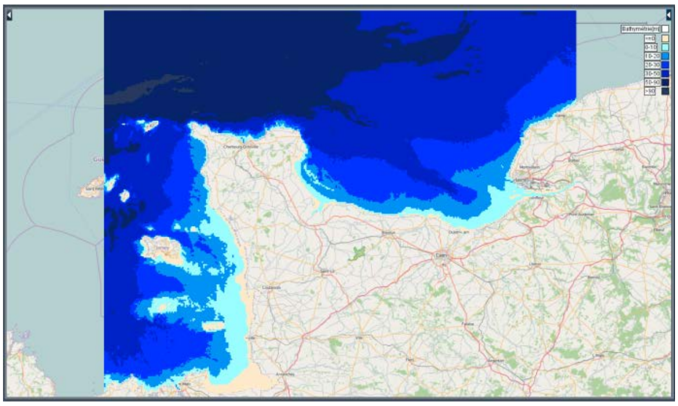
- Data collected or specifically produced by Ifremer and combined to produce some indicators
- Visualisation of data produced by other organisations

10.5. Application of tools

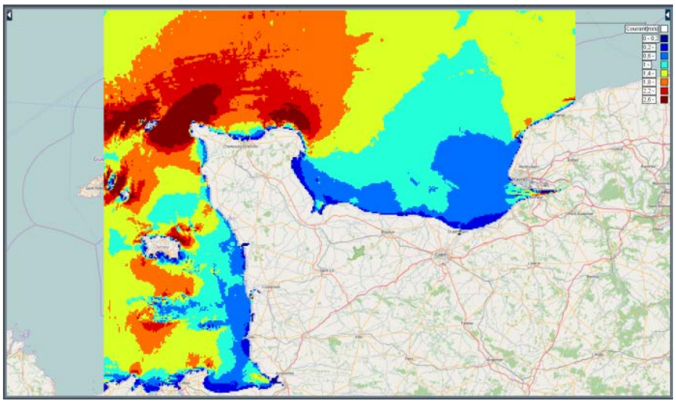
10.5.1. Data collected or specifically produced by Ifremer & indicators

Data produced by Ifremer within the frame of the SISQUONOR project mainly rely on numerical modelling and coupling with satellite data. A first series of physical data came from the hydrodynamic model MARS 3D NORM developed by Le Gendre et al. (2014). This model is centred on the Normandy region and extended from 48.52-50.20°N to 2.5°W-0.5°E with a resolution of 200 m. Maps of bathymetry (see also Figure 10.6), chlorophyll a (see Figure 10.7) currents, waves and nature of the substrate are derived from this model (Figure 10.11, for more details see Gangnery et al.2016).

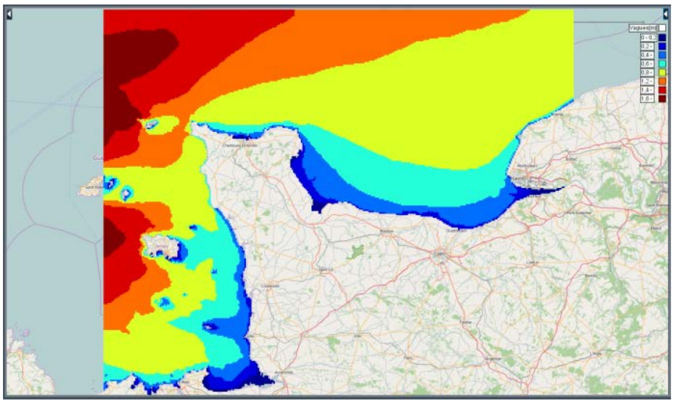
A. Bathymetry



B. Currents



C. Waves



D. Nature of substrate

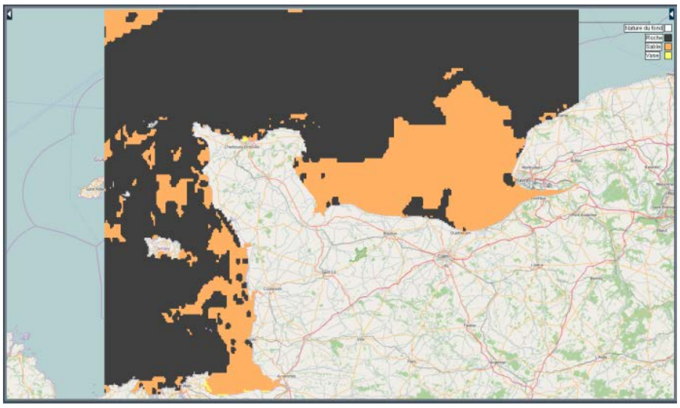
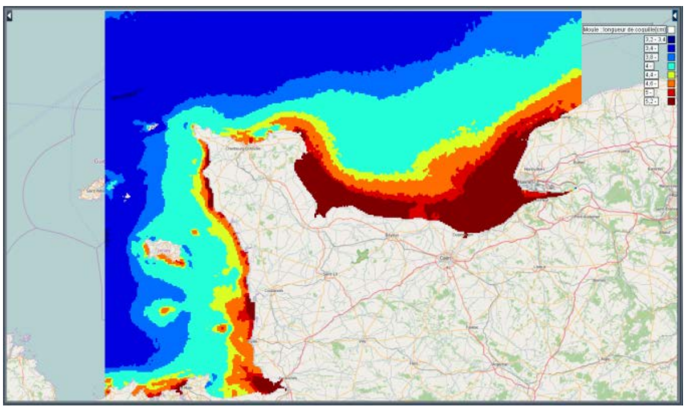


Figure 10.11. Maps of bathymetry, currents, waves and nature of substrate as they appear in the SISAQUA application. Metadata are available in the application or in Gangnery et al. (2016).

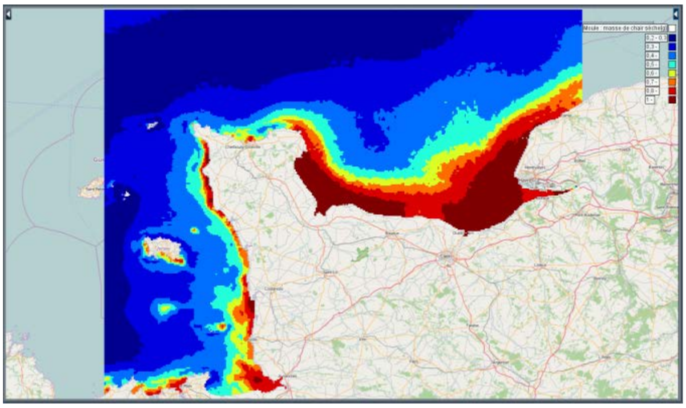
A second series of information is coming directly from satellite data MODIS/Aqua-MERIS/SeaWifs and concern the concentrations of chlorophyll a and suspended matter (see Figure 10.7).

A third series is coming from the coupling between DEB eco-physiological models of oysters and mussel growth and satellite data. This allowed for the computing of maps to show growth prediction: shell length, dry flesh mass, condition index (ratio between dry flesh mass and total mass) and time to reach commercial size (Figure 10.12 & Figure 10.13).

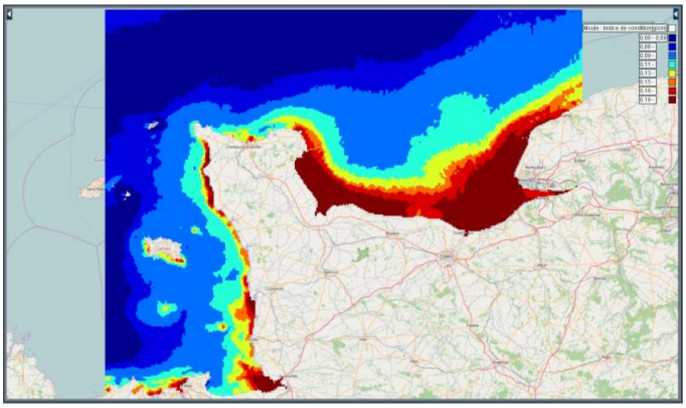
A. Shell length (cm)



B. Dry flesh mass (g)



C. Condition index (-)



D. Time to reach commercial size (days)

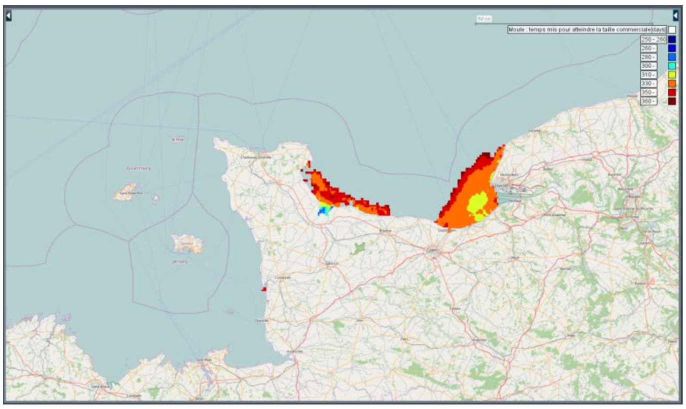
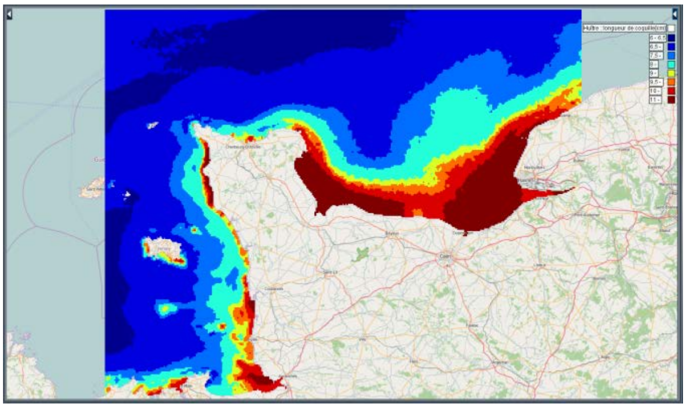
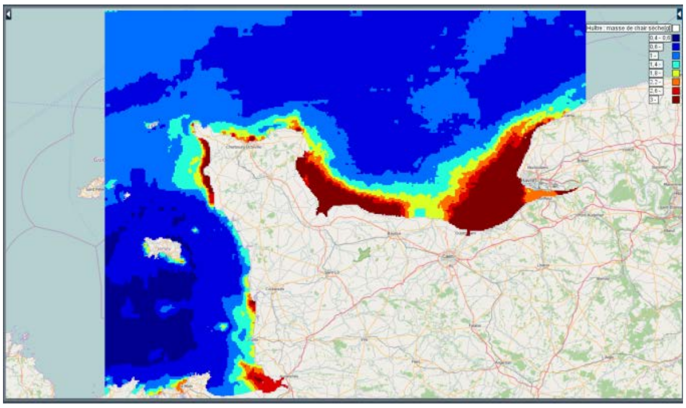


Figure 10.12. Maps of mussel growth predictions as they appear in the SISAQUA application. Metadata are available in the application or in Gangnery et al. (2016).

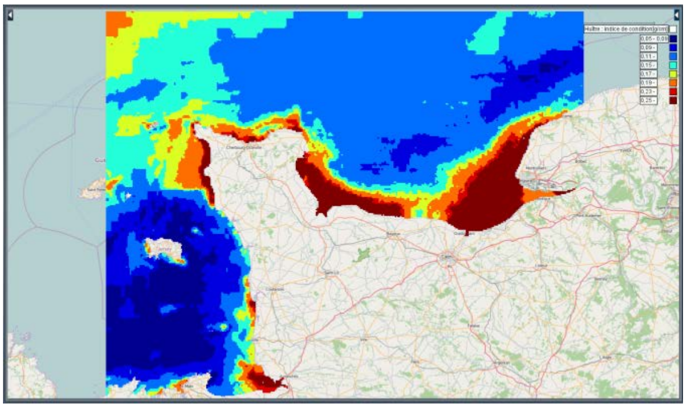
A. Shell length (cm)



B. Dry flesh mass (g)



C. Condition index (-)



D. Time to reach commercial size (days)

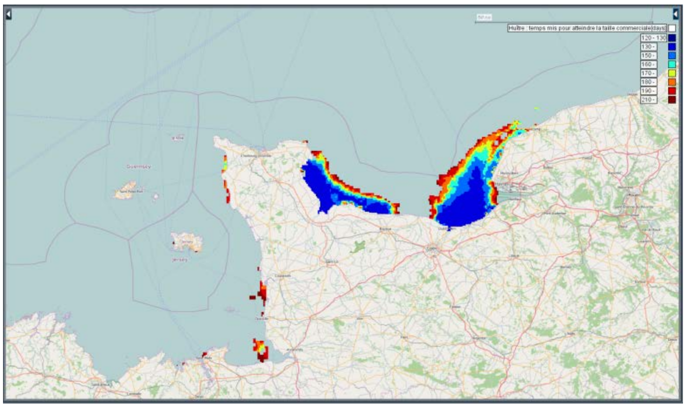
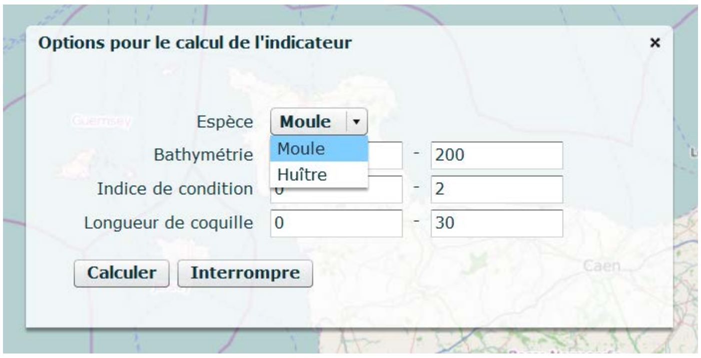


Figure 10.13. Maps of oyster growth predictions as they appear in the SISAQUA application. Metadata are available in the application or in Gangnery et al. (2016).

Bathymetry, shell length and condition index maps have been combined to compute a first indicator allowing for the definition of areas suitable for oyster or mussel culture based on these criteria. The user selects the values required through an interface window and the application sends back a resulting map (Figure 10.14).

A. Interface window



B. Exemple of result

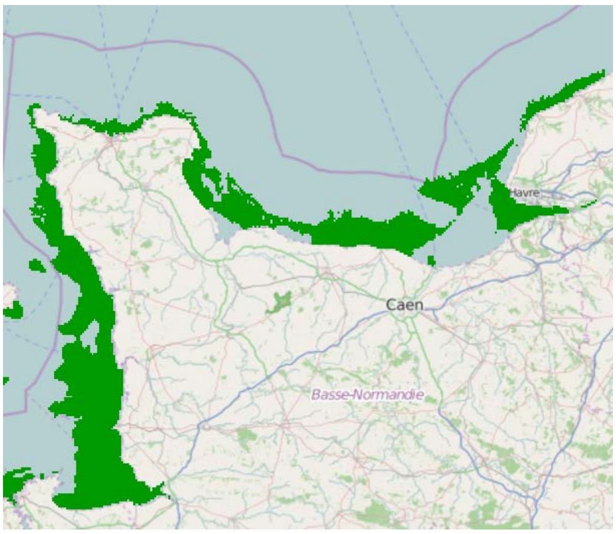


Figure 10.14. Interface window available for the user (A) and result example: the green area corresponds to the criteria selected by the user (B).

Finally, other data collected by Ifremer within the frame of other programs or projects have been integrated through standardised communication protocols WMS (Web Map Services), allowing the visualisation of following data:
- Intertidal area
- Catchment areas
- Detailed representation of sediments
- Location of harbours
- Aerial photos of shellfish culture areas

10.5.2. *Data produced by other organisations*

Data produced by other organisations can also be integrated to the application through WMS. At this time, the following data can be visualised coming from national authorities:
- Cadastral plans of shellfish culture areas
- Types of access to the sea from the coastline
- Nature of the intertidal areas
- Coastline
- Types of environmental protection

10.5.3. *General presentation of SISAQUA*

The home screen of SISAQUA is divided into 3 sections (Figure 10.15):
1. The free background map coming from OpenStreetMap (http://openstreetmap.fr/),
2. The menu presenting all the date integrated to the application,
3. A set of action buttons available for the user.

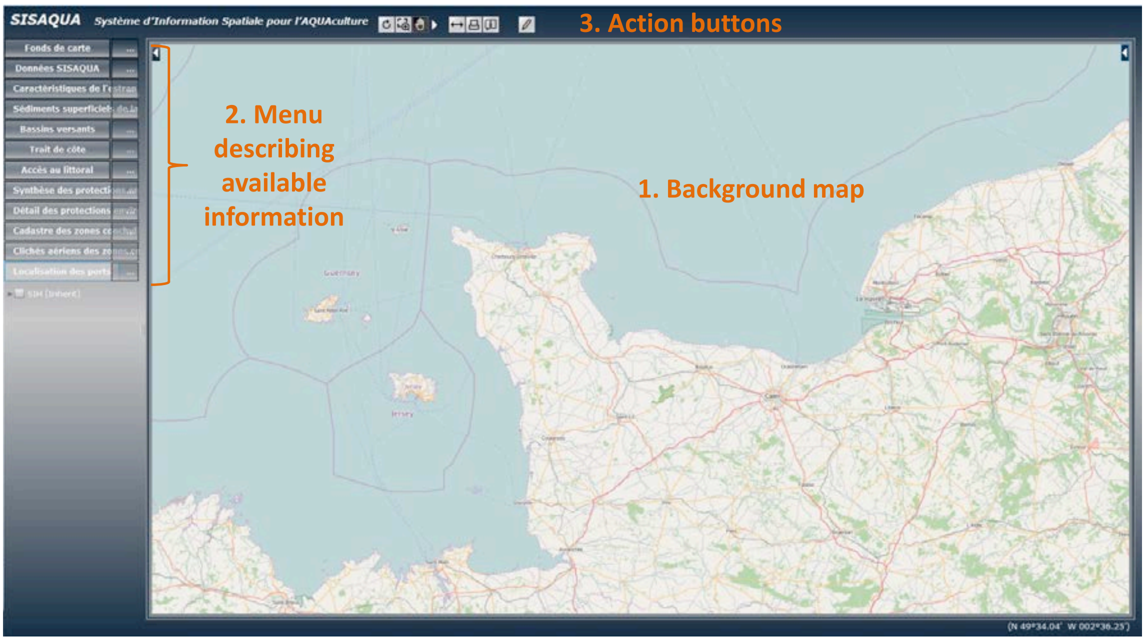


Figure 10.15. Home screen of SISAQUA.

Essentially, SISAQUA was developed through a scientific and technical prism. The prototype of this tool was presented to stakeholders on 2 occasions: the kickoff meeting of the SISQUONOR project and the first workshop organised within the AquaSpace project. At this time, SISAQUA is still under development, so it is not distributed, and is not used either by regulatory agencies or decision-makers and there is no evidence that it will be in the future. We can mention the call recently opened by the French Ministry of Environment, Energy and Sea to conduct a feasibility study to set up a national procedure to determine best possible aquaculture locations (MEAP in French) based on an experiment on pilot sites. The objective is to propose a methodology based on planning tools and methods already existing in France or in Europe. The technical document associated with this call mentions in its article 8 (Documents and tools) the SISQUONOR and AquaSpace projects and the SISAQUA demonstrator. The Ministry chose the consortium in October 2016 and a first steering committee was organized in November 2016. The second steering committee occurred on April 11th 2017 and both M. Callier and A. Gangnery, involved in AquaSpace for Ifremer, participated. Normandy and PACA (bordering Mediterranean) regions were chosen as pilot sites for shellfish and marine fish farming, respectively. The SISAQUA tool was identified and analyzed as an existing planning tool.

10.6. Case study results

10.6.1. *Stakeholder output/feedback*

Main issues regarding aquaculture development in Normandy have been identified on the basis of exchanges during the workshop and consultation of the French Strategic National Plan for Aquaculture Development (MEDDE 2014):

olicy and management issues

- Complexity of procedures regarding projects installation
- Multiplicity of services/structures involved in the procedures and zoning systems
- Transparency in the decision making process
- Time scale for case investigation is too long
- Lack of a unique regulatory tool for a quick diagnostic, integrating a maximum number of aquaculture types
- Difficulty/Constraints related to the civil society consultation process
- Lack of a political willingness to develop aquaculture at global and local scales

Economic and market issues

- Lack of well identified consumers' expectations (need of market studies)
- Need to better know the international market (competitiveness issues)
- Mismatch between market reality and time needed to start a new production
- Need to develop an industry based on high quality products and eco-awareness
- Need stability and reliability of the production system
- Difficulty to predict costs related to externalities (energy costs, feeding costs)
- Lack of existing infrastructure which would facilitate the development of new farmers/activities

Aquaculture-Environmental issues

- Existing risks not taken into account: submersion, coastline erosion
- Evaluation of emerging risks, diseases

Aquaculture-Other sectors issues

- Need to balance aquaculture activities with respect to other ecosystem services provided by coastal ecosystems (patrimonial issues)
- Lack of a society willingness to develop aquaculture at global and local scales; Social license

Global issues on data/tools

- Lack of knowledge on information/data relevant to aquaculture and about their availability
- Up-date data, tools / make them resilient
- Friendly Tools (design for different users)
- Transfer of tools

10.7. Application of tools

Concerning SISAQUA, different objectives will be completed in the next months:

- ⇨ Implementation of the tool into Sextant (http://sextant.ifremer.fr/fr) is under construction. Sextant is the infrastructure developed by Ifremer to manage geo-referenced data. At this time, SISAQUA is still hosted on a Norwegian server. It implies that SISAQUA will still be hosted by Ifremer and will be accessible to the public through the Sextant platform.
- ⇨ Integration of new data collected from CEREMA and others into SISAQUA is also under construction.
- ⇨ Proposition of new indicators in agreement with stakeholders.
- ⇨ Integrate marine fish aquaculture as well as shellfish.

10.8. Relevance of the case study within Aquaspace

- A site with numerous and various activities (including aquaculture), a high patrimonial value implying numerous issues. One of these issues is the maintenance of existing aquaculture and the sustainable development of new aquaculture activities collocating with other uses.
- A site where scientific and legal approaches are working in parallel
- A site characterised by a huge shellfish culture activity (about 400 companies, an important economic contribution) compared to a weak marine fish aquaculture (2 companies).

10.9. Conclusions and future prospects

AquaSpace gave us the opportunity and the framework to engage in discussions with various stakeholders. Numerous benefits were obtained from this approach:

- ⇨ Possibility for scientists to communicate, disseminate, transfer their knowledge and tools.

- ⇨ Reinforce exchanges, communication between stakeholders: government, industry and representatives, NGOs, scientists…
- ⇨ Identification of various issues related to aquaculture development in Normandy.
- ⇨ Emphasis on the notion of social acceptance of aquaculture.

AquaSpace also gave us the possibility to improve the SISAQUA tool developed in a previous project:

- ⇨ Technical improvement (migration from Norway to France).
- ⇨ Integration of new data.
- ⇨ Creation of new indicators.
- ⇨ Extension to marine fish aquaculture.

These things are made in consensus with stakeholders.

- ⇨ Application of the same type of tool to other case study (Carlingford Lough): allowing for the comparison of experiences

In the future, the possibility to include elements of Aquaspace tool within this tool should be examined.

A future perspective is the implementation of MSP by French regulators: development of the Strategic Document for the East Channel – North Sea façade and call concerning the determination of Best Possible Aquaculture Locations.

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11. NORTH SEA, GERMANY

Antje Gimpel, Vanessa Stelzenmüller, Sandra Töpsch, Tobias Lasner, Michael Ebeling.

11.1. General characteristics

The German case study site refers to the German Exclusive Economic Zone (EEZ) of the North Sea and adjacent coastal waters (Figure 11.1). The German EEZ (North Sea) is approximately 28,600km² and the German coastal zone is approximately 11,400km².

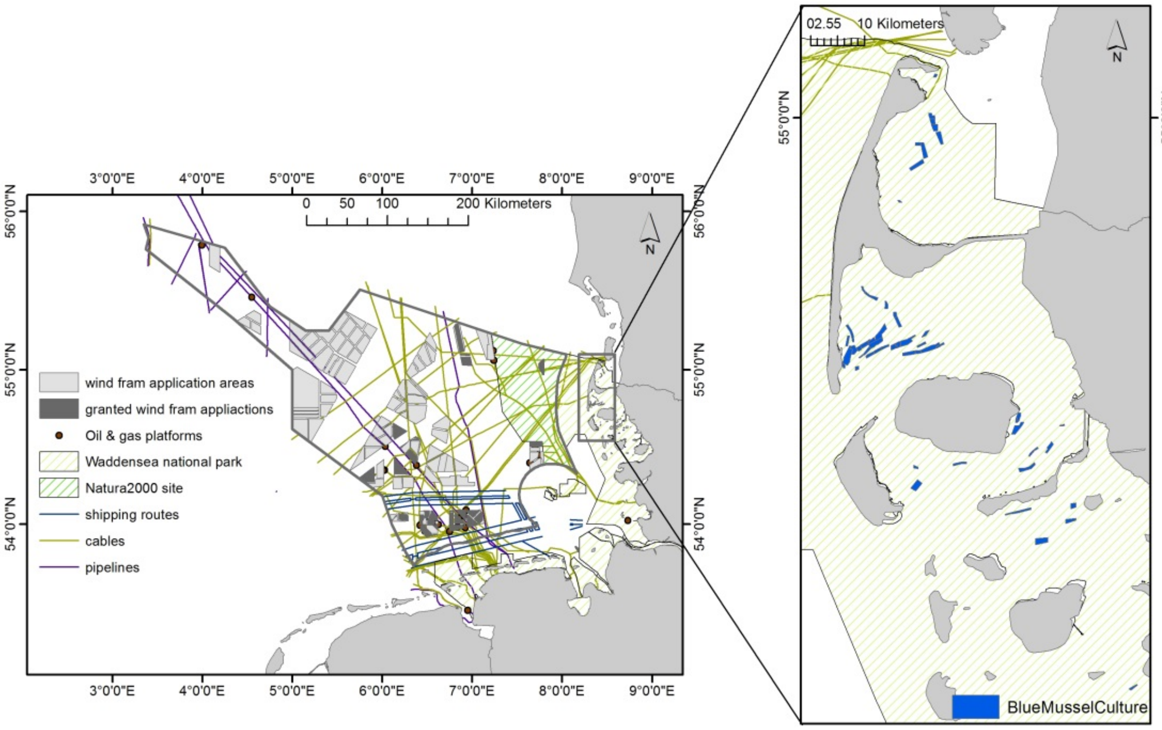


Figure 11.1: German EEZ of the North Sea with adjacent coastal waters, embedded between Denmark and the Netherlands with a maximum depth of 60 meters. The map shows the main offshore activities managed by the maritime spatial plan. Blue mussel licence areas are located 20 km of the coast close to the island of Sylt within the Wadden Sea national park.

In Germany, Maritime Spatial Planning (MSP) is regulatory and enforceable. The federal plan for the North Sea came into effect in September 2009 and the federal plan for the Baltic Sea in December 2009 (BSH, 2009a). The plans are based on zoning, creating areas that favour a particular use and areas where certain uses are prohibited. The German MSP was stimulated by the effect of newly developed maps displaying numerous proposals for large-scale offshore wind energy farms

(UNESCO, 2014). The main human activities regulated are shipping, oil and gas exploitation, cables and pipelines, renewable energy development, and aggregate extraction (Buck et al.2004; BSH, 2009b). The allocation of fishing activities is not included (Fock 2011; Stelzenmüller et al.2011). As marine aquaculture is taking place nearshore, it is not included (Gimpel et al.2015).

Recently, existing license areas of 3.300ha have been designated for bottom cultures of blue mussel with an annual production of round about 5,000 tonnes. Those are located within the Wadden Sea National Park (Figure 11.1), which falls under the jurisdiction of the federal state of Schleswig-Holstein and which has numerous restrictions regarding human activities. The National Aquaculture Strategy (NASTAQ; http://www.portal-fischerei.de/fileadmin/redaktion/dokumente/fischerei/Bund/Nationaler_Strategieplan_Aquakultur_Deutschland.pdf) foresees an increase of the current blue mussel production from 5000 tonnes to 40000 tonnes within the existing license areas.

To date 22% of the current offshore wind development applications, (in total covering approx. 30% of the EEZ) have been granted. The enormous spatial expansion of this sector exerts pressure on other human uses such as fisheries. To mitigate this increasing potential for conflict, the German planning authority is currently interested in the development of suggestions for potential synergies between different sectors such as offshore wind development and aquaculture.

11.2. Spatial planning and management issues

MSP in Germany is based on the Federal Land Use Planning Act that was extended to the EEZ. The responsibility lies with the Federal Agency for Shipping and Hydrography (BSH) as a representative of the Federal Ministry of Transport and Digital Infrastructure (BMVI) (BSH, 2009a; Berkenhagen et al.2010). Spatial plans for the territorial waters (up to 12 nm) were developed by the coastal Federal States.

On behalf of the Ministries of Interior and the Ministries of Rural Areas, Nutrition, Agriculture and Consumers Rights, Schleswig Holstein and Lower Saxony are developing their own spatial management strategies (SH, 2003; LS, 2005). While Schleswig Holstein developed an Integrated Coastal Zone Management Strategy (IKZM, Integriertes Küstenzonenmanagement), Lower Saxony developed a MSP concept (ROKK, Raumordnungskonzept für das niedersächsische Küstenmeer).

According to the NASTAQ, the main factors hampering aquaculture development in Germany are the requirements arising from environmental law, federal waterways law, fisheries law, building law and/or veterinary legislations, which lead to expensive and time consuming approval procedures. A pooling of responsibilities has not yet happened. Furthermore, aquaculture has become associated with a bad image and environmental issues such as the influence of predators, impact on protected species etc.

11.3. Stakeholder engagement and participation

The Thünen-Institutes of Sea Fisheries and Fisheries Ecology hosted an Aquaculture Expert Workshop on April 14th 2016 in Hamburg, Germany. The main goal was to identify the key issues linked to an expansion of the aquaculture sector. To synergise approaches of the European fisheries and aquaculture research, AquaSpace partners worked closely with the EU Horizon 2020 projects SUCCESS and CERES in preparation for the stakeholder meeting. It brought together 22 experts and stakeholders from the fields of nature conservation (3), governance (3), industry (5), science (8) and administration (3), to discuss the present and future of aquaculture in Germany.

All invitees were selected as a sample of expert knowledge regarding aquaculture and deal with marine and/or freshwater aquaculture in their day-to-day work. They were chosen as representatives of an institution and/or for being an opinion leader in the field of aquaculture in Germany. Discussion took place in three focus groups, each consisting of 7-8 experts. Each field of expertise mentioned above was represented in each focus group. The discussion started with the following question from the moderator:

'Aquaculture can be seen as an international success story. Indeed, within the EU strategy „Blue Growth" high expectations towards aquaculture are formulated. In Germany, the sector is comparable small and diverse. The development of the German sector has been stagnating for many years. Today, 90 % of German aquatic products are imported. Some people say, there is no need for a domestic aquaculture in Germany. What do you think?'

After this, the moderator did not control the focus group in their discussion. This open-inductive procedure is a core principle of qualitative social research, which allows for gathering of the expert's interpretation of a situation. After 60 minutes, the moderator asked two further questions, one addressing factors hampering the growth of aquaculture and one pointing to assumed climate change impacts towards aquaculture. Those questions had been chosen to meet all objectives of the Aquaspace, SUCCESS and CERES projects. All three focus groups spontaneously discussed factors which hamper aquaculture growth in Germany, but only one group discussed the topic of climate change without the introduction of this topic by the moderator.

11.4. Tools used in the case study

Within the German case study, the tool applied to address current issues is the *AquaSpace tool*, a GIS Add-In developed in WP3 (Gimpel et al.in prep.). The tool provides a spatial representation of costs and benefits of a proposed aquaculture site in a multi-use context. It comprises functions that enable the user to assess the spatial variation in inter-sectorial, environmental, economic and socio-cultural indicators in different aquaculture planning scenarios. Besides this functionality, the AquaSpace tool also includes s a Geodatabase (GDB) with European-wide data layers. The tool outputs consist of detailed reports and graphics which should facilitate planning trade-off discussions and thus allow key stakeholders (e.g. industry, marine planners, licensing authorities) to make better evidence-based decisions on proposed aquaculture developments and the associated risks and opportunities (Gimpel et al.in prep.).

11.4.1. ***Case study description***

The case study aimed to i) conduct a spatially explicit and integrated assessment of socio-ecological costs and benefits of the co-location of aquaculture and offshore renewables and ii) assess the potential for implementing the German Aquaculture strategy by increasing blue mussel production. This is a multiple objective case study operating at two different spatial scales. Building on previous results, European seabass (*Dicentrarchus labrax*) and Blue mussel (*Mytilus edulis*) were identified as suitable aquaculture candidates on the basis of their native occurrence in the German North Sea, their resistance to hydrodynamic conditions in offshore environments, and their economic potential for the EU market (Gimpel et al.2015; Ebeling 2016).

The first case dealt with the medium to large scale, assessing possibilities to co-locate wind farms with *D. labrax* cultures in 15 different scenarios. These locations were selected due to their low potential for management-related constraints, their low conflict and high synergy potential, the local aquaculture suitability and the distance to a chosen harbour. The assumed annual production did not exceed 4,000 tonnes, the maximum amount estimated from current market conditions for this species. Using prior studies as a baseline, the most efficient culture system identified was one free standing cage. A stocking density of 0.025kg per m^3 and a cage size of 8960 m^3 was determined. Assuming a production cycle of two years, with 36 cages, a production of 4000 tonnes each year was simulated. The port from which the aquaculture site would be managed and supplied was defined to be Helgoland.

The second case dealt with the small scale, assessing 15 scenarios of increased production of *M. edulis*. The sites were selected because of their local aquaculture suitability, the proximity to sites where blue mussel aquaculture already existed, and their low potential for management-related constraints. The story-line assumed that production quantity would be raised from 5000 tonnes to 40000 tonnes per year, the maximum for the designated and licensed areas available. Using prior studies as a baseline, a longline culture system was chosen. A stocking density of 0.01 t per meter and a longline system providing 1675m culture line each was simulated. Assuming a production cycle of two years, with 4776 longlines, an annual production of 40000 tonnes was simulated. The port from which the aquaculture site would be managed and supplied was defined to be Hörnum (Sylt).

Consequently, suitability maps for selected aquaculture candidates were combined with economic, technical and legal constraints and an environmental impact assessment to assess the overall risk for both cases.

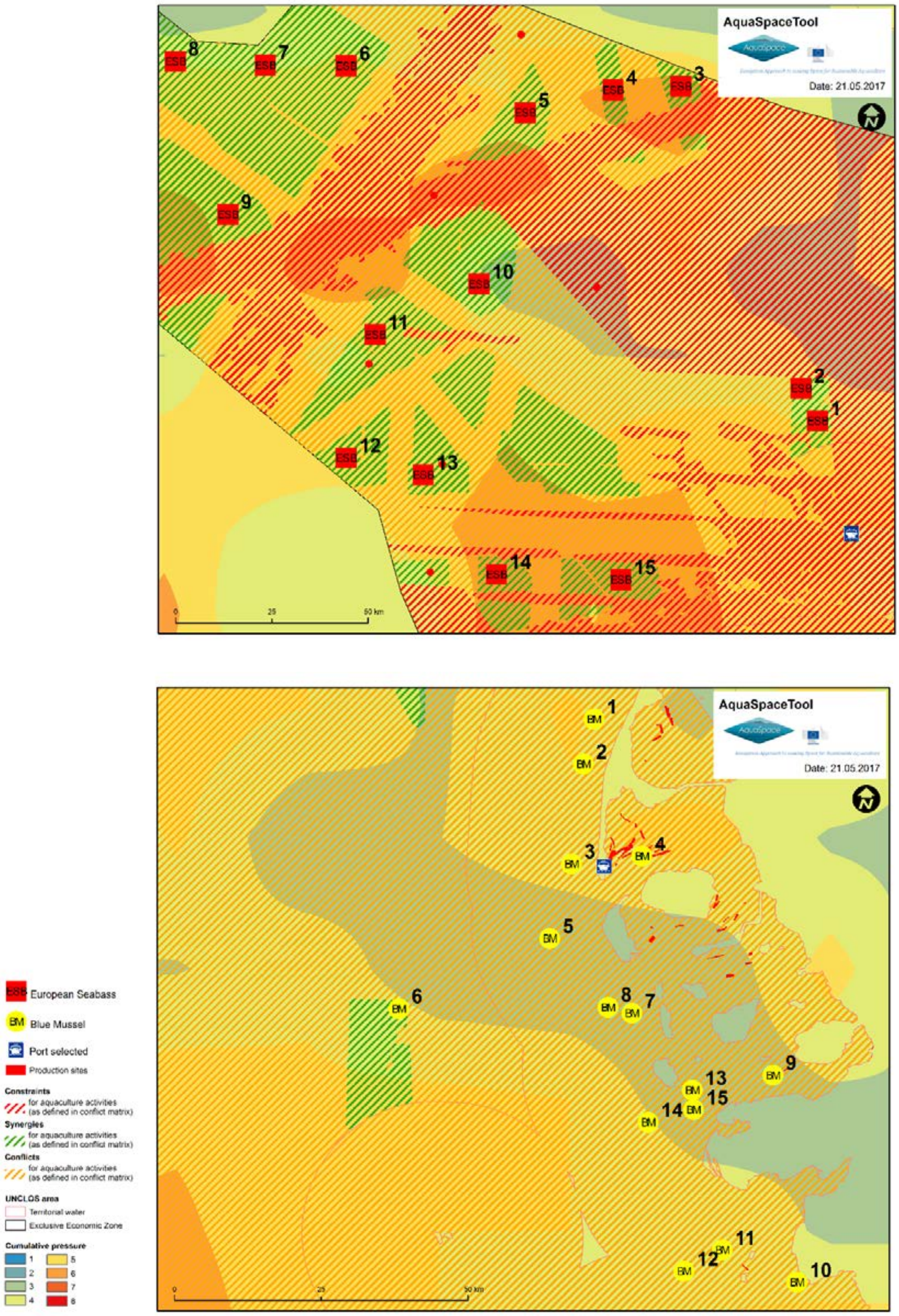


Figure 11.2: AquaSpace tool output map (pdf format) for *D. labrax* (top) and *M. edulis*. Shown are the locations of the scenarios 1 – 15, the case-specific port selected (*D. labrax* = Helgoland; *M. edulis* = Hörnum/Sylt)., areas of constraint, synergy and conflict, management boundaries, areas of aquaculture production (please note, that finfish culture sites are just proxies to showcase tool functionality) and a cumulative pressure map, selected manually as background map for the AquaSpace tool map output.

11.5. Case study results

Results from the stakeholder workshop revealed several issues constraining the growth of aquaculture and therefore the implementation of the NASTAQ objectives. The main challenges perceived by the stakeholders were: the plurality and complexity of authorisation procedures; strict regulations; difficult marketing for newcomers; price competitiveness with imports; lag in modernisation; contradictions between consumers' expectations towards the sustainability of aquaculture products and consumers willingness-to-pay; and disunity between the federal states and the national state as well as in-between the federal states (Gimpel et al.2016).

Those issues were compounded by, for instance, insufficient authorisation competence in authorities, high import rates which hamper German production, and strict nature conservation laws which obstruct aquaculture expansion and discourage investors.

From a socio-economic perspective, the issues include an unfavourable image of aquaculture products or a lack of product diversification, which again drives undesirable consumer behaviour. Furthermore, the sectors suffer a shortage of qualified professionals.

Results from the AquaSpace tool have been processed in a spider chart. These are shown in Figure 11.3a for the medium-large scale case, involving *D.labrax*, and Figure 11.3b for the small-scale case involving *M. edulis*. Each numbered scenario corresponds to the site numbering in Figure 11.2. The data in the spider diagrams have been normalised by the application of a z-transformation.

The objective in the medium-large scale case was to co-location of offshore wind farms and offshore aquaculture with *D. labrax*. The Integrated Multi-Trophic Aquaculture (IMTA) potential remained low (0) at all sites. In contrast, the risk of disease spread reached its peak value at site 13, followed by a comparable high value at site 11. Sites 2 and 3 as well as 12 - 15 showed decreased conflict potential. Surprisingly, the spatial synergy potential showed a negative value at site 1, meaning that no co-use is possible at this site.

The AquaSpace tool allows assessments at large scales, but with a high-quality resolution. Nevertheless, the negative synergy potential value at site 1 for *D. labrax* highlights the importance of an appropriate user-specific handling of the GIS Add-In (especially the zoom function), which needs to be highly precise.

Looking at the environmental effects, the habitat vulnerability and water quality were similar at most sites. While Phosphorous peaked at site 9, Nitrogen reached lowest values at sites 11 and 12. Wave height specific exposure and the cumulative pressure were least at site 1. The aquaculture suitability and the sediment sensitivity were similar at most sites, but decreased at sites 7 and 8. The latter reached a similar low value at site 11. The water depth was maximal at site 6 and its minimum at site 3.

The economic indicators added value, induced direct impact on production and induced indirect impact on production, Net Present Value (NPV) and revenue were similar at all sites. In contrast, the opportunity costs, the profit and the Return on Fixed Tangible Assets (RoFTA) showed peak values at site 1 and the lowest at site 8. Finally, comparing the sites from a socio-cultural perspective, only the distance related indicator tourism showed significant variability, with lowest value at site 15 and highest at site 8.

Interpreting the results according to site in this medium-large scale case, site 12 exhibits a low risk of disease spread, a relatively low conflict potential, low Nitrogen values and a stable aquaculture suitability for *D. labrax*. Site 14 presents an even lower Nitrogen level, water depth and impact on touristic attractions, and offer more profit and a higher RoFTA. A site's distance to the coastline (or rather the selected port Helgoland) appeared to be the factor with the greatest influence on the results, especially in relation to environmental effects.

While aquaculture suitability decreased from 5 to 4 (10 = highly suitable), the impact potential due to cumulative pressures increased from 2 to 4 (maximum = 8). NH3 decreased from 2.08 to 0.18mol/L. In contrast, PO4 increased from 0.1 to 0.18mol/L. Results analysed using indicators such as sediment sensitivity or water quality were fairly similar over sites, whereas wave height values showed high variability and site-dependence. Economic effects followed the same principle. The indicators RoFTA, profit and opportunity costs changed in the same way. In the case of profit, the results varied around €95,432.97. Inter-sectorial effects could be seen in the indicator conflict potential. In contrast to an assumed decrease of conflicts with other human activities, the potential increased with distance from Helgoland.

In the small-scale case (Figure 11.3b), site-specific inter-sectorial effects due to a production increase were assessed for *M. edulis*. The conflict potential, which showed peak values at sites 9 – 15 was low at sites 1 – 8. While the risk of disease spread was not considered, the IMTA potential and the synergy potential stayed mostly low (0). Nevertheless, the latter showed one high score at site 6. Looking at the environmental effects, the habitat vulnerability, the sediment sensitivity and water quality were similar at all sites. Nitrogen reached lowest values at site 1, while Phosphorous showed peak values at site 9, 11, 13 and 15. Moreover, the peak of aquaculture suitability was at site 11. The latter showed again a high value of cumulative pressure which even increased at site 10. In contrast to site 1 – 5, the wave height specific exposure remained low at sites 6 – 15. The economic indicators added value, induced direct impact on production and induced indirect impact on production, NPV and revenue were similar at all sites. The opportunity costs, the profit and the RoFTA showed peak values at site 3 and lowest values at site 10. Finally, comparing those sites from a socio-cultural perspective, site specific contrasts show the best outcome at site 1, based on the distance related indicator tourism and the visual impact, which is lowest at that site.

Figure 11.3a: Spatially explicit performance of inter-sectorial, environmental, economic and socio-cultural indicators for 15 different aquaculture planning scenarios (sites)with *D. labrax*. Shown are, the potential trade-offs in between the AquaSpace tool indicators by comparing data normalised in application of a z-transformation. IMTA = Integrated Multi-Trophic Aquaculture, RoFTA = Return on Fixed Tangible Assets.

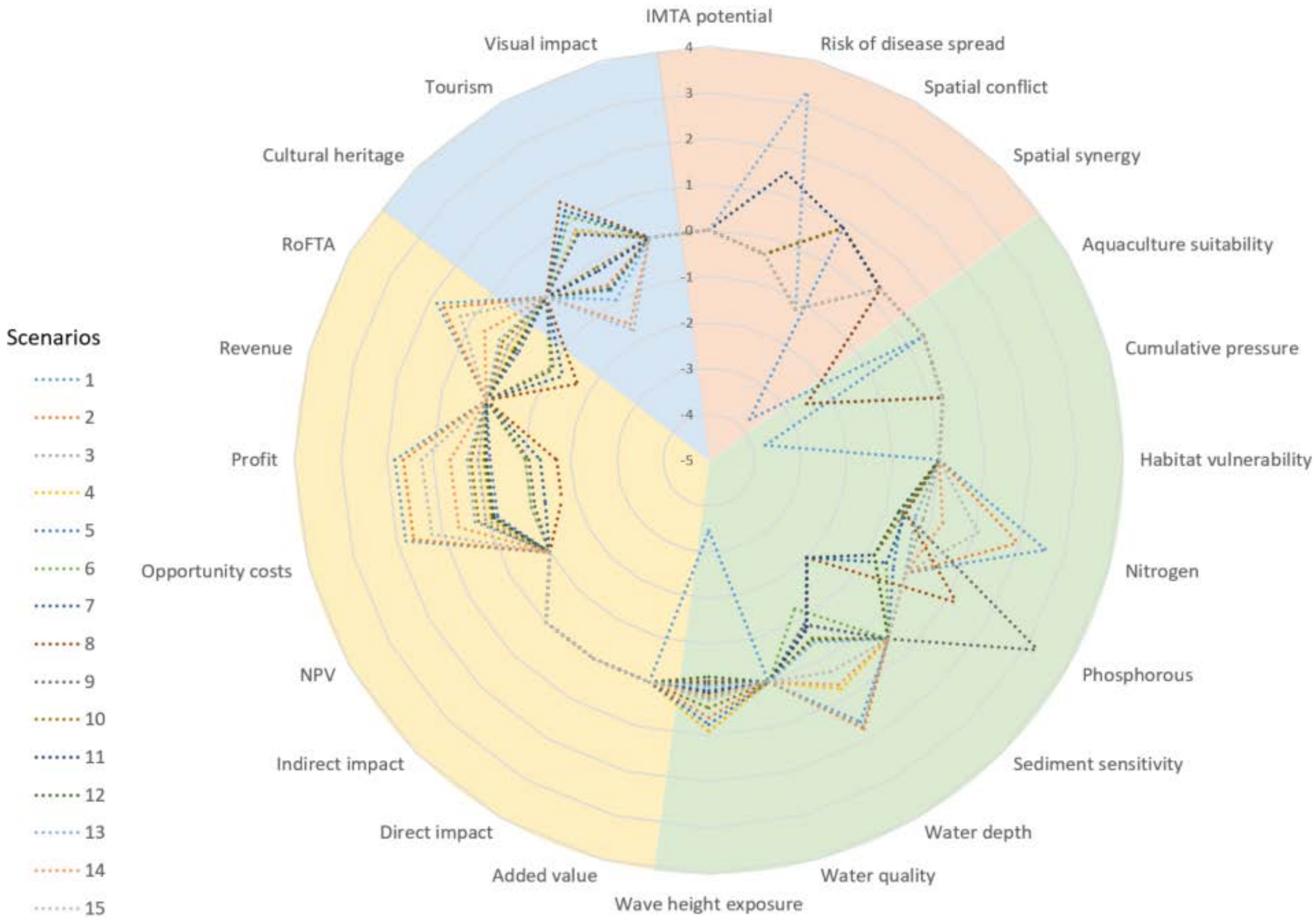
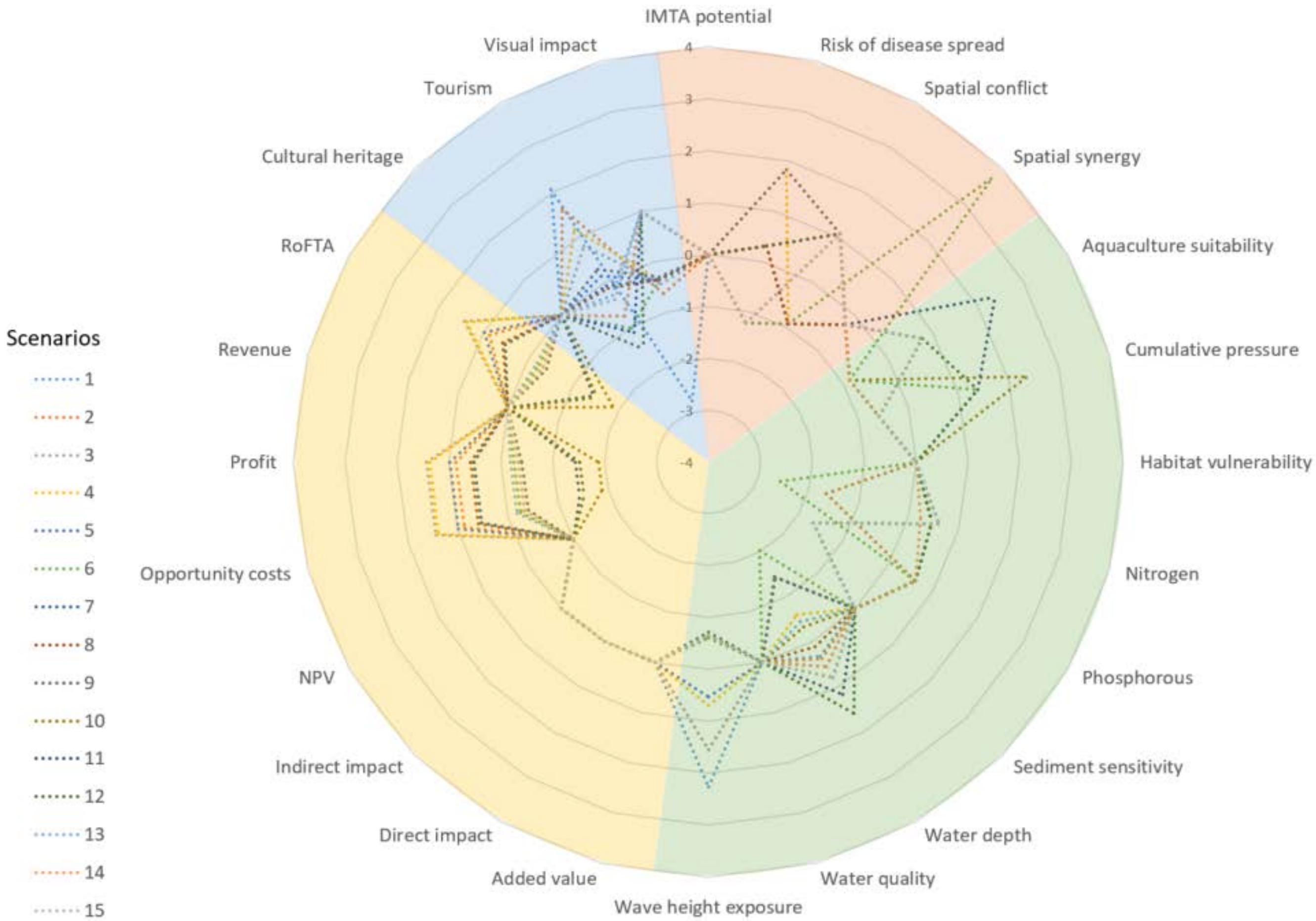


Figure 11.3b: Spatially explicit performance of inter-sectorial, environmental, economic and socio-cultural indicators for 15 different aquaculture planning scenarios (sites) with *M. edulis*. Shown are, the potential trade-offs in between the AquaSpace tool indicators by comparing data normalised in application of a z-transformation. IMTA = Integrated Multi-Trophic Aquaculture, RoFTA = Return on Fixed Tangible Assets.



Considering sites, the highest aquaculture suitability is at site 12. In contrast, spatial synergy with low water depth, wave height specific exposure and visual impact is at site 6. Nevertheless, the highest profit is achieved at site 3. Here, the distance to the selected port (Hörnum, Sylt) did not seem to be the most important factor. Environmental effects were observed to vary in between tested sites, increasing or decreasing constantly. NO_3 decreased from 2.56 to 4.65mol/L while PO_4 decreased from 0.1 to 0.09mol/L. The sediment sensitivity and water quality were the same at all sites. Indicators such as wave height exposure decreased with distance from the port. Similar effects were found for economic values, which decreased with distance due to increasing fuel costs. Considering the effect on the profit, the results varied around €23,359.32. Socio-cultural effects using the indicator tourism were hard to see. All scenarios were tested relatively near to the coastline and the islands, and therefore close to several bathing sites. In contrast, inter-sectorial effects were clear: While conflict potential increased with distance to the port, only one site (at 25 km Euclidian distance) showed high synergy potential.

11.6. Relevance of the case study within Aquaspace

The German EEZ case study scenarios exhibit both, i) areas of potential compatibility between uses at a large scale (German EEZ) and ii) the effects of intensified production in allocated zones at a small scale (German coastal zone).

The outcomes are, on the one hand, a transparent and spatially explicit risk assessment of co-location scenarios which can be provided to the German planning authority to inform the upcoming revision process of MSP, and on the other hand, a comprehensive evaluation of the production increase scenario including all relevant management aspects which can be provided to the responsible authorities. A comprehensive and integrated assessment of such a management option includes the assessment of inter-sectorial, environmental, economic and socio-cultural effects. Based on this, requirements for an implementation in German management processes or decision-making can be defined on a finer scale. Outputs demonstrate the (economic) importance of aquaculture operations to decision makers, community stakeholders and other stakeholders such as NGOs (and other non-profit organisations) that want to ensure that aquaculture operations benefit local communities. The application of the tool informs a systematic process for calculating and comparing opportunities and risks of a proposed aquaculture site in a multi-use context. It allows for determining: if it is a sound investment, seeing how it compares with alternate projects; and spatially representing all opportunities and risks (incl. environmental ones).

11.7. Conclusions and future prospects

The participation of stakeholders led to lively discussions, touching on the multiple factors expected to hamper aquaculture growth in Germany. Most of the needs and objectives were addressed to government and authorisation institutions (e.g. simplify and standardise authorisation procedures or ease regulations). The objectives addressed to science/research have been listed by the German case study team to be solved in application of the AquaSpace tool. Those objectives read as followed i) spatially explicit aquaculture siting to make more informed, evidence-based decisions; ii) integrate indicators of sustainability, iii) support the licensing process, iv) facilitate investments in regional products and v) support modernisation.

The AquaSpace tool outputs comprise detailed reports and graphical outputs which can facilitate planning trade-off discussions, thus allowing key stakeholders (e.g. industry, marine planners, licensing authorities) to make more informed, evidence-based decisions about proposed aquaculture developments and the associated risks and opportunities. In applications of the AquaSpace tool to both *D. labrax* and *M. edulis* cases, spatially explicit information about each scenario was assessed to evaluate consequences and trade-offs from a multi-sector perspective while applying indicators of sustainability. The main outcomes facilitated regional and local production costs. Those are highly expensive offshore and decrease with distance to the port selected. Furthermore, finfish production constitutes a time- and cost-intensive venture.

Unfortunately, stakeholder validation of tool functionality and outputs has not yet happened. For the German case, close collaboration with the main stakeholders suffered from a lack of time and needs to be improved in the future. Expected outcomes are a comprehensive evaluation of the tool functions and the data included.

New functionality in the tool might be implemented by increasing the spatial resolution of economic data. Currently, most economic indicators are driven by 'distance to port' calculations. Furthermore, the link to Web Feature Service (WFS) datasets needs to be integrated. Currently, the tool performance is slowed by time loading the data. Finally, the resolution and the extent of spatially explicit data layers underlying indicators of sustainability need be increased, as those are currently not comprehensive at EU extent (e.g. habitat vulnerability). Once revised and validated, the outcomes of the German case study application of the AquaSpace tool can be provided to the German planning authority to inform the upcoming revision process of the MSP.

A clear outcome of the stakeholder workshops is this: measures or strategies to be adopted to “increase space for aquaculture” at the German scale must allow for a prior consideration of aquaculture in the spatial planning processes. One operational step might be a pooling of responsibilities (accompanied with a training of authority employees), at least related to marine aquaculture. Such a task could be solved by implementing common MSP initiatives across federal borders. In the long run, this would simplify and standardise authorisation procedures (for the federal states and the national state as well as between the federal states) and ease regulations. Another workshop outcome is the strong need to address price competitiveness with imported aquacultural products. This might be addressed by enhancing the traceability of products or allowing upscaling of enterprises/farms to use economies of scale. Further steps should be to support modernisation, to assist newcomers (e.g. concerning marketing issues), and educate consumers (about the sustainability of aquaculture products and prices).

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12. NORWEGIAN COAST, NORWAY

Øivind Strand, Lars Asplin, Øivind Bergh, Ørjan Karlsen

12.1. General characteristics

Aquaculture planning in Norway is regulated by the Building and Planning Act (Anon 2008) which involves a range of sectors, and is ultimately decided at the municipally level. Licenses are regulated by the Aquaculture Act and issued at the regional County Council level (Kvalvik and Robertsen 2017).

The governmental aquaculture policy (Anon 2015), which is the planning process for the allocation of space and aquaculture licenses, and the ongoing process leading to the zoning for production and regulation, are all within the framework of the Norwegian case study. Several elements can be identified from this framework that follow the steps of the MSP process;

- Establish institutional framework;
- Assess baseline and identify issues;
- Establish vision and objectives;
- Produce plan;
- Establish public consultation;
- Implementation;
- Monitoring and review.

This case study represents all licenses for open water cage farming of salmonids along the Western coast of Norway (Figure 12.1). The same coastal area overlaps with migration routes for wild salmon and trout populations, which are considered to be at risk from the environmental impacts of fish farming (Taranger et al. 2015). The risk assessment of Norwegian aquaculture (Taranger et al 2015), is updated annually by the Institute of Marine Research (IMR) (www.imr.no/en), and salmon lice impacts on wild salmonid populations are considered to be the highest risk. The main issue within this case study is the environmental impact from salmon lice spreading from salmonid farms and potentially affecting the survival of wild salmonids.

This case study establishes production zones at the national scale, in order to regulate production levels based on the degree of assessed infestation pressure from salmon lice on wild fish due to open water salmonid farms. The production is regulated using a traffic light indicator system at the zoning level (13 zones) and thereby provides guidance on the total allowed farmed salmon biomass, as well as area allocation and siting of farms. The policy is that salmon lice impacts on wild stocks will regulate the management and allocation of space, and biomass regulation within the production zone as a whole.

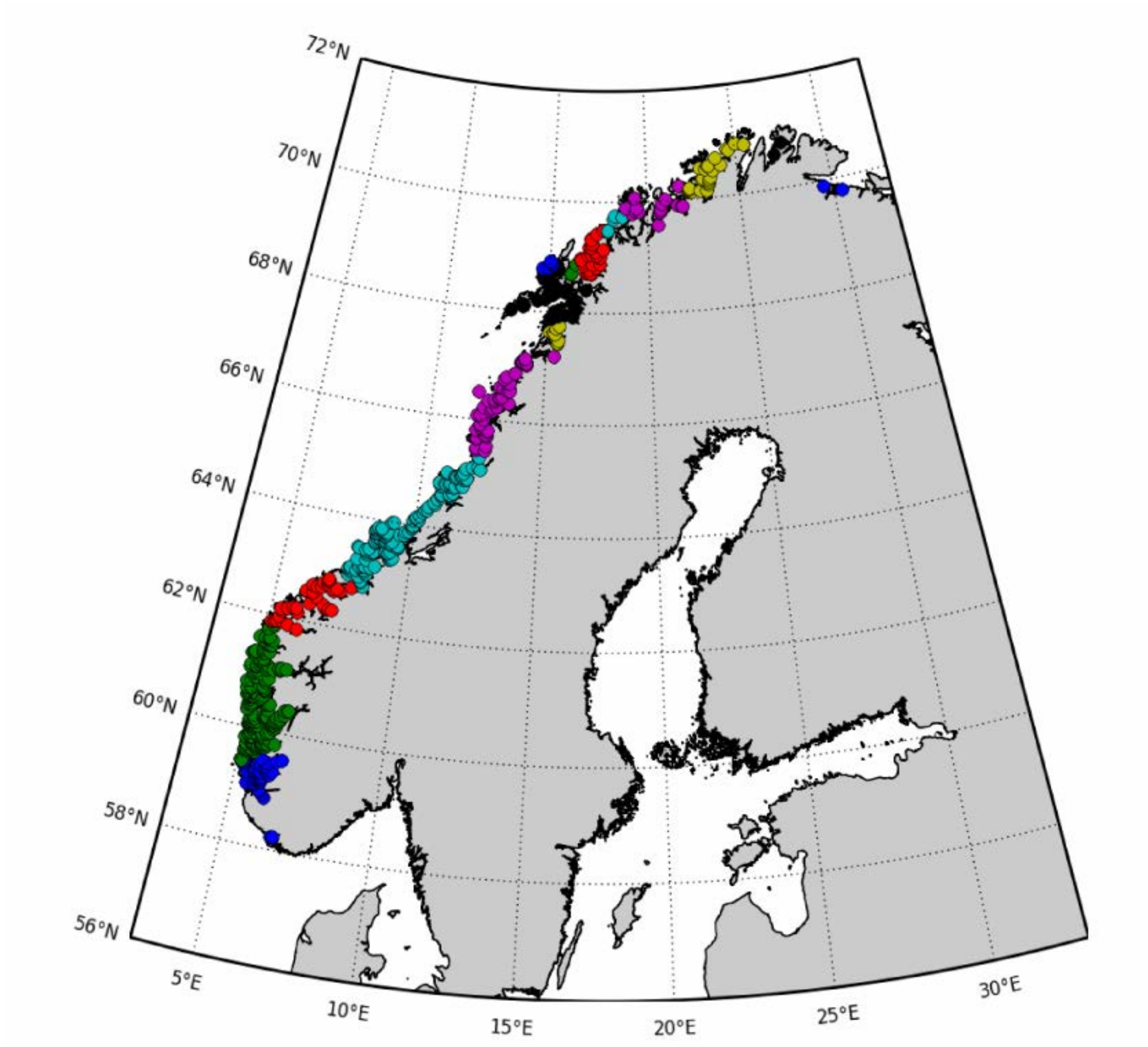
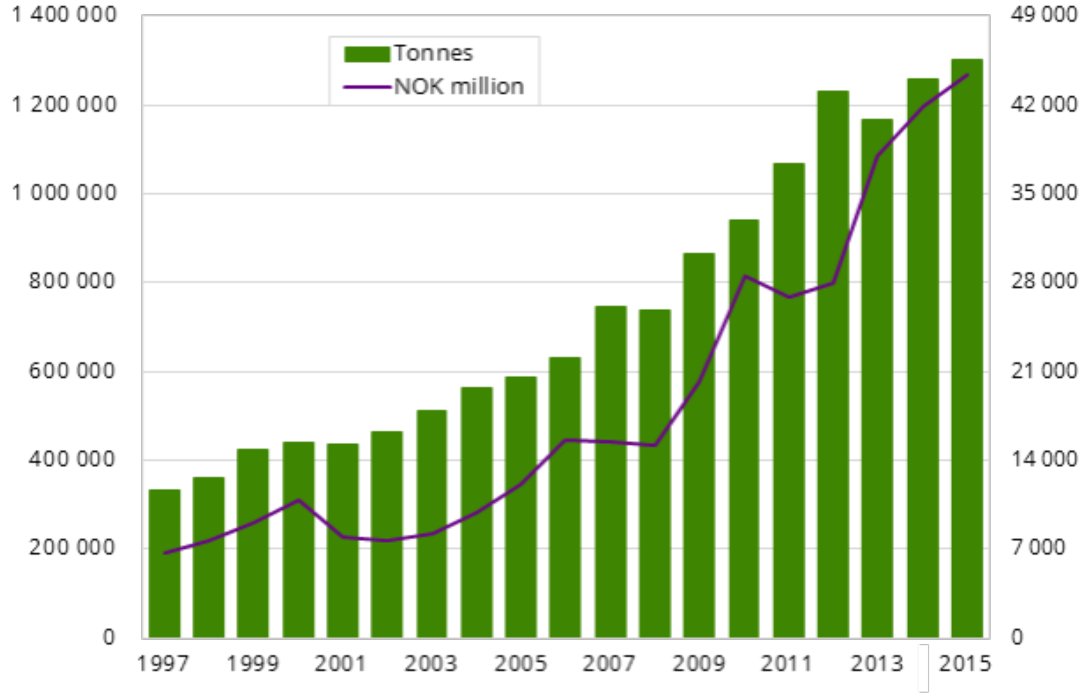


Figure 12.1. Open water cage farming locations for salmonids.

12.1.1. ***Socio-economic context***

In Norway, the farming of Atlantic salmon (*Salmo salar* L.) and rainbow trout (*Oncorhynchus mykiss*) has grown to become one of the country's largest export industries by economic value. In 2015, the first-hand value of Norwegian fish farming came to NOK 47 billion (5 billion Euro), up 6 per cent from 2014 (Figure 12.2). The produced quantity was 1.38 million tonnes, from 1,067 licenses for open water cage culture, employing 4,754 workers (Table 12.1). In addition, the hatcheries and fingerling production employed 1,598 workers. The importance of aquaculture to the Norwegian economy is expected to increase. There are prospects for diversification of the aquaculture industry, with specific interest for the development of seaweed farming and increasing the production of Blue mussel and Atlantic halibut farming. Current production (2015) of mussel is 2,731 tonnes and halibut is 1,243 tonnes (Directorate of Fisheries).



Source: Statistics Norway.

Figure 12.2. Sales of salmon. Quantity and first hand sale.

Table 12.1. Number of licenses running, workers and labour, by type of production and county. Salmon and rainbow trout.

	Total			Production of fish for food			Hatcheries and fingerling production		
	Licences	Persons	Man-hours (1 000)	Licences	Persons	Man-hours (1 000)	Licences	Persons	Man-hours (1 000)
2005	1 143	3 055	4 297	923	2 181	3 158	220	874	1 139
2006	1 136	3 353	4 823	909	2 388	3 579	227	965	1 244
2007	1 157	3 737	5 075	929	2 537	3 627	228	1 200	1 448
2008	1 142	3 919	5 513	922	2 714	4 048	220	1 205	1 465
2009	1 204	4 238	5 734	990	2 930	4 230	214	1 308	1 504
2010	1 207	4 932	6 449	994	3 456	4 791	213	1 476	1 658
2011	1 225	5 316	6 867	1 016	3 784	5 075	209	1 532	1 792
2012	1 206	5 426	7 194	1 006	3 969	5 364	200	1 457	1 830
2013	1 208	5 565	7 863	1 018	4 177	6 028	190	1 388	1 835
2014	1 204	5 759	8 141	1 015	4 298	6 239	189	1 461	1 902
2015	1 256	6 352	8 744	1 067	4 754	6 743	189	1 598	2 001
2015									
Rogaland	88	456	554	74	310	410	14	146	144
Hordaland	224	1 518	1 774	175	1 105	1 339	49	413	435
Sogn og Fjordane	108	506	631	92	378	509	16	128	122
Møre og Romsdal	156	688	998	126	441	686	30	247	312
Sør-Trøndelag	122	635	1 056	105	475	806	17	160	250
Nord-Trøndelag	99	402	638	84	286	454	15	116	184
Nordland	219	987	1 428	189	735	1 083	30	252	345
Troms - Romsa	112	675	930	103	608	824	9	67	106
Finnmark - Finnmárku	97	405	643	93	:	:	4	:	:
Other Counties	31	80	92	26	:	:	5	:	:

StatBank source table 08967
StatBank source table 07633

Other specific issues of relevance are:

(i) policy-management issues: The Norwegian process is relevant to the Blue Growth policy, advocating for the sustainable expansion of aquaculture, improved environmental control and management.

Although Norway is not included in the Marine Strategy Framework Directive (MSFD) (http://europalov.no/politikkdokument/eos-komiteens-statusrapport-til-eos-radet-mai-2017/id-10074), the policy is still relevant to that directive. Many of the goals of the MSFD are already implemented.

(ii) aquaculture-environment issues: Salmon lice is a growing concern and the major environmental issue that is regulating spatial planning. Other environmental issues of relevance for spatial planning are, i) genetic introgression of escaped farmed salmon into wild populations, (ii) potential disease transfer from farmed salmon to wild salmonid populations, and (iv) local and regional impacts of organic load from salmon farms.

iii) aquaculture-other sector issues: The environmental issues of salmon lice, impact, motivate and drive research and industry to develop new technologies that can mitigate the salmon lice problem. Examples of new technologies are; cage (containment), land based (RAS) and offshore siting, affecting other sectoral issues land based and offshore.

(iv) economic-market issues: As above (iii), the imposed actions on mitigation and development of new technologies affects the economic performance of the industry. Regulated production because of the zoning has already had effects on the market.

12.2. Spatial planning and management issues

Farming of Atlantic salmon (*Salmo salar* L.) and rainbow trout (*Oncorhynchus mykiss*) is mainly carried out in open water net pens suspended from ring floaters which are 50 meter in diameter. The total area covered by the farming industry in 2011 was about 40 km^2 (Gullestad et al. 2011), occupying 0.05% of the Norwegian coastal zone (75,000 km^2).

A major sustainability issue in salmon aquaculture is farmed fish acting as hosts for the natural parasite salmon louse (Taranger et al. 2015). With more than 500 times farmed salmon compared to wild salmonid fish, salmon lice have become a potential problem for the latter. Sustainable growth of aquaculture, which is an expressed goal by the Norwegian authorities (Anon. 2015), is limited by the potential negative influence on the environment and natural ecosystem affecting spatial issues in management, such as site selection and zoning.

Environmental goals set by the governmental “Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry” (2009) stated a location structure and zoning of the industry was needed in order to reduce impacts on the environment and the risk of disease transfer. This was followed by an expert committee report in 2011, on new measures to allocate areas for sustainable aquaculture development (Gullestad et al. 2011), including the suggestion to establish zones and production areas where farming activity, production levels and the allocation of areas should be regulated based on environmental impact measures. The plan for implementation was provided as part of a White paper in 2015 on “Predictable and Environmental Sustainable Growth of the Aquaculture Industry” (Anon 2015). IMR was requested to provide scientific advice for decisions on positioning borders for the zoning.

The expert committee report in 2011 (Gullestad et al. 2011) also reviewed competition for space with other sectors in the coastal zone in relation to aquaculture development. A well-managed aquaculture industry including scientifically funded and optimal stakeholder involvement mechanisms on issues of area allocation is a key measure to secure space for aquaculture. A general recommendation was to maintain and develop the cooperation mechanisms between industry, management, governance and research.

12.3. Stakeholder engagement and participation

The advices provided by IMR on the positioning of borders for zoning were key topics at a series of stakeholder meetings with representatives from research, management and industry. The following represents meetings that were hosted by IMR and involved internal discussions, dialogue with industry and specific research and methodology issues.

- Internal meeting at IMR (9 participants) on the coordination of spatial planning tools in line with the objectives of AquaSpace. 8th - 19th of November 2015.
- A meeting between IMR, the Norwegian Food Safety Authority and industry representatives was held on the 25th of November 2015 (Table 12.2).

  Related meetings on the zoning issue leading up to the meeting was hosted by the Norwegian Seafood Federation on the 16th of October and 10th of November 2015.

  As a follow up from this meeting, IMR representatives participated in the following meetings with unregistered attendance:

  3-4 May 2016: Follow up meeting with land- and river owners in Hardanger

  25 August 2016: General director Sissel Rogne (IMR) met with the Norwegian Seafood Federation leader group, Trondheim

  9 September 2016: Meeting with NGO «Norwegian Salmon rivers»

  17 November 2016: Meeting with Norwegian Seafood Federation – Region west

  17 February 2017: Meeting with Norwegian Seafood Federation

  16 March 2017: Meeting with Salmar Group on the Traffic light system

  3 May 2017: Meeting with “Sammarbeidsrådet for Sunnhordaland (politicians and managers at municipal level)

Table 12.2. Participants at the meeting between IMR, the Norwegian Food Safety Authority and industry representatives on the 25th of November.

	Dialogue meeting Bergen 25 nov 2915				
		Industry	Government	Research	NGO
1.	Rune Jensen, Salmon Camera				x
2.	Olav Moberg, Fiskeridir.		x		
3.	Bjarte Haugland + 14 stk fra Austevoll vg		x		
4.	Eli Skoglund, Faglærer Strand vgs.		x		
5.	Kristine Gramstad, Marine Harvest	x			
6.	Ole Jacob Myre, As	x			
7.	Ole Torrissen, HI			x	
8.	Sigurd Bjørgo, Sør Trøndelag Fylkesk.		x		
9.	Vibeke Lokøy,	x			
10.	Joar Grindheim, journalist				x
11.	Marit Stormoen, Marine Harvest	x			
12.	Kjetil Heggen, Lerøy	x			
13.	Tore Hovland, MSD Animals Health	x			
14.	Alf M. Sollund, Kystverket		x		
15.	Bjørn Barlaup, Uni Research			x	
16.	Asle Haukaas, VI			x	
17.	Jan Arve Gjøvik, NSL	x			
18.	Marius Kambestad, Rådgivende biol.			x	
19.	Friede Andersen, Mattilsynet		x		
20.	Inger Eitun, Mattilsynet		x		
21.	Erik Sterud, Norske lakseelver				x
22.	Linn T. Skår Hosteland, Norsk fiskeoppdrett AS				x
23.	Tom Kjøde, CMR			x	
24.	Geir M. Knutsen, Bremnes Seashore	x			
25.	Anne Sandvik, HI			x	
26.	Hulda Bysheim, Mattilsynet		x		
27.	Harald Berglihn, DN		x		
1.	Ole Fredrik Skulstad, HI			x	
2.	Atle Kambestad, Miljødir.		x		
3.	Knut Wiik Volset		x		
4.	Frode Berge-Haveland, Resientanalyse				x
5.	Rolv Sigurdsen, Naturvernforbundet				x
6.	Paul Gustav Nyland, Kystforvaltningen		x		
7.	Eivind Nævdal-Bolstad, Marine Harvest	x			
8.	Trond Wahl, Hordaland Fylkesk.		x		
9.	Julie Døvle Johansen, HI			x	
10.	Gordon Ritchie				x
11.	Hans Olav Djupvik				x
12.	Hans Kleivdal, Uni Research Miljø			x	
13.	Kenneth Bruvik, NJFF Hordaland				x
14.	Hilde Toften, Nofima			x	
15.	Frank Gaardsted, Akvaplan Niva			x	
16.	Bjarte Lygren, MSD Animal Health				x
17.	Frode Reppe, NSL	x			
18.	Jens Chr. Holm, Fiskeridir.			x	
19.	Else Marie Djupevåg, Fiskeridir.			x	
20.	Karianne Thorbjørnsen, Fiskeridir.			x	
21.	Einar Brobakke, Fiskeridir.			x	
22.	Sara A. Straumsnes, UiB			x	
23.	Kjersti Sandvik, FiskeribladetFiskaren				x
24.	Jorunn Jarp, Veterinærinst.			x	
25.	Erik Sterud, Norske lakseelver				x
26.	Alv Arne Lyse, Norges Jeger- og Fiskerforbund				x
	TOTAL	10	13	21	13

- AquaSpace co-hosted an international meeting on salmon lice dispersion modelling from the 20th – 22nd of April 2016, at Finse, Norway.

Participants

Jon Grant	Canada
Ramon Filgueira	Canada
Jeff Barrell	Canada
Daneille Burnett	Canada
Crawford Revie	Canada
Sandy Murray	Scotland
Thom Adams	Scotland
Nabeil Salama	Scotland
Lars Asplin	Norway
Anne D. Sandvik	Norway
Ørjan Karlsen	Norway
Øivind Strand	Norway
Øivind Bergh	Norway
Ingrid A. Johnsen	Norway
Francisca Samsing	Norway
Tore Strohmeier	Norway

Feedback from the industry is characterised by strong involvement ranging from support to opposition and confrontations affecting the implementation process. This opposition also links to opinions from public, research communities, management and politicians. The industry feedback can be regarded as:

- The large companies operating in several zones are supporting the production regulations;
- The small companies operating in one-two zones are more affected and some of them show strong resistance to the suggested zoning.

In the scientific community, the debate focusses on the methodology and use of models; opposition suggests that empirical salmon lice incident models are superior to the salmon lice dispersion and connectivity approach. In the management community, the concern is about the feasibility to manage the traffic-light system for production regulation.

As an example, the industry NGO " The Norwegian Seafood Association", representing a range of mainly smaller aquaculture industries had an open conflict with the Institute of Marine Research during the winter 2017 and the Minister of Fisheries needed to intervene in order to mitigate the conflict. Their view included targeted attacks against specific researchers, using the press and social media.

Another industry NGO “The Federation of Norwegian Industries”, which has Norway’s, and the world’s largest aquaculture company as a member, has taken a different approach, and launched a “Roadmap for the Aquaculture Industry” Norsk Industri (2017). As a summary, the organisation acknowledges environmental problems in the Norwegian aquaculture industry that need to be solved and managed before further growth can be sustainable. In particular, it refers to salmon lice and escapees, but it also addresses other aspects, such as disease proliferation, food availability and organic impact. Their strategy includes several development lines of new innovative farm designs as well as multitrophic integrated aquaculture.

12.4. Tools used in the case study

The tool used in the case study to determine the positions of the borders for zoning, is based on a framework of models. A hydrodynamic model, operational for the entire coastal zone of Norway (Norkyst800; Albretsen et al. 2011), is coupled with a salmon lice dispersion model and used in connectivity analysis based on existing locations of aquaculture farms (Ådlandsvik, 2015). The source of salmon lice information is from weekly data on the estimated abundance at each farming site and the output is the abundance of infected salmon lice along the coast. The primary goal is to give a geographical overview of infestation pressure from salmon lice on wild fish, as well as assessing the siting of farms at local and regional spatial scales and on a larger national scale for the implementation of production zoning.

The connectivity analysis is based on a matrix of influence giving an estimate of the potential sea lice infection between a pair of existing farms along the entire coast, separated into two “dimensions”, thus being a source or target for pressure from infections. This analysis was used to establish the positioning of the “fire brake” areas located where the method predicts the least connectivity between farming areas. This creates the basis for suggestions on where to position “fire brakes” in order to make up for the requested 11-13 zones along the coast, or alternatives (Ådlandsvik 2015).

In 2017, 13 separate production zones (Figure 12.3) were implemented by the Ministry of Trade, Industry and Fisheries, following a public hearing process. These areas are responsible for the sustainability of the natural ecosystem. For salmon lice, the sustainability index is based on the estimated mortality on wild salmonid. If the mortality due to salmon lice exceeds 30%, the aquaculture biomass must decrease by 6%. If the mortality is less than 10%, the industry can increase by 6% and in between there will be a status quo. For other impacts from aquaculture on the environment, such as, organic waste, sustainability indexes will be determined, but for now it is salmon lice that have the largest negative effect on the ecosystem.

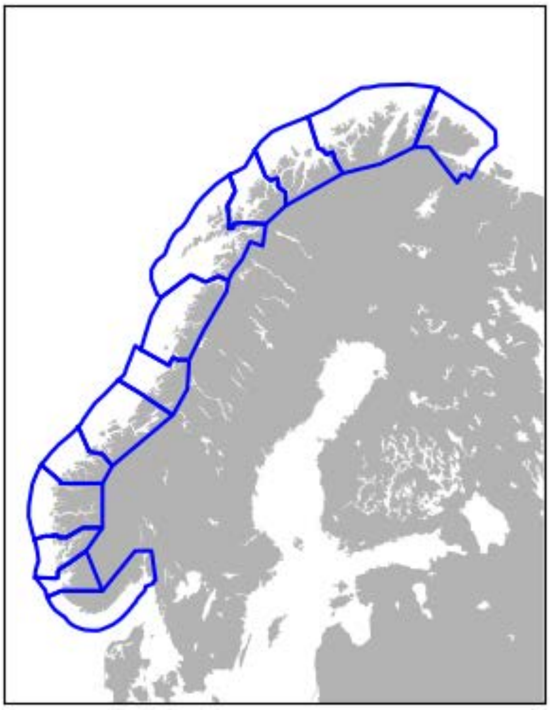


Figure 12.3. The 13 production zones used in salmon aquaculture in Norway from 2017.

12.4.1. ***WEB based decision support tools***

The salmon lice dispersion model also provides weekly results for information on salmon lice copepodite concentrations (infection pressure). This information is presented on the IMR web portal "Infection pressure – Salmon lice" (Figure 12.4) http://www.imr.no/forskningsdata/smittepress_lakselus/.

The web portal Barentswatch (Figure 12.5) will present similar results from the same IMR source, and also includes information on other fish health issues (pancreatic disease (PD) and infectious salmon anaemia (ISA)) https://www.barentswatch.no/en/fishhealth/ .

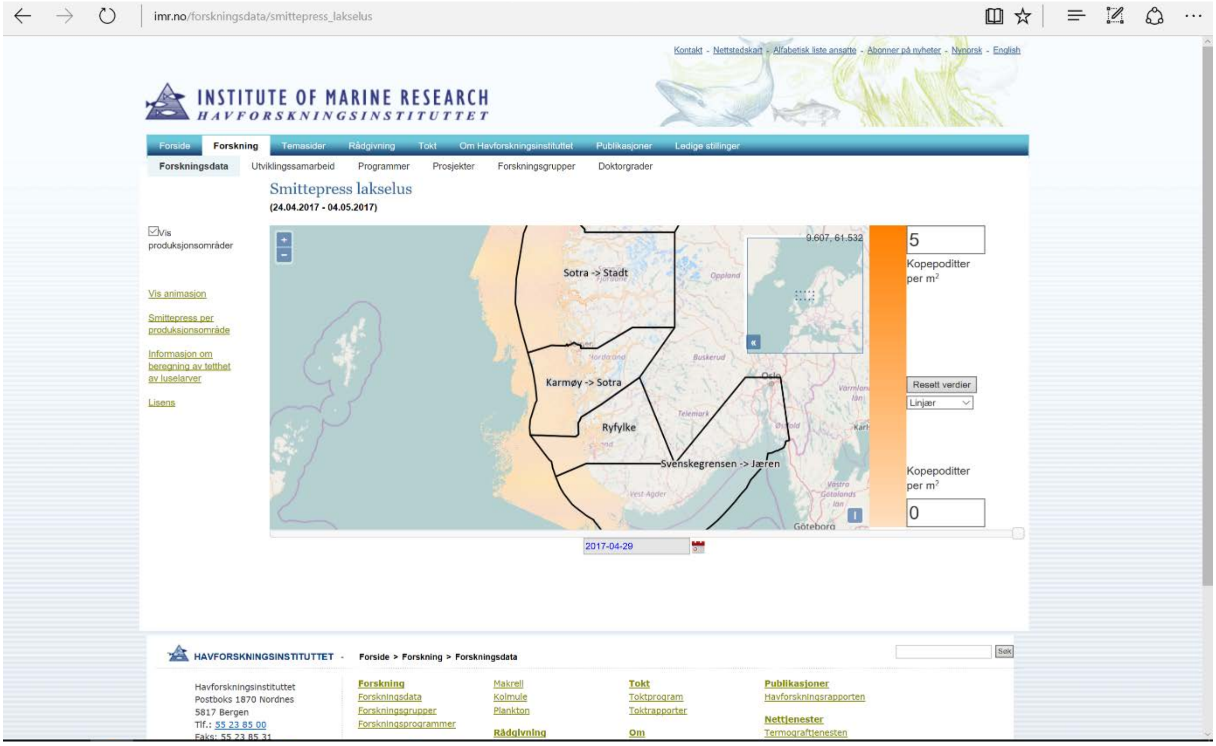


Figure 12.4. Screenshot of the IMR web portal "Infection pressure - Salmon lice"

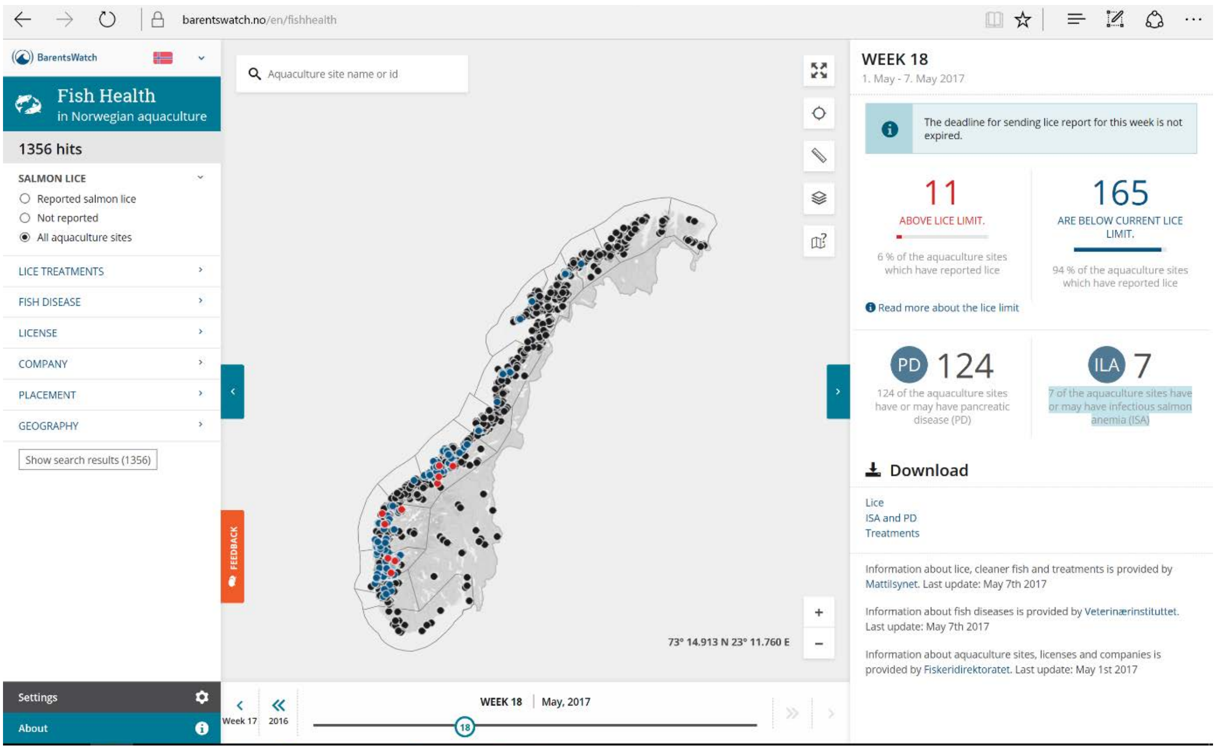


Figure 12.5. Screenshot of the Barents watch web portal on Fish Health including salmon lice information

An early version of the salmon lice dispersion model was tested for application in the web based tool AkvaVis, restricted to the area of Hardangerfjord in western Norway http://akvavis.no/akvavis2 . The AkvaVis concept has been tested in Aquaspace as a novel tool designed for the purpose of spatial planning in aquaculture (see case studies - China, Normandy and Carlingford)

The Directorate of Fisheries (DoF) hosts the web based GIS/database tool “map service” with an open public interface and a closed interface for management purposes. The goal of this tool relates to spatial planning and management issues (Directorate of Fisheries), food security issues (Norwegian Food Safety Authority) and licensing issues (The county council sector). DoF was subcontracted to AquaSpace by IMR, in order to provide input and evaluations as a regulator/planner stakeholder. Initiatives are also being taken to integrate tools at IMR and DoF.

12.5. Case study results

13 production zones (Figure 12.3), were established at national scale to regulate production levels based on the degree of assessed infestation pressure of salmon lice on wild fish from open water salmonid farms. The production is regulated using a traffic light indicator system which provides guidance on decisions for the total allowed farmed salmon biomass in the zones, as well as the allocation of areas and sites for production. The policy is that salmon lice impacts on wild stocks, will regulate the management and allocation of space.

The "traffic light system" which regulates the zone-wise aquaculture growth, was implemented in spring 2017, although it is still in a pre-operational phase. It is based on a sustainability index for the relationship between wild salmonid fish mortality versus salmon lice abundance, this is the first measure. The authorities have established an expert group consisting of 10 experts to assess this relationship. The experts are represented by the Institute of Marine Research, the Sea Lice Research Centre, the Norwegian institute of Nature Research, The Norwegian Veterinary Institute, Uni Research Environment, SINTEF (R&D institute) and Rådgivende biologer AS (environmental consultancy firm). The expert group has provided advice for the "traffic light colours" (red-yellow-green) for each of the 13 production zones based on various information on wild fish versus salmon lice carrying capacity measures (including model results and observations of lice on wild fish), the first assessment took place in March 2017. The system regulates production within each zone based on; green = growth, yellow = no change and red = reduction in production. This result is based on the assessed salmon lice pressure on wild salmonids derived from the farming activity.

A steering group consisting of representatives from the Institute of Marine Research, the Norwegian institute of Nature Research and The Norwegian Veterinary Institute is mandated to conclude and hand the official advice to the Ministry of Trade, Industry and Fisheries who will make a political judgement and produce a final regulation. This procedure will be repeated in early fall 2017 with data from spring 2017 included. The regulation will not be effective until 2019, since this first issue is still in a test phase. Some of the procedures have yet to be evaluated and the operational system may be modified. The knowledge base behind the assessment of wild fish mortality is likely to be improved, and improvements will be implemented instantly.

The current process on implementing the traffic light system supports the recommendation to maintain and develop the cooperation mechanisms between industry, management, governance and research. There is a relatively strong research and policy component in this process.

As part of the policy to mitigate the environmental issues with salmon lice, the government have launched “research and development” licenses to promote the development of methodologies and technologies to solve specific questions. Development of new technologies affects economy issues by production costs and others. Regulated production affects market issues.

It is concluded that the main threat to the case study process is the industry’s resistance to accept the zoning principle, scientific disagreement on methodology and models and management concerns about the feasibility to manage the traffic light system for production regulation.

12.6. Relevance of the case study within Aquaspace

This case study represents a full national scale spatial planning process to regulate production based on the environmental impact/pressure of salmon lice on wild salmonid stocks. It is designed and currently implemented for an aquaculture industry of high socio-economic value along most of the Norwegian coast, a case which is unique within the AquaSpace project. The policy and implemented planning process managing and supporting this industry, and the specific process leading to the zoning and production regulation system of the case study comply with relevant EU frameworks and involve several elements of the steps of the Ecosystem Approach to Aquaculture (EAA) process.

The current implementation of tools regulates the production of the entire salmonid cage farming industry. It involves a range of enterprises from local farmers operating in only one zone to large enterprises operating along the entire coast and relying on production from many of the zones.

The salmon industry is regulated using a traffic light indicator system which provides guidance on decisions to allocate areas and sites for production. The policy is that the impacts of salmon lice on wild stocks will regulate the management and allocation of space.

12.7. Conclusions and future prospects

This case study represents an industry of major socio-economic importance on the local, regional and national level. Norway is the world’s largest producer of marine finfish. The fisheries and aquaculture sector is Norway’s second largest export industry; thus, this case study represents a highly developed and industrialised aquaculture industry within the Aquaspace project.

Establishing zones and production management systems using the “traffic light” categories (red-yellow-green), is highly debated among stakeholders even if there is a thorough process leading up to the implementation. The positioning of borders which make the zones are based on a strong research component using advances in hydrodynamic modelling, dispersion modelling and connectivity analysis. It is anticipated that there will be relatively low transport of salmon lice larvae as well as other pathogens between zones. The “traffic light” system which regulates production within each zone is based on a strong policy process (governmental White paper) which has well-defined sustainability goals and measures. The stakeholders are participating willingly. They are not given any other option, due to strict governmental regulations of the industry. However, there are large differences among the views expressed by the stakeholders.

The zoning efforts are supported by the large companies, but strongly opposed to by smaller companies. In general, the efforts are supported by environmental NGOs, who are aiming to reduce the environmental footprint of the industry.

As this case represents a highly developed industry, most of the available space is in use. It is not regarded as politically acceptable to reduce the demands regarding sustainability, and the measures of the environmental footprint, as both the previous and current government have supported these measures. Thus, there are essentially two possible pathways for the growth of the Norwegian aquaculture industry.

- Expansion into unused areas;
- Reduced the environmental footprint of present production, allowing higher biomass within existing locations and zones.

Although the present functionality of the management system (the Traffic light) is a collective biomass regulation for all aquaculture farms within the zone, it is an opening for future development towards individual farm lice quotas. This means that when it is possible to identify the pressure that lice from individual farms have on the carrying capacity of the wild fish, the regulation can be pin pointed to those farms that contribute the most. With reliable dispersion models for salmon lice release from individual salmon farms, it will be possible to regulate on local farm scale. This can be done by giving each farm a maximum allowed release of lice as requirement for keeping or increasing production. This will probably require the improvement of the system that is currently quantifying the release of lice from a farm (counts on up to 20 salmon per week). Such individual farm lice quotas will change the spatial production planning from national and regional scale to local scale.

12.8. References

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13. NOVA SCOTIA BAYS, CANADA

Jon Grant

13.1. General characteristics

13.1.1. A description of the geographical and biological context

A single salmon farm (14 pens) is situated off Coffin Island, near Liverpool, Nova Scotia Canada (44.037°N, 64.629°W) (Figure 13.1). Liverpool Bay is an open system with inner depths of about 25m. The Mersey River flows into the bay past the town of Liverpool (population 2700), but the rest of the shoreline is sparsely populated and includes rocky headlands. There are few previous studies of the bay.

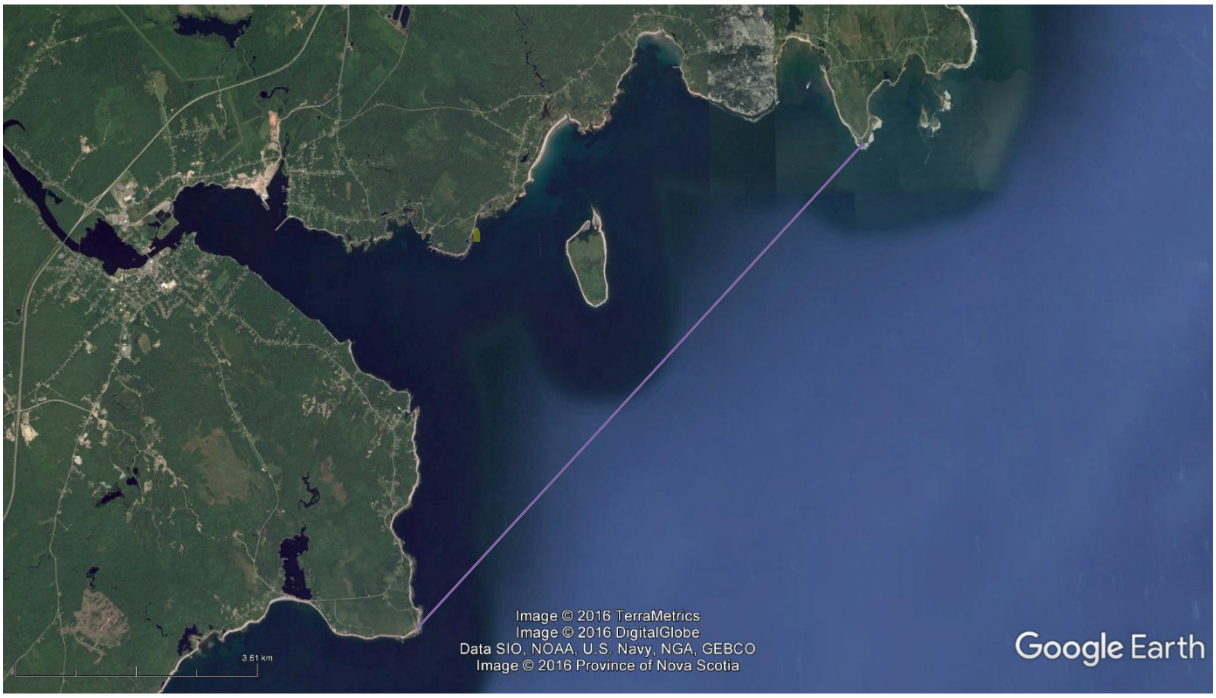


Figure 13.16. Liverpool case study site. Yellow line (10km length) is outer model limit. Fish farm in yellow.

13.1.2. Socio Economic context

Rural employment is always problematic in coastal communities of eastern Canada. Liverpool once had a thriving pulp and paper industry that has since closed. The lobster fishery is very healthy in southwest Nova Scotia, although statistics specific to Liverpool were not available.

13.1.3. *Spatial planning and management issues*

Aquaculture development is controversial on both coasts of Canada. Although there is a vast amount of physical space in unpopulated coastal areas, there is fierce public opposition based on concerns about wild salmon, waste impacts, and disease. Federal and provincial agencies take these concerns seriously and attempt to address them in the regulations. In Nova Scotia the same concerns apply, but their relative significance is variable. In our case study area of Liverpool Bay, we attempt to anticipate potential sources of conflict of aquaculture with other resources, as well as enabling planning capability that will assist fish farmers. This is important in light of intended development of two more fish farm sites in the bay. We have chosen spatial overlap with lobster fishing, and disease risk as the two relevant foci.

Lobster is the most valuable eastern Canadian fishery and stocks seem to be continuously increasing in the southwest NS. Lobster fishers have two sources of conflict with fish farming. First is the notion that farm sites occupy trapping grounds and reduce their fishing options. Second is the concern that therapeutants used to treat cages could harm various stages of the lobster life cycle. At present, no medicinal treatments are used in NS.

Although our primary focus of the research was Liverpool Bay, we also conducted studies in the adjacent Shelburne Bay. This system had historical problems with persistent organic loading effects from fallowed fish farms, and our emphasis became benthic impacts and sulphur cycling. We pursued fewer planning studies there because plans for expansion of farm sites in Shelburne were longer term, and planning exercises would have been less productive at this stage.

Two major issues exist in Liverpool: (1) Conflicts between aquaculture and lobster fisheries and (2) potential for disease risk when two more farms are established. Since there is no disease at present, this planning is pre-emptive.

13.1.4. *Which aquaculture species, types and systems exist in the area*

There is a single salmon farm consisting of 14 100m cages, with an annual production of 2000 tonnes. The salmon farming industry is under moratorium in Nova Scotia but 2 more farm sites are eventually planned for the bay. Salmon farming in NS is conducted by Cooke Aquaculture, and they are a close partner with our laboratory and a major sponsor of our research in aquaculture sustainability.

13.2. Stakeholder engagement and participation

Public seminar with entire regional invitation (50 people) held in Liverpool 10 March 2015. Meeting with Community Liaison Committee (8 people) in Shelburne (Cooke office) 22 June 2015. Atlantic Coastal Zone Information Steering Committee Presentation: 'The importance of spatial perspective in aquaculture management", 16 September 2015 in Halifax.

Canada-Norway-Scotland Workshop on sea lice modelling, 20-22 April 2016, Finse, Norway. AquaSpace participants and others discussed spatial modelling of sea lice epidemiology.

Participation:

Jon Grant	Canada
Ramon Filgueira	Canada
Jeff Barrell	Canada
Daneille Burnett	Canada
Crawford Revie	Canada
Sandy Murray	Scotland
Thom Adams	Scotland
Nabeil Salama	Scotland
Lars Asplin	Norway
Anne D. Sandvik	Norway
Ørjan Karlsen	Norway
Øivind Strand	Norway
Francisca Samsing	Norway
Tore Strohmeier	Norway

6-12-2016/ /Provincial R&D meeting with presentation of MSP projects. & December 2016 at Dalhousie, Halifax. Seafloor mapping. Meeting with lobster fisherman. In Liverpool September 2016.

13.2.1. *List of stakeholders, descriptions of their background (industry/management/other)*

The stakeholders include Cooke Aquaculture, the province of Nova Scotia and the region of Queens. In order to facilitate community relations, Cooke has created a Community Liaison Committee (CLC), a structure they have used successfully in other locations. However, due to the moratorium on site development, the CLC has not met.

The Nova Scotia Department of Fisheries and Aquaculture recently underwent a two-year review of aquaculture leasing and licensing, resulting in new legislation. Licensing for new salmon sites has still not occurred. The implication is that the new salmon farms we were anticipating for Liverpool Bay have not been sited. Nonetheless, we are able to undertake continued planning with Cooke regarding intended siting.

Aquaculture Stewardship Council (ASC) is involved as a stakeholder through Cooke's certification, although not engaged by the Case Study (http://www.asc-aqua.org/upload/2_20160804_%20Kelly%20Cove%20Salm_Liverpool%20Farm_DRAFT.pdf)

13.3. Tools used in the case study

GIS - ArcGIS is used, and we have discussed being able to use the Aquaspace tool in cooperation with Thunen, although not yet implemented.

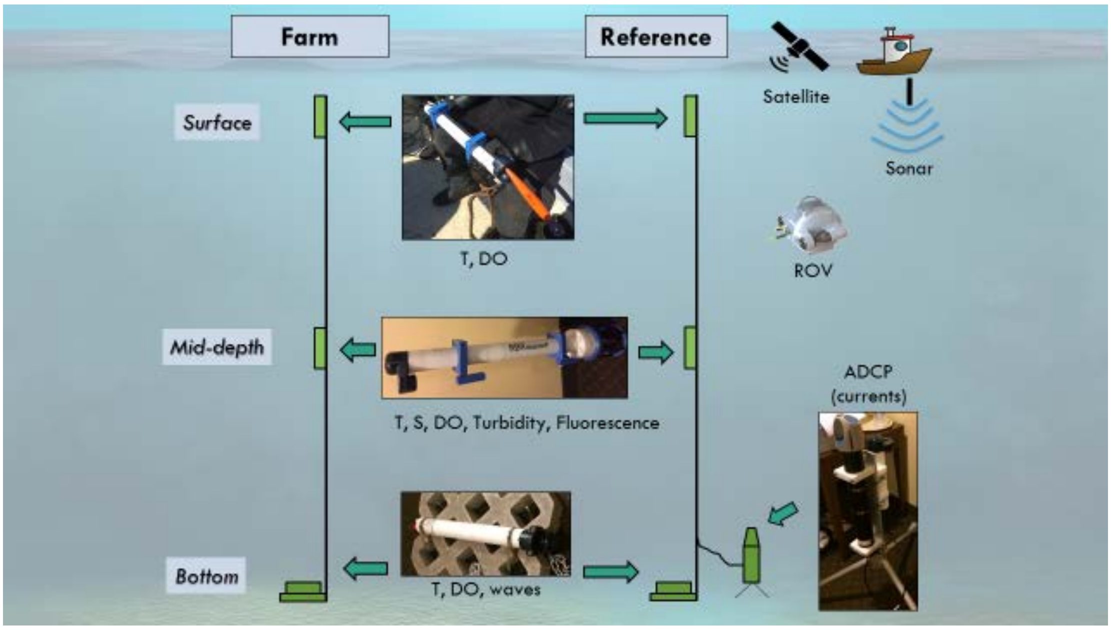


Figure 13.17. Oceanographic moorings deployed in Liverpool Bay case study

Moorings **-** We maintain oceanographic moorings near the fish farm at Coffin Island which includes an acoustic Doppler profiling current meter, CTD, and sensors for chlorophyll, turbidity and oxygen (Figure 13.2).

13.4. Case study results

13.4.1. *Hydrodynamic modelling*

Although we have developed a 2D tidal model for many bays in eastern Canada, a comprehensive 3D model program has been pursued by Fisheries and Ocean Canada (DFO). Liverpool is on the list of targeted sites, but is in the early stages. By example, we show the finite element grid for the adjacent system, Shelburne Harbour (Figure 13.3).

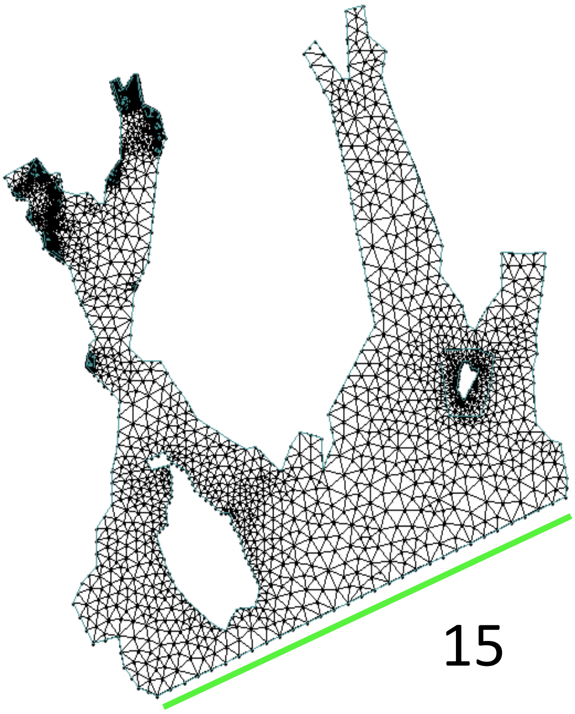
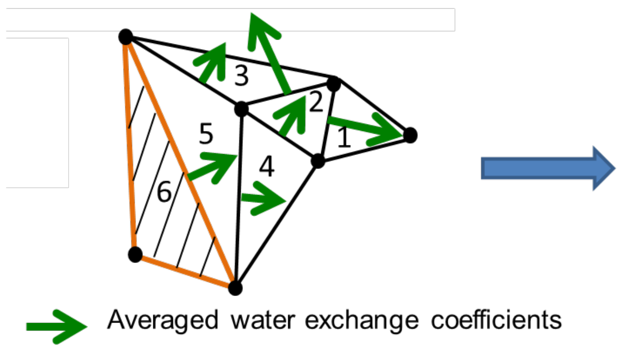


Figure 13.3. Hydrodynamic model grid used for Shelburne Bay, southwest Nova Scotia. This bay is shown for illustrative purposes. Although it is not the case study site, it is near Liverpool, has salmon farming, and there are parallel modelling efforts

13.4.2. ***Disease risk***

Although our case study emphasises habitat mapping and separation of aquaculture from fisheries, we recognise that disease is the basis of zonal management as initiated by the Global Aquaculture Alliance and other parties. As indicated in the description of the Ocean Frontier Institute (OFI) programme below and other initiatives, connectivity derivation is incorporated into our hydrodynamic models of Liverpool (Fifure 13.4).



Connectivity of the system

To element #	From element # 1	2	3	4	5	...
1		0.234				
2				0.234		
3		0.562			0.245	
4					0.145	
5						
...						

Figure 118.4. Connectivity calculations in hydrodynamic models

13.4.3. ***Acoustic bottom mapping***

We undertook acoustic habitat mapping in Liverpool and Shelburne for the purpose of defining lobster habitat (Figure 13.4). The final phase of habitat mapping in Liverpool is taking place in November 2016. Video ground-truthing will also be repeated. Maps will be categorised (sand/mud, gravel/cobble, seaweeds, eelgrass, hard bottom). An example of the type of map created is shown for Shelburne where this work has been completed.

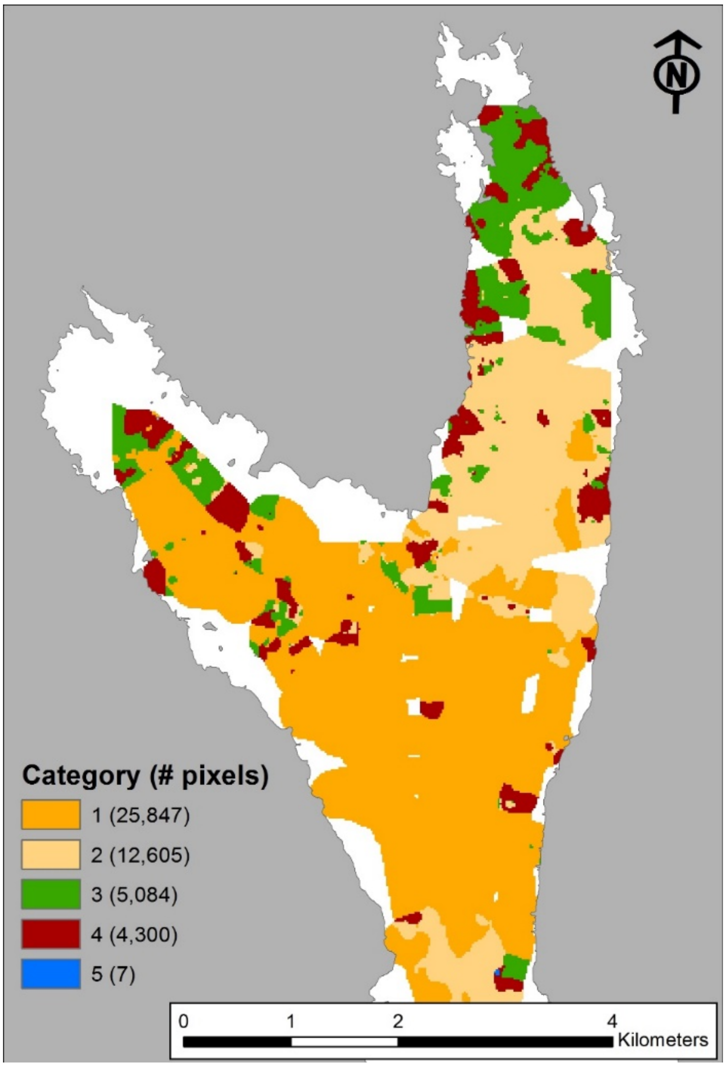


Figure 13.19. Acoustic bottom map of Shelburne Harbour

13.5. Cooperation within AquaSpace

Vanessa Stelzenmüller was an invited guest speaker in a special session on Coastal Management at Aquaculture Canada 2016 (October, St. John's Newfoundland). Her travel was paid by DFO Canada. We were able to agree on use of Aquaspace GIS tools in Liverpool, and are in the initial stages of implementation.

We have had two challenges during the case study. First, vessel availability and bad weather have hampered our field work. Secondly, Nova Scotia has not granted salmon licenses for 5 years, and the planned aquaculture development has been slow.

Other challenges that were experienced during the tool implementation were on, data compilation, map production, difficulty of conflict analysis or scoring.

13.6. Relevance of the case study within Aquaspace

This study is consistent with EAA in assessing ecosystem scale components of habitat and attempting to accommodate other resource uses in aquaculture development. In addition, it incorporates disease risk by determining connectivity between any set of points in the bay. Maritime spatial planning (MSP) is not advanced in coastal Canada, and we seek to make progress on the integration of aquaculture into MSP, along with other coastal resource issues such as fishing.

The case study involved a large aquaculture enterprise (Cooke Aquaculture) and concepts of disease risk, carrying capacity, habitat mapping and maritime spatial planning

13.7. Conclusions and future prospects

Stakeholders in this case study are engaged, and in Nova Scotia we have traditionally had a strong anti-aquaculture movement. We anticipate that there is also constructive input from a future Community Liaison Committee. A social license project conducted at the Ocean Frontier Institute (https://www.dal.ca/research/centres_and_institutes/ofi/about-ofi.html) will explore this potential.

Our federal and provincial regulatory agencies are open to improvements in management processes, and a comprehensive case study is required to demonstrate this progress. Moreover, more formal cooperation arrangements facilitate input. We are in the midst of negotiating a new committee structure with Nova Scotia Fisheries and Aquaculture (NSDFA) to enable more cooperative planning. In addition, NSFDA has a new request for proposals to further aquaculture planning, so we expect closer ongoing coordination.

The MSP process highlighted in AquaSpace has not been adequately demonstrated in eastern Canada. We expect that MSP could be emplaced as a rigorous approach, similarly, so too could other concepts developed in AquaSpace.

We intend to use Aquaspace tool in site planning of two more farms in the bay, but this has not yet been implemented. Other tools needed for the future are disease risk and nutrient plume modelling.

Regarding adaption of measures or strategies for increasing space for aquaculture, there needs to be sufficient demonstration in multiple case studies that approaches such as Aquaspace tool are effective, and can be adopted internationally. This can be supported from cases already making progress with Aquaspace tool.

Regarding the role of AquaSpace in development of MSP and other relevant approaches, demonstration of success in solving a significant problem, and making it operational in the long run. Aquaspace tool must be incorporated into a wider GIS culture that seems to exist in many places, although not necessarily with a marine orientation.

Beyond AquaSpace, in 2016, the largest marine science initiative in Canadian history, Ocean Frontier Institute (https://www.dal.ca/research/centres_and_institutes/ofi/about-ofi.html), was funded within the Canada First Research Excellence Fund. Jon Grant led the development of the aquaculture component. Projects that will start and benefit Liverpool include (a) studies of social license in coastal communities; Aquaspace tool may have a role in this project, (b) wireless sensor technology for fish cages, monitoring oxygen and temperature, epidemiological/oceanographic models of disease transmission risk; this feeds back directly to maritime spatial planning components involving connectivity.

14. ZHANGZIDAO ISLAND AND SANGGOU BAY, P.R CHINA

LIU Hui[1], YOU Junyong[2], JIANG Zengjie[1], FANG Jianguang[1], BIAN Dapeng[3], ZHANG Yuan[4], CHANG Lirong[3]

[1]Yellow Sea Fisheries Research Institute, PR China, [2]Christian Michelsen Research AS, Norway, [3]Xunshan Fisheries Group, PR China, [4]Zoneco Group Co Ltd, PR China

14.1. General characteristics

This case study will identify the key environmental limiting factors for aquaculture carrying capacity in both Zhangzidao Island (Zoneco Sea Ranch) and Sanggou Bay sea areas, and set up management tools based on ecological models and the aquaculture policy framework.

Aquaculture sea use in China is governed, at the national level, by the Marine Functional Zoning (MFZ), which is China's equivalent to MSP. At the regional and local level, it is governed by the local MFZ and, by judiciary and administrative means, controlled by the Sea Use Permit and Aquaculture Permit systems. The Fisheries Law of China, Fisheries Water Quality Standard (GB3097-1997), and several other rules and mandates also regulate aquaculture feedstuff, chemical use, food quality and environmental impacts. Generally speaking, the process for MSP in China is very similar to those of other (incl. EU) countries (Ehler and Douvere 2009).

Policy revision in China in recent years echoes the need for ecosystem conservation and sustainable development. This is also reflected in the aquaculture sector, in the 13th Fisheries Five Year Plan (2016), the Water Pollution Prevention Action Plan (2015) etc. and ecosystem-based spatial planning is also promoted by China's current national policies.

14.1.1. Location of Zhangzidao Island and the social economic context

Zhangzidao sea area is the largest base for aquaculture and sea ranching of high-valued seafood in the north of the Yellow Sea (Figure 14.1). As the Zhangzidao sea area is mostly open ocean with water depths of 30~40m, bottom ranching is the main style of aquaculture operation in this area. Zoneco Group Co. Ltd (formerly Dalian Zhangzidao Fisheries Group) is one of the main aquaculture and fishery companies in China, and it is the largest company operating in Zhangzidao sea area.

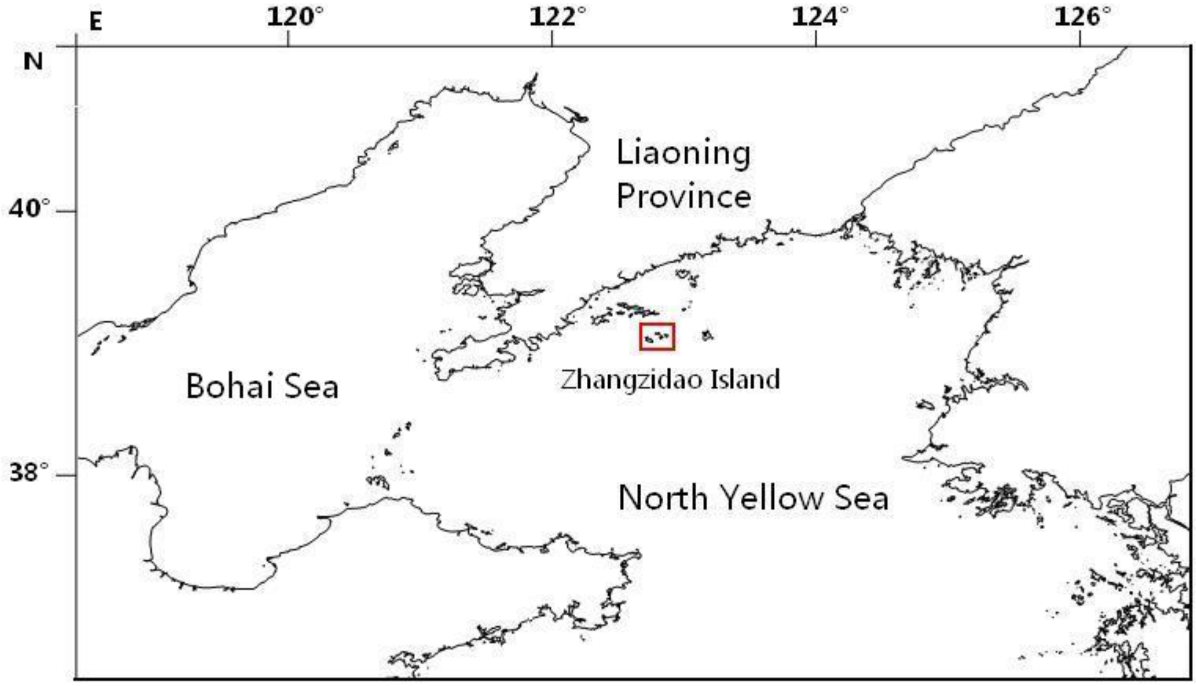


Figure 14.1. Chart of Zhangzidao Island and its surrounding waters]

Zoneco Group Co. Ltd operates a 1600 km^2 ocean farm, producing about 20,000 tonnes scallop *Patinopecten yessoensis*, 200 tonnes sea cucumber *Apostichopus japonicus* annually, and some other species such as abalone *Haliotis discus hannai*, sea urchins, clams and sea snails (Figure 14.2). The Zhangzidao (Zoneco) Sea Ranch employs 1200 people and had a total production value of 901 million Yuan RMB (120 million Euro) in 2016.

Figure 14.2. Main products of Zoneco Group Co. Ltd (from top left: Japanese scallop, sea cucumber, abalone, sea urchin, conch and clam]

Capacity of the Zoneco company for sea ranching and aquaculture:

- Total area of 1,600 km^2, in the inter-tidal zone to a maximum depth of 50m
- Mainline product - scallop ranching with a total production of 20,000 tonnes
- Six hatcheries, producing 3.5 billion scallop seeds, 6 million juvenile sea cucumbers, 10 million abalone and 20 million sea urchin seeds

14.1.2. *Location of Sanggou Bay and the social economic context*

Sangou Bay is a semi-enclosed bay located on the eastern tip of Shandong Peninsula, facing the Yellow Sea, with a surface area of 133.3km^2 and an average depth of 8m (Figure 14.3). Currently seaweed culture extends more than 8km outside the bay, reaching a water depth of 40m at some points. In 2016, the total marine aquaculture production in Sanggou Bay was 258 thousand t, with a total area of about 10 thousand ha, generating a total value of 4.6 billion Yuan RMB (0.6 million Euro). The aquaculture industry employed slightly more than 11000 in the bay (data from the local Ocean and Fisheries Bureau). Seaweed has been cultured in the bay since the mid-1960s and the major seaweed species produced in Sanggou Bay is kelp *Laminaria japonica*. There are more than 20 aquaculture farms in the bay, with a diverse range of culture facilities including longlines for seaweed, lantern nets for scallop and abalone, and net cages for finfish etc. There are also some shrimp ponds on the tidal zone of the bay. Annual mariculture production of Sanggou Bay is as follows:

- Kelp: 80,000 tonnes in dry weight
- Abalone *Haliotis discus hannai*: 2,000 tonnes in fresh weight with shell
- Oyster *Crassostrea gigas*: 120,000 tonnes in fresh weight with shell
- Scallop *Chlamys farreri*: 10,000 tonnes in fresh weight with shell
- Finfish: 100 tonnes
- Sea cucumber *Apostichopus japonicus*: 100 tonnes in fresh weight

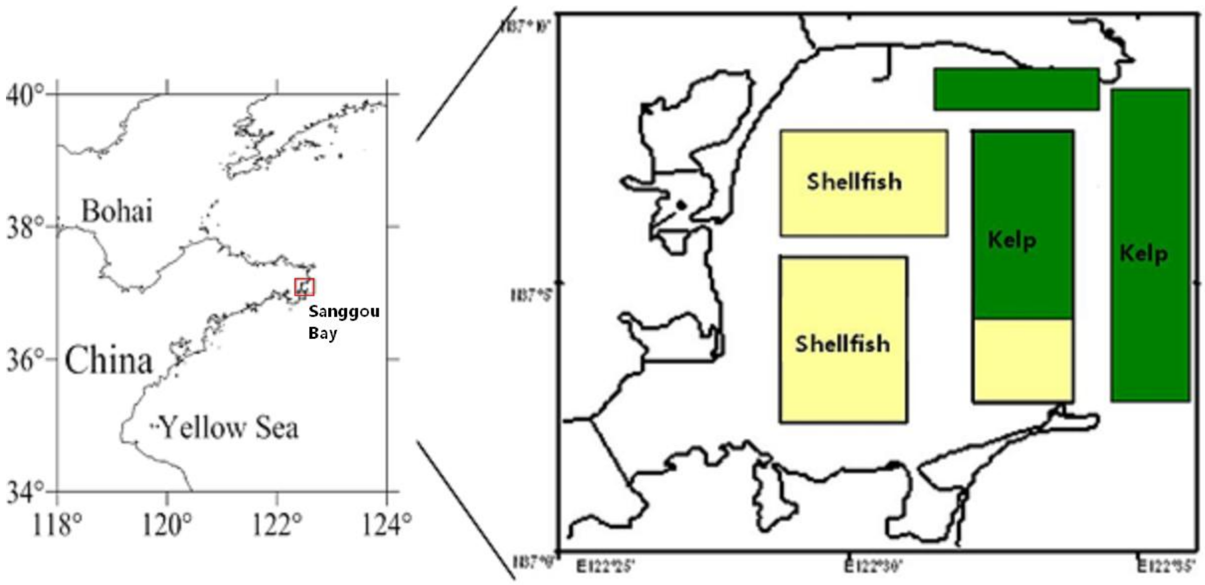


Figure 14.3. Chart of Shandong Province and Sanggou Bay]

14.2. Spatial planning and management issues

Chinese coastal seas are facing many problems associated with the loss of wetlands and habitats, water pollution, and increasing harmful algal blooms in both temporal and spatial dimensions. These problems are partly generated by aquaculture which is tremendous in scale of operation but these problems may, in turn, affect aquaculture and endanger food safety and sustainable development of the industry. These problems are fully recognised by China, and new policies, legislation and management measures are successively implemented to deal with these issues. MFZ is one of the measures, which was recently supplemented by the Marine Ecological Red Line System (the Red Line). The Red Line refers to a special marine spatial planning focusing on very strict ecological protection of sensitive or vulnerable marine habitats; it has been promoted following a 2011 decision of the Chinese State Council to strengthen environmental protection.

At the farm level, there is also an urgent need for spatial planning of aquaculture. Since the current layout and density of aquaculture facilities (e.g. the longlines) has reduced the water exchange in Sanggou Bay to a certain extent, the productivity of the seaweed and the quality of the fish and shellfish may have been affected. Some of the companies have recognised that optimised spatial planning is probably an effective way to increase aquaculture productivity, offset labour costs and improve food safety. At the same time, some of the companies try to diversify their products and close the year for aquaculture activities. One example is the ‘shift’ in longline culture of seaweed extending the classical production of kelp (*Laminaria*) during November-May by culture of *Gracilaria* spp. during May – August. This makes better use of the space for farming of seaweed.

In Sanggou Bay, Integrated Multi-Trophic Aquaculture (IMTA) is carried out inside the bay, while seaweed mono-culture largely occurs outside the bay. The water depth in Sanggou Bay is relatively shallow, <15m inside the bay and 15~25m for seaweed culture outside the bay. As seaweed culture extends further offshore, longline seaweed monoculture is the main culture mode in Sanggou Bay. Different types of IMTA is carried out inside Sanggou Bay, e.g. the lantern net oyster – longline kelp – net cage fish combination or longline seaweed – lantern net abalone + sea cucumber combination.

Zhangzidao Island, on the other hand, is characterised by its deep open ocean, at depths of up to 50m. The scallop is cultured largely via bottom sowing in depths of 30-40m. In the nearshore areas <20 m depth, is bottom IMTA for sea cucumber, abalone, sea urchin, and other species, covering a total area of about 2000 ha. Since the scallop seeding areas in Zhangzidao island has extended further from the ports in deeper waters, socio-economic issues may arise from increased management costs.

These two case study sea areas are mostly allocated for fisheries, and currently there is no obvious conflicts between sea uses in these areas. However, according to the latest version of local MFZ and the proposed Marine Red Line systems (not yet officially adopted), there may be some conflicts, e.g. in Sanggou Bay, between aquaculture and MPA/harbour/navigational uses until 2020. At the same time, tourism is a priority in the Rongcheng City development plan, and considering its possible conflicts with aquaculture, the city government is now demanding further retreat of aquaculture facilities to 2000m off the coastline of Sanggou Bay. As a result, inner bay finfish and bivalve culture may see a 10% or so reduction over the next two years, and bottom culture may replace lantern nets in some areas.

There are both opportunities and constraints for aquaculture from co-existence with other sea uses. An upper limit of 2.2 million ha area for mariculture has been created by new Chinese policies. Limited availability of suitable space for aquaculture means more interaction of aquaculture with other interests (conservation, tourism, fishing, etc.). Allocating space by ecosystem-based planning for aquaculture may result in benign environmental interactions through co-existence, by considering buffering distance etc. A trend of ‘return aquaculture sites to natural tidal flats’ is also seen in China as a mean to maintain the natural status of marine ecosystems. Collaboration and dialogue between the industry and regulatory authorities is highly needed in China, so as to facilitate mutual-beneficial co-existence.

Sea ranching is a method of aquaculture that integrates stock enhancement, artificial management and harvesting. It is widely accepted in China that such ranching may enhance the sustainability of the coastal seas, so a great amount of government funding and industry investment has been allocated to research and technology relating to sea ranching. A significant increase in the scale of sea ranching, and bottom IMTA in particular, is foreseeable in the next few years in both Sanggou Bay and Zhangzidao island.

In China, aquaculture sea use must comply with Marine Functional Zoning (MFZ) - China’s MSP. For aquaculture area allocation, there is a permit system; and for water quality control, there is the Fisheries Water Quality Standard (GB3097-1997). Several other rules and mandates also apply to aquaculture governance, which regulates aquaculture feeds, chemical use, quality control and environmental impacts.

The 13th Fisheries Five Year Plan marks the transition in China’s fisheries policies –from *Aquaculture Priority* to *Return Aquaculture to Natural Tidal Flats*, and quantitative targets are set for output reduction and increase in profit in aquaculture by 2020. The Water Pollution Prevention Action Plan (2015) also clearly stipulates that an ecologically healthy aquaculture industry will be promoted, with prohibitions on aquaculture in key rivers, lakes and coastal seas. An upper limit of 2.2 million ha is also prescribed for total mariculture production.

Additionally, China’s national policies for the 13th Five Year Plan promotes Integrated Spatial Planning at all levels, which will probably bring about changes in China’s marine spatial planning and eco-conservation.

For both case study areas, there are clear elements of EAA or MSP process, including production planning made by respective aquaculture companies.

14.3. *Stakeholder engagement and participation*

Two AquaSpace stakeholder workshops were held in Sanggou Bay during 2015 and 2016. The list of participants and outputs are detailed as follows:

14.3.1. *WORKSHOP 1: AquaSpace Project Meeting – Sanggou Bay (8–9 December 2015)*

LIST OF PARTICIPANTS

Øivind Strand	Institute of Marine Research (IMR), Norway
Samuel Rastrick	Institute of Marine Research (IMR), Norway

YOU Jun-Yong	Christian Michelsen Research AS (CMRAS), Norway
LI Xiao-Bo	Xunshan Fisheries Group (XS), PR China
BIAN Da-Peng	Xunshan Fisheries Group (XS), PR China
XIAO Lu-Yang	Xunshan Fisheries Group (XS), PR China
GUO Wen-Xue	Xunshan Fisheries Group (XS), PR China
TANG Xiao-Yang	Xunshan Fisheries Group (XS), PR China
WEI Hao	Tianjin University, PR China
FANG Jian-Guang	Yellow Sea Fisheries Research Institute (YSFRI), PR China
JIANG Zeng-Jie	Yellow Sea Fisheries Research Institute (YSFRI), PR China
FANG Jing-Hui	Yellow Sea Fisheries Research Institute (YSFRI), PR China
LIU Hui	Yellow Sea Fisheries Research Institute (YSFRI), PR China

Feedback from stakeholders at the workshop suggests that a science-based carrying capacity evaluation and spatial planning is vital to tackle the current productivity bottle-necks in Sunggou Bay.

14.3.2. *WORKSHOP 2: Aquaculture governance related to environmental sustainability principles – Rongcheng City (29 November – 1 December 2016)*

LIST OF PARTICIPANTS

Øivind Strand	Institute of Marine Research (IMR), Norway
Rolf Engelsen	Institute of Marine Research (IMR), Norway
Lars Asplin	Institute of Marine Research (IMR), Norway
Pia Kupka Hansen	Institute of Marine Research (IMR), Norway
YOU Jun-Yong	Christian Michelsen Research AS (CMRAS), Norway
Jan Wilhelm Grythe	Counsellor, Development, Royal Norwegian Embassy in Beijing
Joao Ferreira	Universidade Nova de Lisboa, Portugal
Jeffrey Ren	NIWA, New Zealand
FANG Jian-Guang	Yellow Sea Fisheries Research Institute (YSFRI), PR China

JIANG Zeng-Jie	Yellow Sea Fisheries Research Institute (YSFRI), PR China
LIU Hui	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Zhang Jihong	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Lin Fan	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Gao Yaping	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Du Meirong	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Jiang Weiwei	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Cai Biying	Yellow Sea Fisheries Research Institute (YSFRI), PR China
Yu Liangju	Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences
Shang Weitao	Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences
Jiang Xiaopeng	Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences
Zhou Feng	Second Institute of Oceanology, State Oceanic Administration
Xuan Jiliang	Second Institute of Oceanology, State Oceanic Administration
Zhu Changbo	South China Sea Fisheries Research Institute (YSFRI), PR China
Liang Jun	Zoneco Group Co Ltd, Dalian
Zhang Yuan	Zoneco Group Co Ltd, Dalian
BIAN Da-Peng	Xunshan Fisheries Group (XS), PR China
GUO Wen-Xue	Xunshan Fisheries Group (XS), PR China
Zhang Yitao,	Chudao Marine Scientific Company

The policy framework for implementing ecosystem-based aquaculture spatial planning in China and the EU countries, and Norway in particular, was discussed; industry concerns regarding sustained production and profitability was presented; and modelling of carrying capacity in China, Norway and New Zealand was discussed, including the MOM model, AkvaVis, DEB model and FARM model. Future collaboration between AquaSpace project partners in the development of spatial planning tools for Chinese aquaculture was also discussed.

Ecosystem-based aquaculture planning is urgently needed for decision making in the industry, in order to maintain sustained output and profitability. Issues regarding project implementation plans and specific technical questions for developing the Chinese Aquaculture Spatial Planning Decision Support System (APDSS) were discussed.

14.4. Tools used in the case study

A demonstrator version of sinoAkvaVis was developed in 2014 based on experiences from the development of the Norwegian AkvaVis tool and the French version SISAQUA, developed for Normandy in France. The work was carried out collaboratively between YSFRI, CAFS, IOCAS, IMR and the ZZD company. It can be accessed on http://insitu.cmr.no/sinoakvavis/akvavis.html.

The front page and a screen showing the area included, with a left bar of thematic layers and a top bar of functional buttons are shown in Figure 14.4. This demonstrator version was developed for the Zhangzidao area in the Liaoning province and used by the company Zoneco Group Co Ltd (ZZD). Input data provided by ZZD, IOCAS, YSFRI and CAFS have been incorporated into the tool and the main functionalities of AkvaVis, including visualization of data layers and localization of new suitable farms, implemented. Further, as the main user of sinoAkvaVis tool, the ZZD company has expressed the intention to undertake further development by making a more operational version of sinoAkvaVis. This intention has been briefly discussed between the project partners and will be further planned in the future.

In addition, preparation to apply the AkvaVis tool in the Sanggou Bay case study has also been performed. The plan was to adapt AkvaVis to this case study based on the previous experience from sinoAkvaVis development. This work will be combined with the following system development in order to make a practical and operational tool for aquaculture planning and management.

Figure 14.4. Screenshot of the sinoAkvaVis homepage, showing the area concerned.

14.5. Application of tools

Currently the Chinese partner is developing an Aquaculture Planning Decision Support System (APDSS), with the AquaSpace co-funding from the Ministry of Science and Technology. APDSS will integrate policy, economic and ecosystem considerations for aquaculture spatial planning, and be tailored to meet the characteristics of large scale mariculture practices in China. The concept of

AkvaVis will be adopted and further developed in the APDSS tool, and is relevant to future development in Sanggou Bay and Zhangzidao sea areas.

14.6. Case study results

The AquaSpace project held a stakeholder workshop on December 8th 2015 at Sanggou Bay, Shandong Province. The stakeholders were asked to address the question: "What are the main issues that constrain the development of aquaculture in Sanggou Bay". The following is a synthesis of the workshop discussions:

- What are the pressing needs of the farm in terms of aquaculture spatial planning?
  - Based on earlier ecological and physical oceanography studies, the current layout and density of aquaculture longlines has reduced the water exchange in Sanggou Bay to a certain extent, which may affect the productivity of the seaweed. Aquaculture companies are under pressure to increase aquaculture productivity via optimised spatial planning, so as to maintain the companies' economic balance (return) though labour costs keep rising. The current level of mechanisation of seaweed culture and harvest is relatively low, and labour costs may comprise 40% of the total production cost.
  - Because the water exchange in inner Sanggou Bay is reduced by the high density of longline culture, the companies are also concerned about the water quality which is possibly degraded. Optimised spatial planning of the raft culture is also needed so as to ensure good quality seafood products, especially oyster, scallop, abalone and sea cucumber.
  - Some of the companies try to diversify their products and close the year for aquaculture activities. One example is the 'shift' in longline culture of seaweed extending the classical production of kelp (*Laminaria*) during November-May by culture of *Gracilaria* spp. during May – August. This makes better use of the space for farming of seaweed.
  - From the companies' perspective, they want to increase the number of cultured species so as to maximise utilisation of the marine space.
  - The main culture mode is longline culture of seaweeds and lantern nets for shellfish. Companies hope to extend their aquaculture to the benthic layer, but this may rely on the development and design of new bottom culture equipment.

- What are the opportunities and constraints for aquaculture by co-existing with other sea uses?
  - New Chinese policy (*Water Pollution Prevention Action Plan* issued in April, 2015) stipulates that ecologically healthy aquaculture will be promoted, with aquaculture prohibited in certain rivers, lakes and coastal seas. An upper limit of 2.2 million ha is also stipulated for total mariculture production. Limited availability of suitable space for aquaculture means more interactions between aquaculture and other interests (conservation, tourism, fishing, etc.).
  - Allocating space will not lead to area expansion, but the aim is for benign interactions with other uses through co-existence. As a result, consideration should be given to the buffering distance between aquaculture farms and different sea uses, in particular marine protected areas and vulnerable benthic habitats nearby, as well as coastal industrial installations. This will protect the aquaculture farms from pollution and other risks.

- What are the barriers to co-existence?

  In recent years, an ecosystem conservation ‘red line’ has been drawn along many coastal wetlands in China, and new policy stipulates ‘return aquaculture to natural tidal flats’, so as to maintain the natural status of marine ecosystems. Industry cannot lead in multi-use because this may reduce the scale of their operation and benefits; but they must do what is legally required. Collaboration and dialogue between industry and regulatory authorities is needed, so that new approaches to planning and consenting to facilitate co-existence can be developed.

Recommendations by the Chinese partners: A science-based carrying capacity evaluation and spatial planning is vital to tackle current productivity bottle-necks, in both Sanggou Bay and Zhangzidao Island.

The second AquaSpace stakeholder workshop was held during 29 November and 1 December 2016 in Rongcheng City, Shandong Province. The policy framework for implementing ecosystem based aquaculture spatial planning in China and the EU countries, and Norway in particular, was discussed; industry concerns regarding sustained production and profitability was presented; and modelling of carrying capacity in China, Norway and New Zealand was debated, including the MOM model, AkvaVis, DEB model and FARM model. Future collaboration between AquaSpace project partners on the development of Chinese aquaculture spatial planning tools was also discussed.

Though the co-funding project Sino-EU Cooperative Research on Ecosystem-based Spatial Planning for Aquaculture was not formally announced, project partners held group meetings during the second AquaSpace workshop. It was agreed in principle by both the research institutes and industry representatives that, ecosystem-based aquaculture planning is highly needed for future decision making in the industry, in order to sustain output and profitability. Issues regarding project implementation plans and specific technical questions for developing the Chinese Aquaculture Spatial Planning Decision Support System (APDSS) were discussed.

14.7. Relevance of the case study within Aquaspace

The case study is a highly relevant contribution to both EU and non-EU partners, as it represents the dominant global aquaculture producer. The new policy and upcoming issues relating to how Chinese aquaculture planning in the coastal environment will develop is of crucial importance and potential transferability to making more space for aquaculture in Europe.

The case study demonstrates how tools used by other partners in Aquaspace can be adapted to different and unique aquaculture production environments, as well as different management contexts.

The case study involved nationally significant aquaculture producers.

14.8. Conclusions and future prospects

1. Stakeholders were highly willing to participate in the case study, including the workshops, field study and other relevant activities, and they very much wish that the project may help

them to solve productivity problems, using *Ecosystem-based Aquaculture Spatial Planning Tools*.

2. In China's case, the partners started preparation for developing *Ecosystem-based Aquaculture Spatial Planning Tools* in 2016 and the MOST funding, once it becomes available, will greatly facilitate this work. This will enable the completion of the R&D work and its application to Zhangzidao Island and Sanggou Bay case studies in the next three years.

   ** Lack of funding has posed a major obstacle to full involvement of non-EU project partners. In March 2016, the Chinese partners submitted an application for co-funding of AquaSpace to the Ministry of Science and Technology (China), in order to facilitate further study in this area, including collection of more field data, more optimised spatial planning for aquaculture activities, and holding more stakeholder workshops. Additionally, this funding would enable Chinese partners to travel to project workshops in other countries. At the time of writing, the partners had not yet been informed of the result of their application.*

3. Despite funding restrictions, the Chinese partners managed to participate in the project workshop held in Hamburg in late September 2016. This provided a valuable opportunity for information and technical exchange, which greatly facilitated work in the case study sites.
4. Ecological Civilization is a kind of cultural ethics that aims at the harmonious coexistence between nature, society and man. This civilization targets a virtuous cycle, overall development and sustainable prosperity. While Chinese government policy in recent years has underlined Ecological Civilization, the concept of Marine Ecosystem-based Management has been more widely accepted and the approaches and concepts developed in the AquaSpace project will hopefully be implemented by Chinese decision-makers in the near future.

14.9. References:

Ehler C. and Douvere, F. 2009. Marine Spatial Planning, a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere programme. IOC manual and guides no. 48. Paris: UNESCO; 2009.

15. ARGYLL AND BUTE, SCOTLAND, UK

Billing S-L., Gubbins M., Miller D., Watret R., Adams T., Black K., Donaldson-Selby G., Wang C., Greenhill L., Tett P.

Scottish Association for Marine Science (SAMS), Marine Scotland Science (MSS), James Hutton Institute (JHI)

15.1. General characteristics

Argyll and Bute has the second largest area (6909 km^2, 10%) of the 32 local authorities in Scotland (Figure 15.1). Its population of 89,590 (2011 census) gives it the third lowest areal density. It is very rural, with 52% of the population living in areas classified as 'rural', which breaks down into 45% in 'remote rural' areas and the last 7% in 'remote accessible' areas. Eighty percent of people live within 1km of the coast and 97% live within 10km of the coast. Argyll and Bute's economy is based on the public administration, education and health sectors, providing 36% of all jobs. The service industry, which is 15% tourism-related, provides the most private sector jobs. Argyll has relatively high levels of employment in agriculture, fishing and aquaculture, as well.

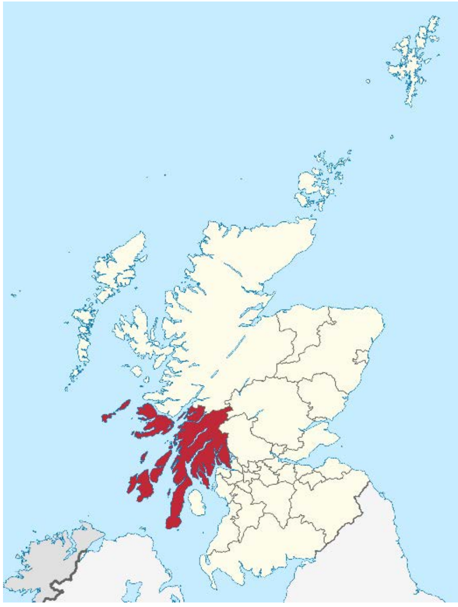


Figure 15.20. County of Argyll and Bute shown in red.

Source: Wikimedia Commons,

15.1.1. *Production and producers*

The major finfish species produced in Argyll and Bute is Atlantic salmon. In 2014, a total of 40 fish farming sites were active in Argyll and Bute, run by 4 salmon farming enterprises (of 11 Scotland-wide) and one marine trout company operating a total of 40 active sites. Scotland's marine trout sector is based entirely in this region, with production comprising approximately 28% of total Scottish trout production. A small output of Halibut is also produced (c. 100 tonnes).

The major shellfish species produced in Argyll is the blue mussel. There are 49 shellfish farming enterprises in Argyll and Bute. The aquaculture production systems in Argyll include hatcheries (mainly fresh and seawater finfish), marine and fresh water cages, longlines (mussels and scallops), and trestle tables (oysters). Table 15.1 summarises production figures for Argyll.

Table 15.1. Argyll[3] aquaculture production 2014 (Marine Scotland Science, 2015; Munro & Wallace, 2015).

	Salmon	**Marine trout**	**Mussels**	**Pacific oyster**	**Native oyster**	**Queen scallops**	**Scallop**
Tonnes	34,976	1,909	822	158.4	18.9	0.9	1.3
000s shells	–	–	–	1,983	241	17	10
% Scottish Production	19.5	100.0	10.7	58.5	99.6	94.4	20.8

15.1.2. *Policy and Planning*

The Aquaculture & Fisheries (Scotland) Act 2013 deals with both shellfish and finfish farming in Scottish waters. It covers environmental aspects as well as licensing, management, and enforcement procedures. The National Planning Framework 3 (Scottish Government 2014a) sets out the national spatial strategy for Scotland, which includes aquaculture. The Framework recognises that aquaculture benefits its coastal communities and as such pledged to "support the sustainable growth of the aquaculture sector" (Poseidon Aquatic Resources Management Ltd, 2016). This contributes to Scottish Planning Policy (Scottish Government 2014b), in that it aims to:

[3] Shellfish statistics are reported for the larger area of Strathclyde, most of the production taking place in Argyll and Bute

- Play a supporting role in the sustainable growth of the aquaculture industry to ensure that it is diverse, competitive and economically viable;
- Guide development to coastal locations that best suit industry needs with due regard to the marine environment;
- Maintain a presumption against further marine finfish farm developments on the north and east coasts to safeguard migratory fish species. (The Scottish Government, 2016).

The current aquaculture planning and licensing regime in Scotland involves a minimum of three licences from three separate governmental agencies, two permissions from the local authority, and one lease from the national governing agency on the seabed. Table 15.2 summarises the permissions associated with relevant authorities and aquaculture activities.

However, the report, 'Independent Review of Scottish Aquaculture Consenting' (Poseidon Aquatic Resources Management Ltd, 2016), noted that the current system does not meet the Scottish Government Planning Policy for aquaculture, particularly in relation to efficiency and community engagement. The Scottish Government opened a consultation on changing Scottish Planning Policy which included aquaculture planning and licensing regulations. The consultation closed at the end of May 2017.

15.1.3. *Seascape and landscape policy*

Scottish public policy, in line with evolving agreements internationally, recognises the rights and value of public participation and engagement in relation to decision-making, with principles embedded in the Land Use Strategy, Scottish Planning Policy, Scottish Biodiversity Strategy, and Creating Places Policy. For example, amongst the set of ten Principles of the Scottish Land Use Strategy is that "People should have opportunities to contribute to debates and decisions about land use and management decisions which affect their lives and their future." Consequently, Scottish Planning Policy (SPP) (Scottish Government, 2014) identifies how the planning system can deliver high-quality places, including making efficient use of natural resources for long-term benefits, and protecting and enhancing natural and cultural resources. This implies a balance being achieved between the use of space for different purposes, and the desirability of multiple benefits from the same spaces.

With respect to aquaculture development, the issue of landscape and seascape is of significant importance. In Scotland the designation of National Scenic Areas (NSAs) represents the areas "of outstanding scenic value in a national context" (Scottish Parliament, 2010). For planning and design of developments, including aquaculture, a broader consideration of landscape is used, namely the Landscape Character Assessment (LCA) (Scottish Natural Heritage, 2002; Hughes and Buchan, 1999). This is the mapping of the unique combination of elements and features that make landscapes distinctive. The LCA provides baseline information for use in guiding landscape change. It includes a note of the types of pressures in each landscape character area which may lead to significant impacts amongst which are aquaculture developments.

Landscape character is taken into account in the guidance Scottish Natural Heritage provide for considering the landscape and seascape capacity for aquaculture (Scottish Natural Heritage, 2008). This recognises that "character of the landscape adjacent to the shoreline will influence the potential sensitivity of the landscape to aquaculture development", providing context and setting for aquaculture, and the context from which land based views are experienced. They identify particular characteristics of the immediate hinterland of greatest significance as being the topography, vegetation and settlement patterns. As of spring 2017, Scottish Natural Heritage is developing guidance on assessing the visual impacts of aquaculture, drawing on those used for wind turbine development. Aquaspace, through JHI and MSS, is participating in stakeholder discussions from which the draft guidance is emerging (Scottish Natural Heritage 2017).

Table 15.2. Aquaculture licensing, legislations and authorising regulator. After Argyll and Bute Council (2016)

Application	**Authorising regulator**	**Legislation**	**Aquaculture type**		
			Finfish	**Shellfish**	**Seaweed**
Planning permission	Local Authority	Town and Country Planning (Scotland) Act 1997	✓	✓	✗
Environmental Impact Assessment (mainly finfish)	Local Authority	The Town and Country Planning (Environmental Impact Assessment)(Scotland) Regulations 2011	✓	✓	✗
Marine Licence	Marine Scotland Licensing Operations Team (MS-LOT)	Marine Scotland Act 2010	✓	✓	✓
Seabed Lease	The Crown Estate	The Crown Estate Act 1961	✓	✓	✓
Authorisation to operate and Aquaculture Production Business (APB)	Marine Scotland Science Fish Health Inspectorate (MSS-FHI)	The Aquatic Animal Health (Scotland) Regulations 2009	✓	✓	✗
Controlled Activity Regulations (CAR) Licence	Scottish Environment Protection Agency (SEPA)	The Water Environment (Controlled Activities)(Scotland) Regulations 2011	✓	✗	✗
Habitats Regulations Appraisal (if necessary)	Local Authority in consultation with Scottish Natural Heritage (SNH)	The Conservation (Natural Habitats & Conservation) Regulations 1994	✓	✓	✓

15.2. *Stakeholder engagement and participation*

The AquaSpace project held a stakeholder workshop on January 18th 2016 at SAMS, Oban, Scotland. The stakeholders were asked to address the question: "What are the main issues that constrain the expansion of aquaculture in Argyll?". Below is a synthesis of the workshop discussion and Table 15.3 details the participants.

Evaluation of current policy and planning regime for aquaculture

- There is a lack of integration between national aquaculture policy (which is driving the growth of aquaculture), local planning (processing planning applications) and decision making, and how these relate to industry needs (commercial and technical). This affects investor confidence and causes uncertainty about the development of the sector as a whole, and of specific projects. An opportunity exists to address this interplay across scales, through the review of Local Development Plans by Local Authorities. It was questioned whether this measure was sufficient in addressing these issues.
- Questioning whether the Town & Country Planning (Scotland) Act 2017 is the best mechanism for aquaculture development. The issues discussed related to flexibility in project development relating marine and terrestrial planning (shoreline infrastructure and access).

Spatial planning and co-existence of aquaculture with other sectors and interests

- Space is being used inefficiently e.g. unused lease areas using up potential development space; how can these be re-leased?
- Considering aquaculture in planning: there is a need to consider the mobility of sites. How could MSP address these issues?
- What are the benefits of co-existence? Issues of limited availability of suitable space for aquaculture, and concerns regarding interactions of aquaculture with other interests (conservation, tourism, fishing, etc.), which means that allocating space will not lead to sufficient development. Therefore, there is a need to aim for benign interactions (at best) through co-existence. Collaboration is needed between sectors to enable co-existence. There is the potential to include integrating infrastructure with other sectors e.g. renewables and IMTA.
- Barriers to co-existence: Industry cannot lead in multi-use as they will do what is legally required of them. There needs to be collaboration between industry and regulatory authorities, so that new approaches to planning and consenting to facilitate co-existence can be developed. Landscape/seascape issues and zoning in planning may be too restrictive.
- Previous experience with spatial planning; ICZM plans are informative and useful but they are limited in reach due to their voluntary nature, limited geographical scope and are rapidly dated so need regular maintenance. What can be learnt from ICZM?
- Cumulative impacts are a complicated aspect of co-location and needs collaborative approaches to understand the combined effects of multiple activities.

Developing accountability in aquaculture

- There is a need to understand the balance of responsibility / accountability between different actors. For example, the responsibility of developers in delivering their project commitments (e.g. monitoring of environmental effects as determined through EIA process, escapes of wild fish, site tidiness, on-going management, etc.) and the responsibility of both developers and governing agencies when things go wrong (e.g. escapes, sea lice outbreaks).
- The level of enforcement should be appropriate and there are still some issues which are not covered by current legislation (e.g. wild fish issues, sea lice). The role of monitoring and enforcement is a debate which is critical, especially in relation to surveillance and management.

- The accountability of actors in governance (regulators, local authorities) in ensuring that national policy commitments in aquaculture development are delivered, in terms of addressing food security and Blue Growth. To enable this there is a need to provide more direction at the regional level, and for account to be taken of local challenges which may not be apparent at a policy level.
- There is a lack of accountability to communities in delivering the benefits of aquaculture development locally, and over the long term. Better and more transparent accountability of actors in aquaculture could ensure more positive public perception and engagement, which relates to investor confidence.

Improving public perception of aquaculture

- There are mixed perceptions of the aquaculture industry, which can be due to misinformation, or a lack of information, especially in relation to planning policy, environmental impacts and management, and community benefits. Perceptions highly variable across regions, and depend upon a range of socio-cultural factors, experience and proximity to sites, but can be indicative of lack of understanding.
- Better outreach is needed to improve public opinion of the sector and in particular the benefits it provides for the community. Outreach activities are necessary to help develop faith from communities and 'social licence' to operate. There is a need to improve the promotion of benefits (including community benefits) accruing from aquaculture including improving water quality and sink for carbon (both shellfish), and possibly relating this to the developing emphasis on the circular economy and understanding and maximising benefits obtained throughout the supply chain. How does industry communicate? Does it need to spend some effort on consulting with public and the reality of their perceptions? Is it sufficient to put 'key myths' on a website, for example?
- There is a need to focus on the role of aquaculture in food provision as part of wider education on its importance.
- Accountability affects public perception, e.g. how sea lice is dealt with; escapes.
- Lessons could be learned from terrestrial farming as a comparable sector to aquaculture. How can the public perception of aquaculture be brought to a level/fair comparison with farming?
- There is a need to consider differences in perception between different areas of the industry, e.g. shellfish differences ('enhanced fishing' rather than farming).
- Community engagement is likely to be of significance in future, with importance attached to considering different models of ownership / benefits sharing, to empower communities as has been promoted in renewable energy, and is related to the wider policy context Land Reform Agenda. There needs to be long-term accountability to communities.
- The scale of development proposed in an area is significant. Development needs to be economically viable and generate appropriate benefits for the community.
- There needs to be better communication with the public, but on a bigger scale, which is difficult at a company level. EU projects could positively influence public perceptions, but there needs to be collaboration with other sectors.
- Improve links to youth engagement and employment in aquaculture, targeting schools and using mechanisms such as apprenticeships and address the perceptions that it is just a physical job, and highlight that skills are transferrable.

Business Development

- There is uncertainty (due to the broad range of issues) affecting investment.
- Inconsistency of planning processes across Scotland can affect developer strategies for where to develop. Differences in community preference can be expected (as dependant on culture, personalities, etc.) but planning process should be fairly and relatively consistently applied.
- Business development: Is there anything to learn from the Common Agricultural Policy e.g. it supports new entrants to farming could there be an equivalent in aquaculture?

Development of novel techniques and approaches

- Innovation in solutions – can we identify areas through planning for the testing of new technologies (e.g. offshore technologies, fish health R&D, and reducing chemical usage) in addition to commercial sites?
- Beneficial solutions need to be supported (including by public investment) until they become economically viable.

Table 15.3. Participants involved in the workshop

Industry type	Company
Salmon farming	Scottish Salmon Company
	Marine Harvest
	Scottish Sea Farms
Trout farming	Kames Fish Farming
	Dawnfresh
Shellfish farming	Isle of Mull Scallops
Producer organisations	Scottish Salmon Producers Organisation
Licensing and governance agencies	Marine Scotland Science
	The Crown Estate
	Scottish Natural Heritage
	Argyll and Bute Council
	Scottish Environmental Protection Agency
Fisheries organisations	Scottish Fishermen's Federation
	Mallaig and North-west Fishing Association
NGOs	Argyll Fisheries Trust
Academia	James Hutton Institute
	SAMS

15.2.1. *Research questions, aims and methods*

Following the workshop, the Scottish case study partners identified three research questions around which to focus their activities, the development of methods, and targeted outcomes. These research questions were circulated to the stakeholders who participated in the workshop, in August 2016, inviting their feedback. The following research questions are a result of the meetings between the Scottish case study partners and the feedback from the stakeholders.

1. How does salmon farm connectivity affect sea lice epidemiology on the Scottish West Coast?

a. How can this information be used by applicants and regulatory bodies to guide locations for developments and appropriateness of planning applications?

Aim: To provide new and relevant information on sea lice interactions with salmon farms. To present it in a useful manner to the industries and agencies that are likely to use it.

Outcome: Better knowledge of sea lice on the Scottish West Coast which will advise management procedures and practices in the area (and more broadly). In particular, work included appraisal of existing area management strategies, assessment of chemical treatment strategies within more tightly connected networks, and providing guidance of relative risks posed by locating new sites in particular locations.

Methods: Connectivity modelling and stakeholder engagement. Tasks undertaken by Marine Scotland Science and Scottish Association for Marine Science.

2. Where do people get their information on aquaculture from and how do they use it?

a. What drives objections (motivations and circumstances)?
b. Are there key actors in influencing perception and how do they use their 'power'?
c. What are the perceptions of the people who drive objections?
d. Where do objectors get their information from and how do they use it?

Aim: To identify areas where the industry can change or improve their information provision and community/public engagement practices in order to combat misinformation or 'myth-information' available to the general public, thus reducing the likelihood of its use in planning and pre-planning processes. It is also likely to identify ecosystem services which are intrinsically valuable to stakeholders and likely to influence whether a potential site is suitable, negotiable – through constructive dialogue with other marine users and stakeholders, or unsuitable.

Outcome: Better understanding of the role of information in promoting/ preventing aquaculture and how information is used by key actors. Potential to provide industry with cost and time-saving information available through consultation and documentation.

Methods: Public Comment analysis (Argyll and Bute and the Highlands and Islands Region) and interviews. Tasks undertaken by the Scottish Association for Marine Science.

3. Moving towards co-existence and co-location between marine industries, users and stakeholders:

a. How to identify valuable space to sectors
    i. What does 'valuable space' mean to different sectors?
    ii. What are the trade-offs and are they quantifiable?
b. Where are the conflicts/ barriers and are they predictable?
    i. What are the issues with current marine management?
    ii. How can policy and high level management strategies address these issues?
c. Where does accountability lie for managing and sticking with consent conditions?
    i. How does this affect social licence levels and the likelihood of objections to new sites either during pre-planning or the planning process?

Aim: The aim of section *a* is to create locational guidance maps for suitable sites based on stakeholder interactions and multi-criteria analysis. The aim of section *b* is to identify and predict management barriers on a regional and national level. The aim of section *c* is to find out where accountability lies currently, and how it might affect the growth and expansion of the industry. The aim of section *c.i* is to identify the bottle-necks in the 'social contract' on a local level to ensure that the industry can address or mitigate for issues where they come up and thus increase their social licence.

Outcome: Identification of spaces where the values of the aquaculture industry and other marine users and stakeholders are aligned, where there are areas that can be negotiated, and areas which are likely unnegotiable. Identification of where accountability lies on a national, strategic level and how the associated policies and regulations might reduce coexistence potential. Identification of where accountability lies at a local level and the actions which reduce coexistence. Increase understanding of what changes and actions are necessary to achieve coexistence. Probable production of area maps using GIS or other software, integrated with more detailed additional qualitative information.

Methods: This question was addressed by analysing public comments on new aquaculture developments, interviewing stakeholders, assessing current marine management policies and strategies, spatial modelling of characteristics relating to landscape and seascape, and interactive visualisation tools. Undertaken by James Hutton Institute, Marine Scotland Science and the Scottish Association for Marine Science.

15.3. *Tools used in the case study*

These include numerical modelling, GIS or GIS-related, and public-perception, tools. In addition to deploying tools, JHI has also acquired landscape, seascape and aquaculture data for use in GIS. The latter includes the distribution of sites within Argyll and Bute where licences have been granted for development (from MSS), and the locations of each fish cage (a new dataset, interpreted and digitised from aerial photography).

15.3.1. *Hydrodynamic modelling for sea-lice connectivity (SAMS).*

An FVCOM hydrodynamic model (Adams et al, in press) was developed to explore the connectivity between populations of sea lice – answering research questions 1 and 1a. It incorporates spatial and temporal variables of sea lice abundance and chemical treatment. The model allows the identification of optimised boundaries for sea lice management, and estimates the lice load to and from sites placed in new locations.

15.3.2. *Visibility mapping (SAMS, UCC)*

SAMS and UCC have been developing a GIS layer which contains information about the visibility of the coastal sea area from buildings, based upon the analysis of visibility using a high resolution Digital Terrain model, addressing question 3a.

15.3.3. *MaRS GIS tool (MSS)*

The Crown Estate's Marine Resource System (MaRS) GIS based multi-criteria evaluation tool has been applied to all of Scottish coastal and offshore waters, addressing question 3a. Eighty data layers describing the technical, environmental, socio-cultural and industrial opportunities and constraints to finfish and shellfish development were used, with weights and scores specific to anticipated level of interaction with each aquaculture type

15.3.4. *AQUASPACE GIS tool (MSS)*

The AQUASPACE tool developed under WP3 has been applied to the Argyll Scottish Marine Region (SMR) as a test case under the Scottish case study, addressing question 3a. The tool is a GIS decision support tool with emerging functionality to allow suitability reports (covering e.g. economic, environmental and multispecies potential factors) to be produced for any given location within the study area domain.

15.3.5. *Google Earth and virtual landscape and farm tool (JHI)*

Google Earth provides access to geospatial information in a free and widely used interface, usable across different platforms (i.e. desktop computer and mobile devices). It was used to provide visibility information (question 3a) and for public discussion of perceptions of aquaculture in relation to landscape/seascape (question 2c). The layers included in the case study's Google Earth application described six types of conservation area (Marine Conservation Areas (MCAs); Marine Protected Areas (MPAs); Special Areas of Conservation (SACs); Special Protection Areas (SPAs); Nature Conservation MPAs; Sites of Special Scientific Interest (SSSIs); Ramsar sites) and data from the Scottish national landscape character assessment. For three sites studied in detail with respect to public comment analysis, 3D simulations of fish cages have been built, with scenarios of changes in layout with increased or reduced numbers of fish cages.

15.3.6. *Public Comment Analysis (SAMS)*

Public comment analysis for spatially relevant and location-specific social management issues, addressed research questions 2 and 3b, c. It involved searching and coding statements of support and of objection to proposed marine aquaculture development, available on the local authority planning web-site (https://www.argyll-bute.gov.uk/planning-and-environment/find-and-comment-planning-applications).

15.4. Case study results

Results for the Scottish case study are summarised in relation to sets of tools.

15.4.1. *Hydrodynamic modelling: management areas for sea-lice control*

SAMS work on optimisation of management area boundaries for sea lice control within the Scottish case study area has helped answer questions about sea lice connectivity. Connectivity between salmon aquaculture sites is defined as the probability that lice from one group of sites will infect another group of sites. Such connectivity in the Scottish west coast region was computed using a biophysical model, with sites aggregated by existing management unit boundaries. The likely effectiveness of these units for sea lice control has been determined, and optimised boundaries based upon strongly connected regions have been defined, based upon the locations of both active sites (133 within the model domain) and all consented sites (195). The level of activity within the domain affects the suggested size of management units, and the addition of new sites within the domain would require a reduction in the size of management units for a given threshold connectivity. Figure 15.2 is an example map, extending beyond the Argyll study area. For details, see Adams et al. (in press)

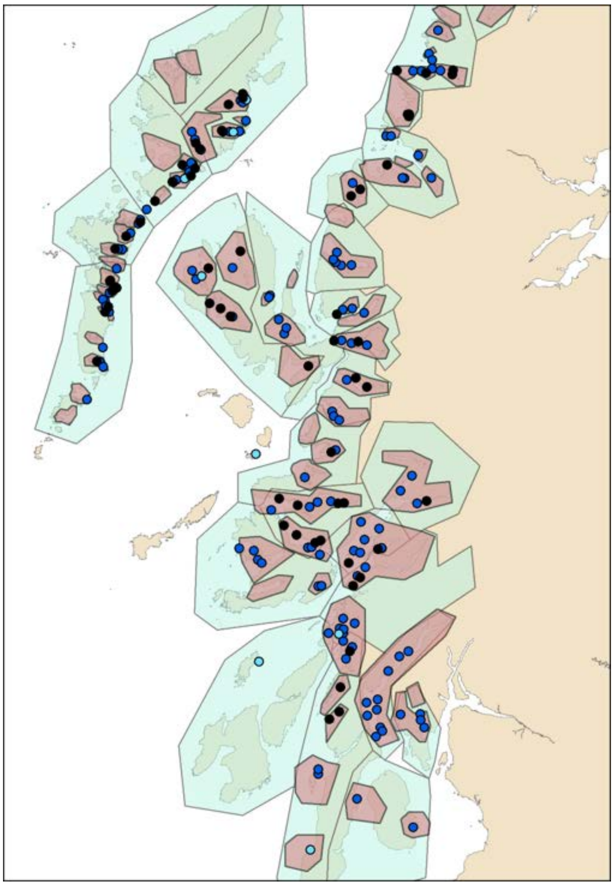


Figure 15.2. A result of the sea-lice connectivity modelling. Each dot represents a consented (and in some cases actual) farm site. The coloured areas are suggested sea-lice management areas, based on two threshold values for connectivity. All farms in a given area should be treated at the same time, because of high internal connectivity (risk of re-infection), but can be dealt with independently of other areas, because there is a low risk of infection between areas.

15.4.2. *7.2. Visibility mapping*

Figure 15.3 is a screenshot of part of the Argyll Case Study area, made using the SAMS-UCC visibility mapping tool; it shows in red parts of the sea that can be observed from many buildings, a consequence both of density of on-shore settlement and open-ness of view. Farms cited here may be subject to more public concern than those in low-visibility areas (in green). This information (and see also O'Higgins et al.(2016)) has been shared with Scottish Government who will include it in their Marine Atlas thus contributing to information available to planners at all levels of Government as well as all other stakeholders.

Figure 15.4 is an analogous map, using results from the JHI Google Earth model: it contours the maximum number of fish cages that can be seen from each point, assuming that sight-lines are not interrupted by trees or buildings. Data on visibility of existing aquaculture sites can be imported to the AQUASPACE tool and used in association with layers relating to cultural heritage, and potential cumulative visual impacts on refining areas of suitability for aquaculture development. They will be used in knowledge exchange and dissemination activities.

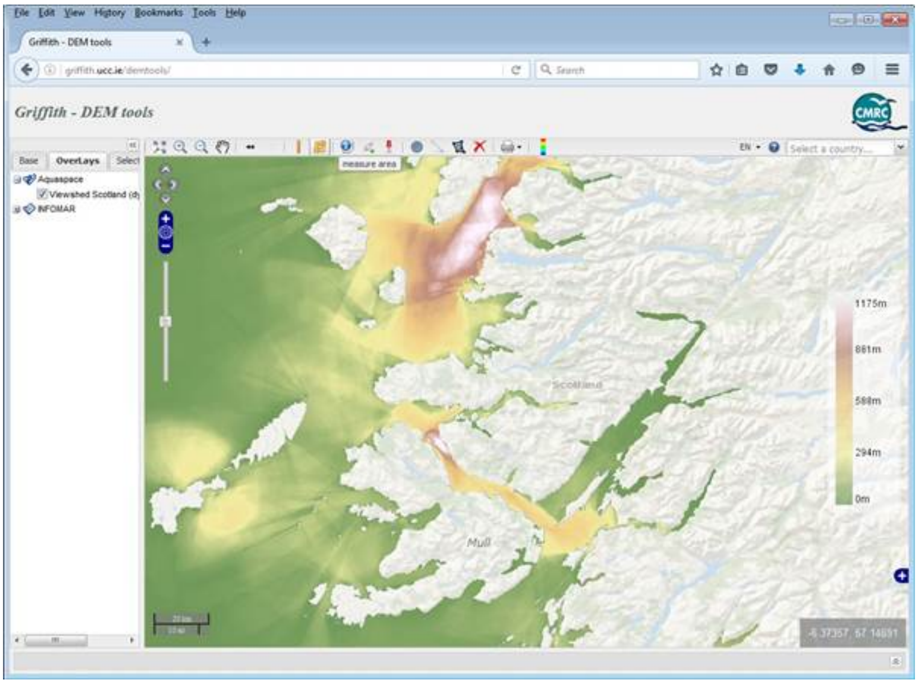


Figure 15.3: view-shed from buildings in Argyll. Green colours represent visibility from a small number of buildings; red colours represent visibility from a large number of buildings.

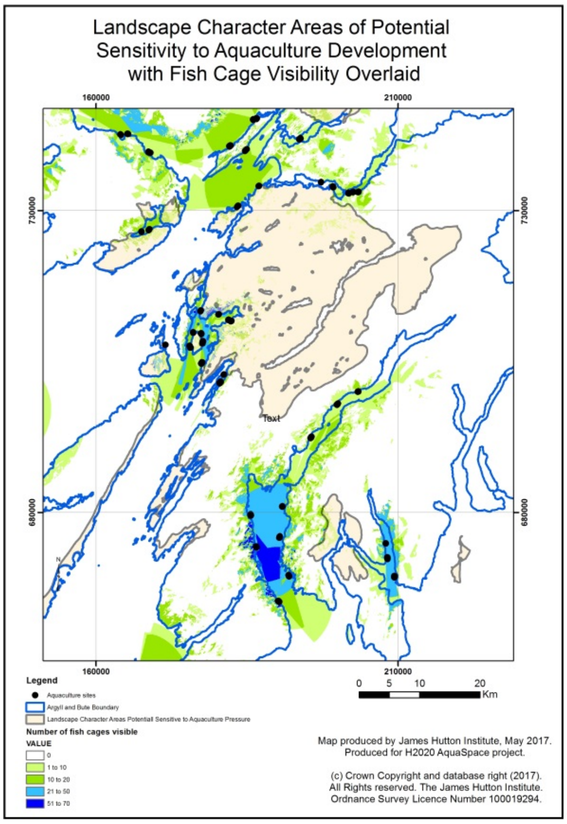


Figure 15.4: Visibility of fish cages in north Argyll and Bute overlaid on landscape character areas identified as sensitive to aquaculture related development. Note that while the black dots show farm sites, the contoured variable is number of cages.

15.4.3. *GIS tools for identifying constraints*

1) MaRS modelling (MSS). Provisional outputs of the different model components have been produced and are being reviewed for suitability. Some data layers are already out of date and are being updated to produce final products. In general terms environmental constraints primarily arise from areas of restricted carrying capacity, locations important to wild salmonid fisheries and conservation. Socio-cultural constraints are dominated by landscape and visual impact concerns and confined to close to the coast (see section 7.2). Some other marine sectors compete for the same space (inshore fisheries, ferry routes, some recreational uses) while others utilise very different areas and offer little constraint (marine energy, shipping). Overall, there are multiple constraining factors present in all parts of the Argyll Marine Region, but considerable variation exists in the level of net or combined constraint across the region (e.g. Figure 15.5). This suggests that the tool is able to identify the most suitable areas for potential expansion of the industry cross a range of possible factors.

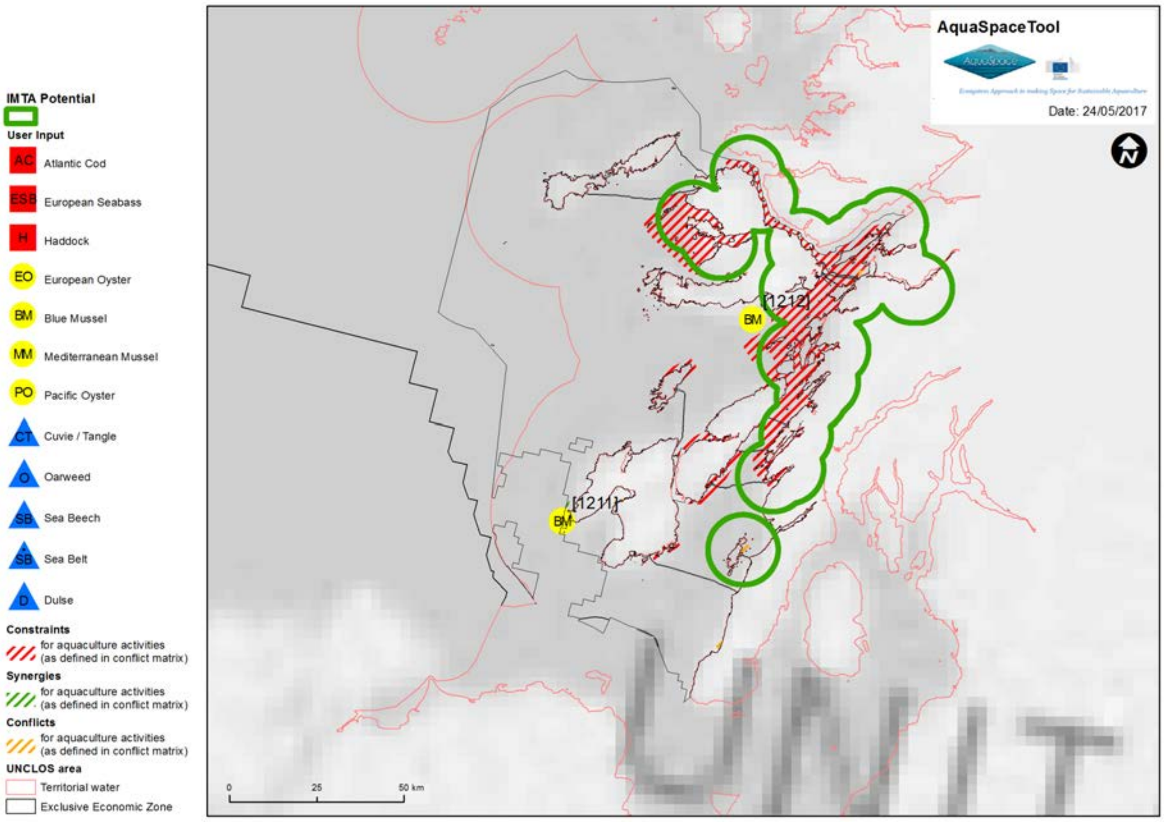


Figure 15.5. Aquaspace tool map showing areas of greatest constraints on finfish aquaculture

2) The AQUASPACE tool has been applied to the Argyll Scottish Marine Region by MSS by applying an aquaculture suitability layer (based on the extent of the marine region minus areas of exclusion identified from the MaRS model), and substituting locally relevant datasets for the European scale datasets initially provided as standard with the tool. The tool is currently able to produce suitability reports for any selected location for chosen species (e.g. Figure 15.5). Locations indicated as most suitable by the MaRS model have been selected and the suitability parameters (environmental, economic, disease) for potential locations recorded from suitability reports for shellfish (blue mussels) and finfish (currently sea bass, but Atlantic salmon is being enabled as a species within the model for imminent release). The suitability indicators are being collated and will be compared between areas of known low and high suitability to test the accuracy and usefulness of the tool. Relative changes in suitability across the region will allow further interpretation of outputs under (1) above, and would help to identify new areas of space where aquaculture can either coexist with current uses and sensitivities or find new under-utilised and less sensitive locations. Recommendations will be made on future potential developments of the tool, based on the experiences in this case study.

Further work is underway to resolve some issues relating to the application of both tools. Specifically, some of the MaRS data layers are being updated with the latest data and sense checked with stakeholders (wild salmonid sensitivity) and some of the European data sets provided with the AQUASPACE tool are being updated with higher resolution, locally relevant data sets to improve the accuracy of reports, particularly for regions with complex topographies.

Final products will be made available on the AQUASPACE website (AQUASPACE tool) and the Scottish Government marine planning portal NMPi (MaRS output files).

15.4.4. *Public reactions to aquaculture visualisations*

To obtain insight to the perceptions of public audiences with respect to seascapes, the interactive model (aquaculture simulator) of the Firth of Lorne was used by JHI, supported by the Google Earth model for discussion of designated areas and the current distribution of aquaculture sites across all Argyll and Bute. A consultation event was carried out in Oban, 27-28 May 2017, with 325 attendees. The tools enabled participants to explore the extract of the case study area, view existing structures, and scenarios of alternative uses of coastal waters by energy, aquaculture and leisure sectors, and the range and type of landscape related designations (Figure 15.7). Initial interpretation of feedback noted:

- Limited knowledge of types of protection of landscape and seascapes (e.g. National Scenic Areas spanning land and sea).
- Associations of fish farming with rural development and a diversified economy in relatively remote rural communities.
- Proposals for siting developments focused on the vicinity of plantations of forestry, reflecting associations of fish farming with primary production landscapes, and a perception of benefits from clustering such activities.
- Links with characteristics of the seascapes of west Scotland, such as traditions of fishing and promoting the international reputation of the area for high quality produce.
- Negative links between fish farm development and coastal areas were noted where participants perceived areas as 'wild' or 'natural', where development was intrusive.
- The data from Google Earth and the mapping of the fish cages in Argyll and Bute showed that the surface extent of such features is small (measured in terms of tens of square meters) but that arrays of cages lead to geometric patterns in a landscape which may be inconsistent with the shape and scale of the coastline.

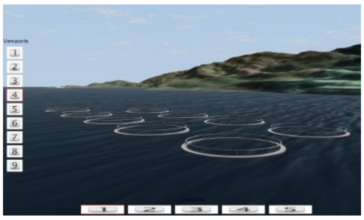


Figure 15.7(a) View of the interface to the model for creating seascapes, including circular fish cages.

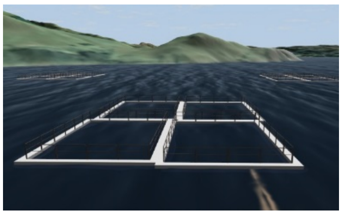


Figure 15.7(b) View of rectangular fish cages placed in model of hypothetical seascape.

Figure 15.7(c) Viewing inside of fish cage, with water surface and reflections visible.

To explore the choices that members of the public could make with respect to the uses of coastal waters, and why, the interactive 3D model for creating seascapes was used. This enabled options for aquaculture, renewable energy and tourism related activities to be selected and located within the model area. These choices of feature and location were recorded, and questions asked to expand upon why decisions were made. Preliminary findings were:

- Strengths of the approach were identified as ease of identification of location, interpretation of land features, and ease of placing features into the model (e.g. aquaculture, renewable energy).
- Weaknesses of the approach were slow re-positioning of features, inability to reorient new features, limited additional information to aid siting (e.g. tides, links to onshore infrastructure)
- Reasons for 'aquaculture' preferences included; away from housing, but not necessarily out of sight, close to shore for access, in vicinity of visual evidence of use of adjacent land for productive means (including forestry).
- Reasons for 'no aquaculture' preferences included; close to existing uses for marina or leisure craft, close proximity to historic features (e.g. Castle), away from areas appearing remote or wild.

To gain further insight to public understanding of aquaculture, the simulator was used to explain the principal infrastructures of such a development. Preliminary feedback, documented using electronic voting and in discussion with participants, noted:

- Limited knowledge of feeding systems as part of the infrastructure of a development.
- The potential significance of feed storage barge in relation to seascape intrusion.
- Questions arising included the colour of cage structures and storage facilities, time periods over which structures remain, layout and positioning of cages, and the shape of cages.

15.4.5. *Public Comment Analysis*

There were a total of nine applications submitted for new marine shellfish and finfish sites between 2012 and 2016 in Argyll and Bute. The public comment analysis was applied to data for four new finfish farms that had submitted planning applications from 2012-2016 and had been commented on by the public. It also included one application for an extension to one of these farms. The 1388 public comments were analysed for:

- Type of comment (objection/ support/ neither)
- Location of commenter, if provided
- The information sourced in the comments
- The themes contained in the comment

All five of the applications received both supportive comments as well as objections; the breakdown can be seen in Table 15.6. The location of the commenters was recorded for both of the Loch Etive applications (2013 and 2016) and the Loch Striven 2013 case. Table 15.7 provides a summary. No locations were recorded for the Loch Slapin or Isle of Shuna cases because they were not available in the public documentation.

The key themes from the comments that were supporting the developments are:

- Employment is a high priority
- Aquaculture supports local supply-chain jobs
- Aquaculture keeps young people in areas which are de-populating
- Those providing comments trust that regulation of the industry is good enough to mitigate environmental damage
- The business of aquaculture is sustainable

The key themes from the comments that were objecting the developments are:

- Environmental concern is the top priority
- Visual impact is the second highest priority and is linked with the perception that tourism suffers when new aquaculture sites are planned
- Those providing comments felt that the industry is not regulated enough, especially in relation to wild fish interactions

Table 15.6. Number of public comments that were analysed

Planning case	Date	Type of comment		Total number of comments
		Objection	Supporting	
Loch Striven	2012	12	35	48
Loch Etive	2013	589	218	812
Loch Etive	2016	225	183	408
Isle of Shuna	2014	29	17	49
Loch Slapin (pilot)	2014	69	2	71
Total		924	455	1388

Table 7. Summary of the locations of the commenters according to the application and type of comment

	Objection		Support	
Planning Application	**Number of locations in UK**	**Number of locations globally (including devolved UK governments)**	**Number of locations UK**	**Number of locations globally (including devolved UK governments)**
Loch Etive 2013	156	11	57	4
Loch Etive 2016	81	10	41	4
Loch Striven 2013	3	1 (Scotland)	18	1 (Scotland)

There were 38 different sources of information that were used in the public comments. These sources included; personal opinion, a standard email that was copied and pasted by commenters, an Integrated Coastal Zone Management Plan (ICZM) for the Loch Etive case, the planning applications themselves, an anti-fish farming NGO, the Scottish Environment Protection Agency, and the fish farm company websites. It was evident that the sources cited were key in engaging public interest in the planning process. It was also evident that they polarised views within the host communities.

Public comments, at the stage of seeking planning permission, cause ‘bottle-necks’ which increase the time and cost of obtaining permissions for a new site or a change in activities at an old site. Findings suggest that individual actors play a key role in the engagement of communities within the consultation period for the Local Authority-led Town and Country Planning (Scotland) Act 1997, planning permission process. They act as catalysts for objections or support of a given development. The information used in engaging communities and individuals is often polarised – there are few sources of objective information which inform the general public. The public consultation period also functions as a platform for public debate on the ethics and morals relating to environmental protection, and corporate interests and behaviour, in certain cases.

As a rural county, Argyll and Bute relies heavily on both aquaculture and tourism for maintaining economic activity (Argyll and Bute Council, 2016a) and as such both are written into its Local Development Plan (Argyll and Bute Council, 2015). However, the interactions that these two industries have with each other on a local scale and within local society, is not well understood or recorded. In order for the strategic policies to be effective, more applied, local scale research is needed, to pinpoint where there are choke points. This study goes some way towards that by showing that perceptions of appropriate 'use' of the marine environment affects social licence to operate (SLO) levels for aquaculture development. It shows that single individuals can disrupt and skew local scale dialogue on aquaculture developments, making it difficult to assess the efficacy and ethical basis of a proposal. Additionally, it highlights that there is a need for robust data on the interactions between aquaculture and tourism in Scotland. This data could be used to alleviate confusion caused by perceived conflict between policies, thus increasing public trust in government and regulatory bodies which would help facilitate the equitable development of both the aquaculture and the tourism industry.

15.5. Relevance of the case study within AquaSpace (Conclusions and prospects)

Argyll and Bute has a long coastline and suitable waters for aquaculture development. However, due to current management, planning and social constraints the identification of areas where expansion is acceptable and desired are limited and difficult to identify. Currently, the aquaculture industry spends considerable time and money seeking to expand into new sites, or change the use of current sites, with varying outcomes. The complexities involved in whether or not the industry gets their licences and planning relate to environmental and social carrying capacity.

1) *The results from the FVCOM hydrodynamic model* (SAMS) will inform better systems for the management of sea lice in marine finfish farming. Although the connectivity issue (and the identification of lice management zones) is only a part of the complex of issues (including fish health, farm management, perception of the industry, and impact on wild salmon), it is one particularly relevant to Aquaspace's goal of identifying increased space for aquaculture.

2*) Comparison of GIS tools for spatial planning* (MSS). The MaRS outputs suggest this tool is able to provide high resolution spatial data indicating areas of greatest / least suitability for new finfish / shellfish aquaculture types. The model is very data and resource intensive and as such does not lend itself to regular or ad hoc application (and future availability is in question as it is owned by the UK Crown Estate, rather than Crown Estate Scotland). However, appropriate weighting and scoring of constraint factors can be used to produce indications of likely suitable areas within the Argyll Marine Region showing a variation in both technical, environmental and socio-cultural constraint / opportunity across the region. While outputs indicate relative suitability they do not allow an exploration of the factors leading to site specific constraint.

Such exploration can be achieved with the functionality of the AQUASPACE tool. This allows users to select a location and receive a detailed site specific report of the environmental factors, economic potential and other factors relevant to the selected sites. The input data varies in resolution and scale from that used in MaRS and is of relatively limited scope, but the application of these tools in combination allows a stepwise approach to be taken. This enables a broad indication of the area of suitability based on a wide variety of data types, followed by detailed site specific investigation of potential by species resulting in site specific suitability reports.

3) *Visibility analysis* (SAMS-UCC and JHI). These analyses have provided maps (and potential GIS layers) to show regions where social constraints are likely to be more or less intense (and, depending on public attitudes to the appearance of farms in relation to landscape and seascape).

4) *Public perception studies* (JHI). The preliminary results from these studies have begun to identify the issues relating to public perceptions of farm equipment.

5) *The public comment analysis* (SAMS) has shown that, despite the aquaculture industry's perception that there is a public acceptance problem, this is only the case in a few high profile areas. The majority of planning applications for new farms in Argyll have been accepted without comment from the public. This means that how individual companies handle the high profile cases is important for the industry as a whole, as they are a 'showcase' for the industry in the local area and sometimes in national press. Two cases have shown that individuals with effective communication techniques can significantly impact planning disputes as well as the industry's perception of public acceptance. Additionally, there can be lack of public trust in regulating agencies. This suggests that greater understanding of Social Licence to Operate (SLO) issues, and better implementation of SLO guidelines by regulators as well as industry, would help ameliorate the social constraints on aquaculture expansion.

15.5.1. *Papers (from the work described here)*

Adams, T.P., Aleynik, D., Black, K.D., in press. Temporal variability in sea lice population connectivity and implications for regional management protocol. Aquaculture Environment Interactions. doi:10.3354/aei00203

O'Higgins, T., Black, K.D., and Dunne, D., (2016). Many points of view: Visual amenity mapping for marine spatial planning and aquaculture. Submitted to PLOS ONE.

15.5.2. *Acknowledgements*

The Aquaspace project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement 633476. Seafloor data for SAMS modelling and JHI seascapes were provided by SAMS through NERC MAREMAP and Hydro-Inis programmes. The component of this work undertaken by JHI was also partly funded by the Rural & Environment Science & Analytical Services Division of the Scottish Government, and further developed under the European Union AquaSpace project (www.aquaspace-h2020.eu/). The aquaculture simulator used by JHI was developed by Anders Bøe, Norwegian University of Science and Technology. Further information can be obtained from www.boeconsulting.no. The MaRS model was developed by The Crown Estate and modified by Marine Scotland Science. Thanks are also due to the participants in the Aquaspace stakeholder workshop, and public attendees at research events in Oban and Aberdeen.

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16. PELORUS SOUND, MARLBOROUGH, NEW ZEALAND

John Zeldis, Amy Whitehead, Michelle Greenwood,

NIWA 10 Kyle St. Riccarton, Christchurch 8022, New Zealand

Mark James

Aquatic Environmental Sciences Ltd., PO Box 328, Whangamata 3643, New Zealand

16.1. General characteristics

Greenshell™ mussel production is the largest aquaculture revenue earner in New Zealand. Of this, Pelorus Sound (Figure 16.1) accounts for about 68% of New Zealand's production, where harvests are about 75,000 tonnes of green weight annually, generating around 170 million Euro per year in revenue. In Marlborough Sounds there are approximately 1,000 people directly employed in aquaculture. In addition, many more are involved in the "downstream or flow on" effects of the industry.

Fluctuations in the per-capita meat yield of Pelorus Sound mussel farms have resulted in substantial economic impacts and distortions within the industry. This case study demonstrates the development of a tool to forecast farmed mussel yield in Pelorus Sound.

Predicting the biological yield of aquaculture is important to the industry carrying out the farming. Planning stocking rates based on predicted growing conditions, or predicting the longevity or return periods of poor growing conditions, requires understanding of the drivers of secondary production of the aquaculture system. Mussel aquaculture relies on suspended seston supply for its nutrition so it can be expected that variability in seston supply over time and space will affect farming success. Seston, in turn, is formed via primary production and is composed of living and detrital material, so it is reasonable to expect that environmental drivers of primary production will have flow-on effects on seston abundance and bivalve aquaculture performance. Such linkages mean that if predictive models and understanding of the drivers of seston abundance can be developed, plausible models for predicting spatial and temporal variability in mussel yield may follow. In the Pelorus Sound case, this raised the potential for gaining information on lead time in terms of predicting growing conditions for different locations, and also on the potential longevity of good or bad conditions, once they take hold. This led to the predictive tool supported in this website.

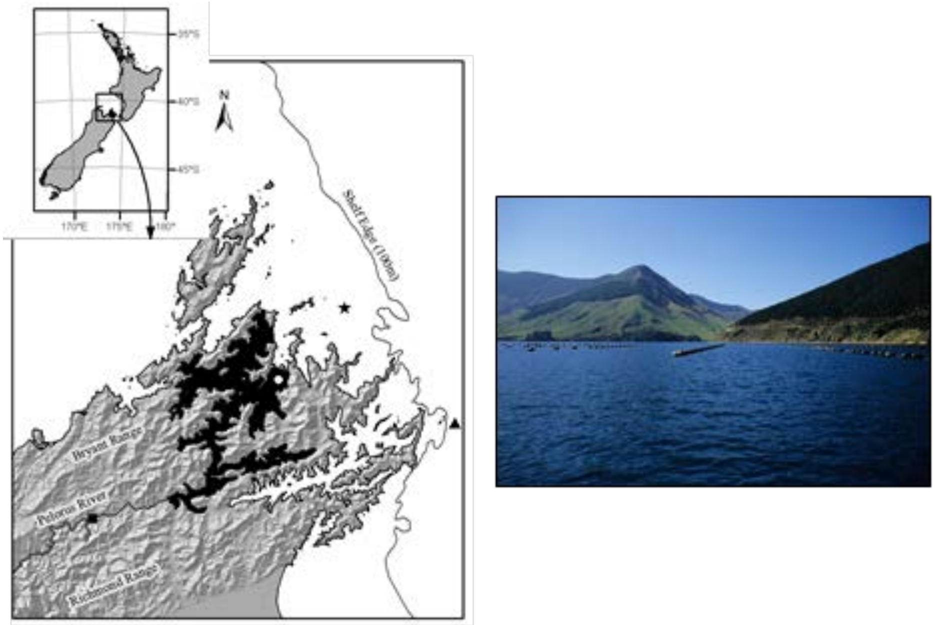

Figure 16.1. Pelorus Sound (blackened) in the Marlborough region of New Zealand. Also shown is a view of a typical mussel farm in the region (Clova Bay, Pelorus Sound).

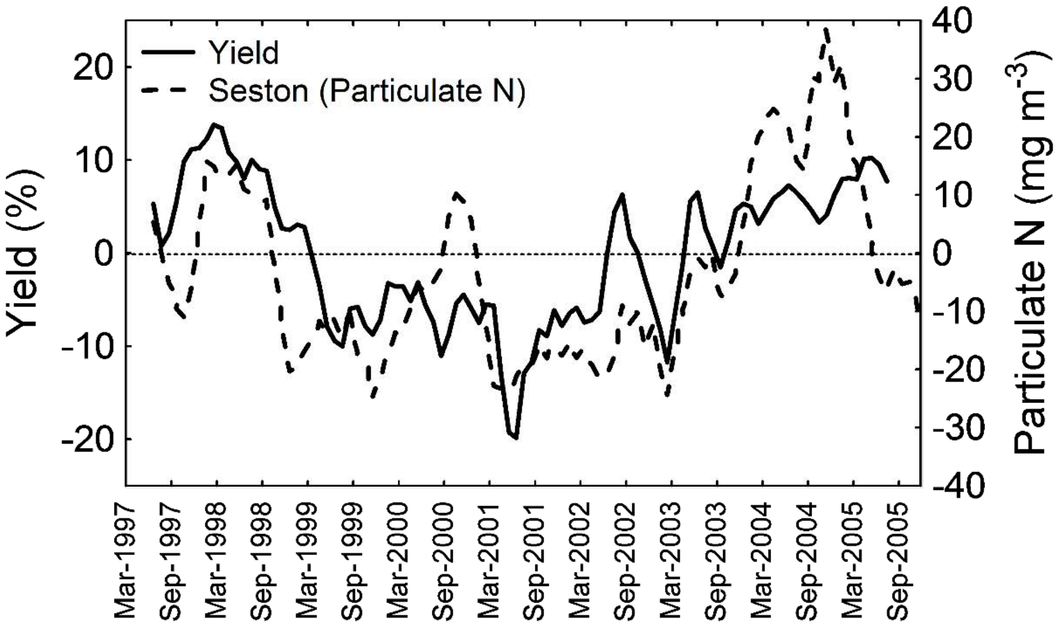

Figure 16.2. Variation in mussel meat yield (solid line), and their food (seston: dashed line), between 1997 and 2005, as measured by Sealord Shellfisheries and the Marlborough Sound Shellfish Quality Programme (MSQP) programme. Data are expressed as anomalies from the long-term average.

16.2. Spatial planning and management issue

Records collected by Sealord Shellfisheries between 1997 and 2005 show a large decline and then upswing in meat yield anomaly over a six-year period, representing more than 20% variation in mussel meat production (Figure 16.2). At the same time, Sealord Shellfisheries were collecting these records, the Marlborough Sounds Shellfish Quality Programme (MSQP, funded by the mussel industry and NIWA) were collecting water quality data throughout Pelorus Sound. The data showed that the abundance of the food of mussels, seston, varied coincidentally with the mussel meat yield (Figure 2). Therefore, it was concluded that variable food supply was at the root of the variation in mussel meat production.

Other management issues for the mussel industry are uncertain spat supply, biosecurity related to biotoxin-producing microalga, plankton depletion and benthic effects.

The fluctuations in the per-capita meat yield of Pelorus Sound mussel farms have resulted in substantial economic impacts and distortions within the industry. Similar fluctuations (both negative and positive) have been observed again in more recent, anecdotal accounts (2007−2008: negative, 2015-16: positive). Major economic incentives thus underscore the need to understand the drivers of mussel production in this area.

The case study in Pelorus Sound is predominately on farming the mussel for *Perna canaliculus*. New Zealand's largest salmon aquaculture farms (for Chinook salmon: *Oncorhynchus tshawytscha*) are also located in Marlborough Sounds.

Mussel farming techniques are predominately ribbon development of suspended line culture. The average lease is between three and five hectares although farms may vary from one hectare to 20 or more. Each three-hectare farm would typically have nine longlines of 110 metres each. Each longline would support 3,500 to 4,000 metres of crop line. Each long line is supported by 50 to 70 polypropylene floats, each of which can support one tonne.

Nationally, in 2011 over 100,000 tonne greenweight of mussels was harvested with an export value of 218 million NZD (150 million Euro) and a domestic value of 24 million NZD nationally. The trend is that there has been a stable increase in the average annual production from 1998 to 2016. The National Aquaculture Strategy is the blue print to becoming a billion-dollar sector by 2025.

Farmers do not own their farms but are granted a coastal permit by Regional Councils to use the water space. There are sectoral plans – by region either preselected for potential investment or more usually, allocation on application. Approval is dependent on EIAs and possibly regional/environmental court hearings to resolve conflict of use issues. Twenty percent of allocated aquaculture space is reserved for the Māori (the indigenous Polynesian people of New Zealand).

16.3. Stakeholder engagement and participation

Aquaculture New Zealand and Marine Farming Association and the companies Sanford Ltd and Seafood Innovation Ltd (SIL) have been engaged as stakeholders.

Acknowledgement is given as; the operationalisation of the forecasting tools, including the setting up of a web site and further validation, using ongoing monitoring of environmental variables and mussel condition/yield from five different growing areas, was made possible through the Seafood Innovation Ltd Project 1404 "Environmental prediction of mussel growth", which is funded

by Seafood innovations Ltd, Sanford Ltd and Marine Farming Association and led by Dr Mark James of Aquatic Environmental Sciences Ltd. The development of the predictive models was funded as part of NIWA's core funding from the MBIE within the 'Aquaculture Applications' project of the 'Environmental Effects of Aquaculture' programme (ACEE 1703).

A workshop on the science behind the tool was held in September 2015, with participants from science and industry. NIWA have received positive responses to the website from industry users.

16.4. Tool used in the case study

NIWA have produced a website application that produces forecasts of mussel meat yield for the Pelorus Sound Greenshell™ mussel industry (Figure 16.3: see Glossary for definitions of terms in bold). The tool is implemented on a password-protected web application for farmers. The forecasts were created from the NIWA research described below, made in conjunction with the mussel industry, which has found that climate influences mussel yield. By combining these climate-mussel relationships with future climate forecasts, we have developed a method for predicting summer mussel yield in Pelorus Sound. These indicate whether upcoming growing conditions are likely to be average, better, or worse than average. Combined with the knowledge of conditions in the recent past, these may help farmers plan stocking and harvest rates and improve business projections over coming months.

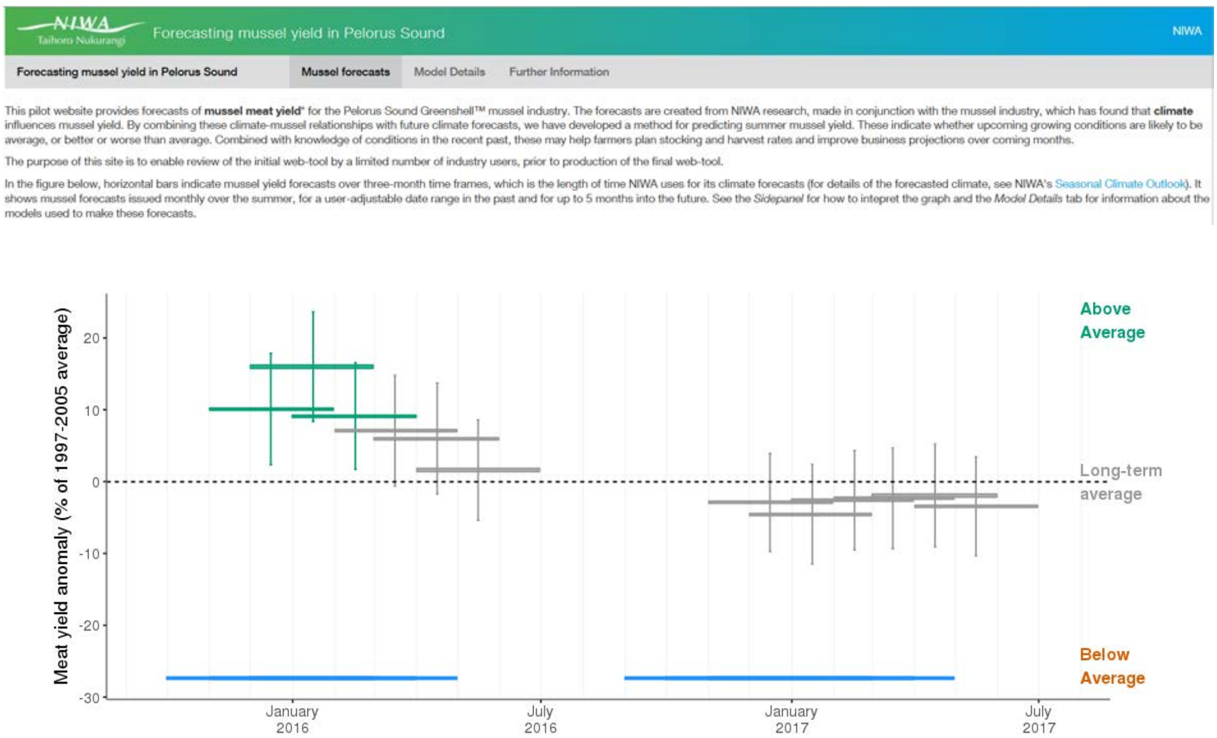

Figure 16.3. A screenshot of the mussel yield forecasting tool front end and example summer mussel yield forecasts for Pelorus Sound.

Figure 16.3 shows a screen grab of the website front end and an example prediction. Horizontal bars indicate mussel yield forecasts over three-month time frames, which is the length of time NIWA uses for its climate forecasts (for details of the forecasted climate, see the 'Climate Forecasts' section below). It shows mussel forecasts issued monthly over the summer, for a user-adjustable date range in the past and for up to 5 months into the future.

A dropdown menu can be used to change the date range to view forecasts between 2006 and five months into the future. Yield data are expressed as anomalies from the long-term average (1997-2005).

In Figure 16.3, the crosses include horizontal bars which indicate the predicted mussel yield anomaly for each month between November and June, expressed as the percent anomaly compared to the long-term average yield. The vertical bars are estimates of prediction uncertainty (explained further below). The dotted line represents the long-term average mussel yield based on observed data from 1997 to 2005. This was the 'base period' for our original model (see 'Background: Variable Mussel Production' section below).

Green bars represent yield forecasts where the error bars are above the dotted line. For these points we are 80% confident that mussel yields will be *above* the long-term average.

Gray bars represent yield forecasts where the error bars cross the dotted line. For these points we cannot say with 80% certainty that mussel yields will be better or worse than the long-term average.

Orange bars represent yield forecasts where the error bars are below the dotted line. For these points we are 80% confident that the mussel yields will be *below* the long-term average.

Blue lines show the duration of the seasonal climate outlook forecasts used to forecast mussel yield. Note that mussel yield forecasts are delayed by two months with respect to the climate forecasts, because it takes about that long for mussel growth to 'react' to climate conditions (see 'How we make the forecasts of mussel yield' section, below).

16.4.1. *How we make the forecasts of mussel yield*

To create the forecasting tool, we used statistical models to combine multiple climate variables with measures of historic mussel yield. We used a historical data set of yields measured on the harvesting vessels when mussel lines were harvested between 1997 and 2005 in Pelorus Sound. We used the mussel yield observations and the coincident climate values, to find the best combination of climate variables to predict those yields. This is detailed in Zeldis et al. (2013).

In the 2013 work, we used monthly values of the El Niño-Southern Oscillation (ENSO; a measure of the strength of El Niño/La Niña conditions), wind directions and strengths from wind monitoring stations in Cook Strait (Farewell Spit and Brothers Island), satellite-derived sea temperature at Pelorus entrance and gaugings of river flows measured at Bryant's Stream in the Pelorus River. All of this data was available from international or NIWA databases for the 1997-2005 period. We then compared our predicted values of mussel yield with those actually observed, to gain an understanding of the reliability by which we could predict yield from climate variables.

However, the next steps in terms of generating forecasts of yield from forecasts of climate, presented a problem which we had to overcome. We are not able to forecast monthly values of sea temperatures, winds or river flow at particular ocean locations, wind stations or river gauging stations as used in the original work (which used historical observations; Zeldis et al. (2013)). We therefore needed 'proxy' climate variables, which emulated those original variables but could also be forecasted.

To get a proxy variable for winds, we took advantage of the fact that wind directions and strengths are a function of air pressure differences across New Zealand (in this case, between Auckland and Christchurch). Because these air pressures can be forecasted, this enabled us to predict future wind conditions. For the river flow proxy, we estimated runoff into the Pelorus catchment using forecasted rainfall, evaporation and temperature, all of which can be forecasted. For ENSO, we used an index called Niño 3.4, which is the average sea temperature anomaly in the central Pacific Ocean.

We forecast all of the proxy variables above using a strategy known as 'analogue forecasting': essentially, using the past, to predict the future. New Zealand climate databases of past conditions (about 45 years long) are searched to find those which most closely match current conditions. The climate which occurred in the 3 months following that previous time, is taken as the forecast from the current state to 3 months into the future. See Mullan & Thompson (2006) for more details.

We then use these forecasts of the climate variables to make predictions of future mussel yield for the coming season using our original climate-mussel yield model. Our work showed that climate conditions related to mussel yields occurring about 2 months later, because it takes about that long for nutrient-rich water to mix into the sound, to create seston, and then for the mussels to respond with improved growth. This, combined with the fact that NIWA climate forecasts are often made 'seasonally' for the upcoming 3 month period, indicates that mussel yield forecasting could extend up to 5 months into the future for the summer months.

Due to uncertainties in the statistical models, we are unable to predict mussel yield adequately using the winter half-year climate data. We therefore do not present any forecasts for the period June through October, inclusive. We do present forecasts based on the summer half-year climate forecasts, but only evaluate them as being above average, average or below average, after considering the imprecision of the estimates.

16.4.2. *What 'drives' the variation?*

Further investigation showed that climate is a main driver of the variation in seston availability. We found that climate conditions occurring in the summer and winter halves of the year affected mussel yields differently. The pathways by which this operates are shown in Figure 16.4.

Ocean upwelling is a strong driver in the summer months (October - March) because it supplies dissolved nitrogen from the deep waters of Greater Cook Strait. As these enriched waters are drawn into Pelorus Sound by **estuarine circulation**, it stimulates seston production, increasing mussel yield. The upwelling is driven by westerly winds in the Greater Cook Strait region, most common in **El Niño** summers. In contrast, **La Niña** summers are dominated by easterly winds, resulting in less upwelling and lower seston concentrations. Therefore, the presence of El Niño and westerly winds are strong drivers of increased mussel yield in the summer months. NIWA has statistical models that enable us to forecast the future state of the El Niño/La Niña condition with moderate confidence three months into the future.

The story in the winter months (April - September) is somewhat different. At that time of year, seston concentration and mussel yield are most strongly associated with increases in Pelorus River flow. Wetter-than-average years have more nutrients added to the sound, increasing mussel yield.

The freshwater also decreases the tendency of the water column to mix vertically, enabling phytoplankton to grow better in the well-illuminated, upper parts of the water column.

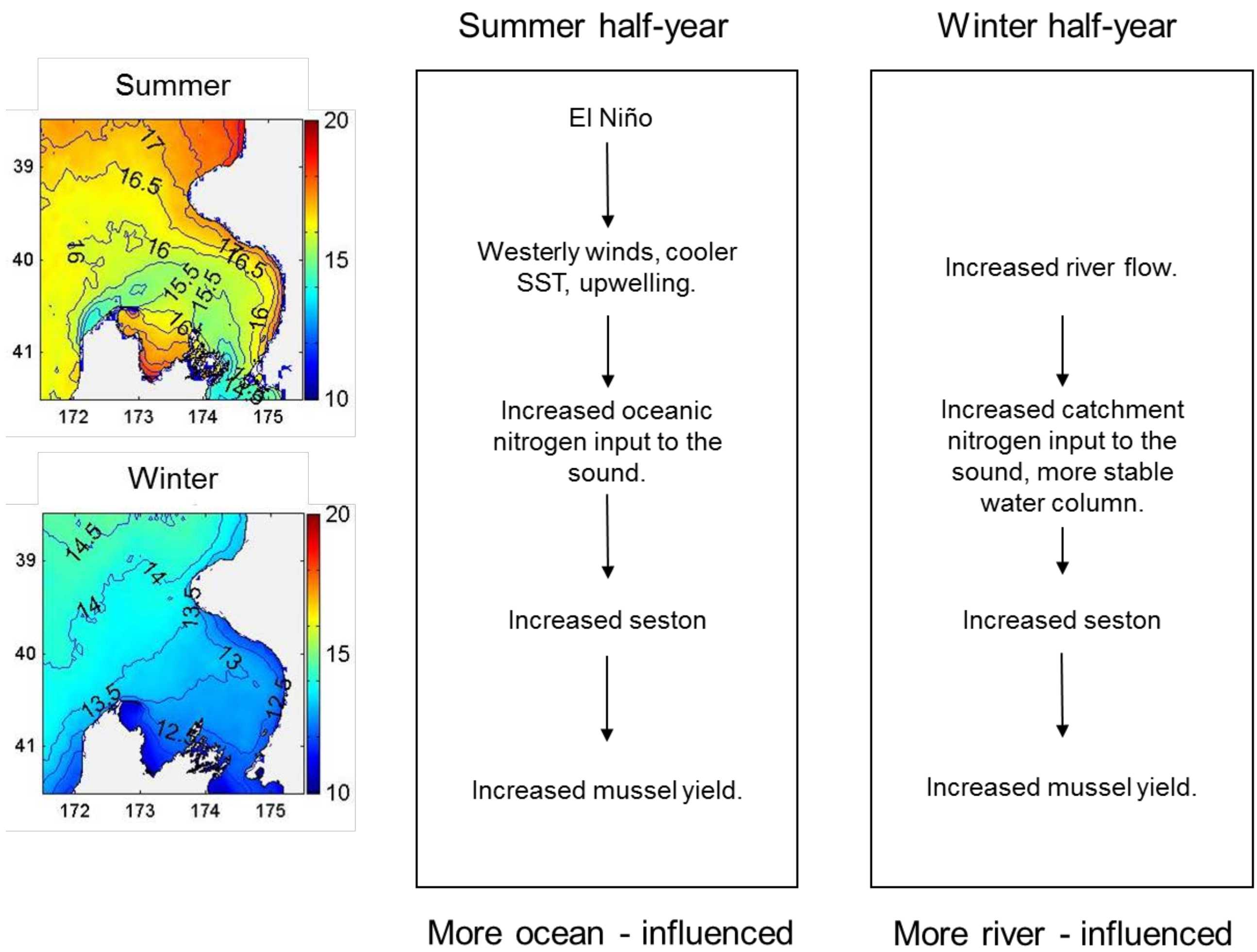

Figure 16.4. How climate affects mussel yield in Pelorus Sound. The left panel shows maps of sea surface temperatures (SST) derived from satellite data, in summer and winter across central New Zealand. Warm temperatures are shown by 'warm' colours and higher values of the superimposed contour lines. In summer, relatively cool, upwelled waters are clearly seen in Greater Cook Strait including the area of Pelorus Sound entrance. In winter, upwelling disappears as sea temperatures cool everywhere, and waters are mixed by winter storms. The right panel describes the chain of climatic effects that drive seston concentration and mussel yield. In the summer half-year (October - March) effects are mainly from oceanic effects (El Niño, westerlies and upwelling), whereas in winter (April - September) the local effects of increased river flow become more important. See Zeldis et al. (2008) and Chiswell et al. (2016) for more details.

16.4.3. *References*

More details about the models that underpin these mussel yield forecasts can be found in the following references:

Chiswell, S.M., J.R. Zeldis, M.G. Hadfield and M. H. Pinkerton. (2016) Wind-driven upwelling and surface chlorophyll blooms in Greater Cook Strait. *New Zealand Journal of Marine and Freshwater Research*:1-25 http://dx.doi.org/10.1080/00288330.2016.1260606

Mullan, A.B. and C.S. Thompson. (2006) Analogue forecasting of New Zealand climate anomalies. *International Journal of Climatology* 26: 485-504. http://onlinelibrary.wiley.com/doi/10.1002/joc.1261/epdf

Zeldis J., C. Howard-Williams, C. Carter and D. Schiel. (2008) ENSO and riverine control of nutrient loading, phytoplankton biomass and mussel aquaculture yield in Pelorus Sound, New Zealand. *Marine Ecology Progress Series* 371: 131-142. http://www.int-res.com/articles/meps2008/371/m371p131.pdf

Zeldis J., M. Hadfield and D. Booker. (2013) Influence of climate on Pelorus Sound mussel aquaculture yields: correlations and underlying mechanisms. *Aquaculture Environment Interactions* 4:1-15. http://www.int-res.com/articles/aei2013/4/q004p001.pdf

16.4.4. *Glossary*

Anomaly: The difference from average over the measurement period, usually expressed for each month of the year. For example, ‘the difference between the value in January 1998, from the average value for all January’s between 1997 and 2005’. In the case of mussel yield, this is given as a percentage of the mean yield that occurred in the data used for the original model created using 1997-2005 mussel yield and climate data.

Climate: To define ‘climate’ we first define ‘weather’, the conditions that have occurred in the last few days or are forecast for the next few days. ‘Climate’ is how the weather behaves averaged over relatively longer periods of time (months to years). In our mussel forecast tool, we are referring to climate as the average of conditions over 3-month-long periods (seasonal forecasts).

El Niño & La Niña: El Niño and La Niña are opposite phases of a naturally occurring global climate cycle known as the *‘El Niño-Southern Oscillation' (**ENSO**)*. They affect patterns of wind and rainfall in different ways in many parts of the world — including New Zealand. During El Niño, in summer in New Zealand we typically experience stronger or more frequent winds from the west, whereas during La Nina we typically experience more easterly winds.

Estuarine circulation: Two-layered circulation in inlets affected by freshwater runoff, such as Pelorus Sound. As river - affected lower - salinity water near the surface flows seaward out of the sound, it entrains saltier water and moves it out of the sound. This is replaced by an underlying shoreward flow of higher - salinity shelf water into the sound. This shoreward flow can carry increased nutrient levels, if upwelling has added nutrients to the shelf water.

Mussel meat yield: Mussel meat yield is indicative of the condition of harvested individuals. The values of mussel yield we are forecasting are the meat weight of an individual mussel as a proportion of the total weight of the individual including shell. In developing our model, we used a historical data set of yields measured on the harvesting vessels when mussel lines were harvested. Between 1997 and 2005, 13,000 such records were collected by Sealord in Pelorus Sound.

Ocean upwelling: Ocean circulation that brings deeper, colder and more nutrient-rich water into shallower waters of inner-shelf (coastal) areas. The nutrients include nitrogen, which can fertilise the production of seston, the food of mussels. In Greater Cook Strait, winds from the west will ‘encourage’ upwelling, whereas winds from the east will ‘discourage’ it. Upwelling effects are strongest in summer, but disappear in winter when the water column is mixed by winds and surface cooling.

Seston: Small particles of organic matter suspended in the coastal sea that mussels filter from the water as food. These particles can be live phytoplankton (microscopic single-celled plants), but are mainly non-living organic and inorganic material bound together in aggregates. In water quality monitoring, the abundance of seston is often measured as the amount of particle-bound nitrogen in a known volume of seawater (expressed as ‘particulate nitrogen concentration’).

16.5. Case study results

The workshop on the science behind the tool (September 2015) and feedback from industry users have shown positive responses to the application of the website.

16.6. Application of the tool

Experiences from developing and applying the tool is used to better understand the forecast quality. Because our mussel yield forecasting is based on a number of assumptions it is inevitably uncertain. The model was derived by comparing known historical yields with corresponding historical measures/indices of climate. We added an additional layer of uncertainty by forecasting the climate variables into the future, and then using those forecasts to predict future mussel yields.

A consequence is that we are unable to predict mussel yield adequately using the winter half-year climate data. We therefore do not present any forecasts for the period June through October, inclusive. We do present forecasts based on the summer half-year climate forecasts, but only evaluate them as being above average, average or below average, after considering the imprecision of the estimates.

The climate and mussel data on which the model was based were acquired between 1997 and 2005. We are confident that the model is valid because it is consistent with known oceanographic and ecological principles. However, data collected in the future could predict somewhat different associations between mussel yield and climate.

These forecasts are based upon mussel yield data from all of Pelorus Sound. Strictly, therefore, the forecast is applicable only at that spatial scale and region. Whilst the forecast should be indicative of the performance of the majority of farms in the region, it may not be applicable to any specific farm. These issues must be understood by the user when they consider how 'good' our predictions of mussel yield are.

16.7. Relevance of the case study within Aquaspace

This case study was included in the Aquaspace project on request from the governmental institute NIWA, after their participation at a stakeholder meeting held in month 20, hosted by partner number 20, YSFRI. The case study has relevance as contributing to the non-EU partners, reflecting the global expertise garnered for this project.

The case study demonstrates the development of a predictive tool using information from climatic and environmental phenomena at global scale, for assessing use of space at regional scale. This is unique within the Aquaspace project. The case study involves industrial stakeholders from an aquaculture farming of national importance.

16.8. Conclusions and future prospects

The tool on predicting production yield on this regional scale has been well received by farmers and industry, who regard climatic effects to be important in determining productivity of the Pelorus mussel industry. Priorities for future development is validation of the forecast model and extending spatial information.

17. SYNTHESIS OF ISSUES AND MAIN CASE STUDY OUTCOMES

The Aquaspace project originally had 14 case studies in Europe, the USA, Canada, Australia, and China. Subsequently, a New Zealand study was added as the 15th case study (Table 17.1). The case studies in USA and China involve two study sites, making up a total of 17 study sites They represent various stages of development and natural conditions that exist in Europe and the world. Differences in Aquaculture production capacity are very large, mainly because of the geographical scale of the case study sites, as well as traditional and established aquaculture industry. In most cases, aquaculture is operational and ranges from large scale industry to small scale local farming. Some cases describe plans for developing commercial aquaculture from an existing experimental scale.

The case studies represent a broad geographical distribution, comprehending various concepts of aquaculture in different environments. Farmed organisms represent different trophic levels with different environmental interactions. Environments range from tropical to temperate, and from freshwater to open sea environments (i.e. fjord and sea lough, open sea, estuary, coastal, bay, harbour and on land, pond and intertidal). One case is in freshwater in a landlocked state (Hungary) whereas the remaining 14 are highly diverse examples of marine cases, with finfish, shellfish, seaweed and different combinations of these. The case studies represent a total of 27 species corresponding to 5 groups: Bivalves (13 species); Finfish (8 species); Seaweed (3 species); Echinoderm (1 species); and Gastropod (1 species). The most commonly studied species were Pacific oyster, Blue mussel, Atlantic salmon and the Mediterranean mussel.

The overarching issues for the Aquaspace case studies were conflicts with other use of the coastal zone, and environment impacts related to carrying capacity assessments. These issues emerged as major factors limiting aquaculture development. Conflicts with other users involved tourism, nature protection, fisheries, energy production, and transport. The case studies revealed a great variety of legislation applying to aquaculture at member state and sub-state levels, or within the nations outside the EU.

All case studies reported descriptions of characteristics of the study region and its aquaculture, spatial planning and management issues, tools used, stakeholder engagement and outcomes of relevance for Aquaspace and its prospects. Engagement with stakeholders was a priority and a major outcome from the case studies. Most case studies involved testing of tools for spatial planning, either tools restricted to a single case location (e.g. Bluefarm2) or tools tested in several cases (eg AquaSpace Tool, web based tools like SISAQUA, APDSS (derived from AkvaVis), and connectivity models for sea-lice management).

The case studies and their outcomes are summarised in Table 1. Some general themes emerge from consideration of the narrative accounts that make up the remainder of this document. It appears that in many cases, restrictions on the inshore expansion of aquaculture arise as much from societal concerns as from physical space and environmental constraints. The societal issues are those of local antagonisms and of conflicts not only between use sectors but also amongst regulatory and planning bodies. Remedying these issues requires social investigation and engagement tools as much as spatial planning tools. The strengths of the planning tools are that they integrate many of the spatial variables that need to be taken into account in siting and zoning decisions, and also that they can support both technical and political components of MSP, depending on the manner in which they are used. These matters are illustrated in the AquaSpace results videos (D6.5) for case studies in Hungary, Italy and Scotland, and discussed at greater length in the AquaSpace Synthesis report (D5.1). The AquaSpace Business Plan (D6.4) points to the need for further investment in, and development of, the integrating tools.

As already remarked, the case studies embraced a variety of cultivated species, farming techniques, scales of operation, economic importance and local societal and regulatory contexts, a variety greatly enriched by the inclusion of sites in Canada, China, New Zealand and USA. They showed the importance of locally tailored solutions, whether through local adaptions of tools, choice of specialist tools suiting specific local problems, or different forms of stakeholder engagement. Although the Ecosystem Approach to Aquaculture provided guiding principles, it seemed that in most cases the implementation of MSP according to the Directive had not proceeded very far, nor was very useful in that most aquaculture was subject to Town & Country Planning. Effective ICZM might prove beneficial to aquaculture expansion, although it was referenced only in the Mediterranean case study.

Although it was not the aim of AquaSpace to study environmental carrying capacity for aquaculture, some case studies did investigate interactions between the activity and the environment using indicators related to carrying capacity in planning space for aquaculture. Connectivity analysis to assess space interactions with disease and parasites were applied in Scotland (UK), Nova Scotia (Canada) and Norway. Shellfish growth in the Adriatic (Italy) and the bay of Seine (France) was shown to be responsive to primary production enriched by riverine discharges of anthropogenic nutrients, whereas there were threats from harmful algal blooms in Algarve coastal waters (Portugal). There was estimation of ecosystem services provided by fish ponds in Hungary and shellfish cultivation in New England (USA).

Finally, some of the case studies suggested multiple use of the sea as a way forward, exemplified by IMTA in China and possibilities for synergies between renewable energy and aquaculture in the German North Sea.

In summary, the case studies have shown that: (i) the investigated tools are useful (but need further development); (ii) regulatory complexity needs simplification; (iii) societal and environmental constraints need to be understood; (iv) local society needs to be engaged. Tools tested in the case studies were mostly study site specific, while the examples of tools adapted and tested in several cases (like AquaSpace Tool) illustrated their applicability, limitations, and the resourse requirements for development. Furthermore, the tools WATER and Aqua Investor Index, developed by the AquaSpace project, and evaluating aquacultural feasibility across Europe, demonstrated how accessible solutions adapted to budget could benefit decision making. A counter-example was presented by the resourse requirements for developing sophisticated tools for nation-wide spatial planning in Norway.

Although there are no panaceas to resolve the obstacles to expanding aquaculture, the wealth of information collected during the case studies, and documented in the remainder of this report, shows how specific local solutions can be developed for local problems as well as the potential for generic tool solutions. Input (as D4.3) to the educational products developed by AquaSpace (the web-based masters module D6.1 and CPD course D6.2), this information will, it is hoped, provide a learning resource to encourage flexible problem-solving in other places and times.

Table 17.1. Case studies of the AquaSpace project, showing scale, environment type, species cultivated, culture system, key issue(s) and main outcome(s). Scale R= region, B = bay, C = country, S= regional Sea, Environment: C= coastal, I = inland, O = offshore

Case study	Scale	Environment	Type	Culture system	Key issues	Main outcomes
Adreatic Sea, Italy	R	C	shellfish	bottom, suspended	proximity to protected area conflicts with tourism, fisheries	Implementation of MSP and the "Bluefarm2" tool facilitated expansion of offshore mussel culture
Algarve Coast, Portugal	R	C, O	warm finfish, shellfish	cages, ponds, suspended bottom	co-use, optimising space allocation, disease connectivity	Improved social licence Tool development for offshore aquaculture management
Basque County, Spain	R	C, O	shellfish	suspended	making space and changing culture for aquaculture	Improved stakeholder interaction Applied AquaSpace Tool for site/area selection
Békés County, Hungary	R	I	FW fish	ponds, tanks	proximity to bird reserves, clean water availability	GIS tool applied for aquaculture area use and assessment of ecosystem services
Carlingford Lough, UK	B	C	shellfish	trestles, bottom	complex governance, co-use.	Estimation of shellfish carrying capacity (SMILE) and a GIS based web application (AkvaVis) applied to assess conflicts with conservation features
Great Bay Pisccataqua and Long Island Sound, USA	B, R	C	shellfish	trestles, bottom	legal constraints and use conflicts	Support of potential inclusion of shellfish growers in nutrient credit trading programs
Houtman Abrolhos Islands, Australia	R	C, O	shellfish finfish	suspended, cages	conservation area, co-use, potential for disease spread	Initiatives for inclusion of hydrodynamic model in application of modelling tool (SMILE)
Mediterranean Sea Multiple EEZ	S	C, O	warm finfish	cages	co-use with other industries, complex governance	Stakeholder group established providing questionnaire feedback on main factors limiting expansion of aquaculture; availability of space; increased costs due to stricter regulations on monitoring, hygiene and safety; lack of industrial investors (possibly due to long and complex licensing periods and other administrative constraints); little support from the

						government/state; quality of juveniles and the quality of fish feed prohibit performance improvement.
Normandy and Cancale, France	R	C	shellfish	cages, bottom, suspended	multiple conflicting uses, complex governance	Web application tool based on GIS (SISAQUA (derived on AkvaVis)) developed by integration of new data and indicators. SISAQUA shown useful in MSP implementation
North Sea, Germay	R	C, O	shellfish, finfish	bottom cages	co-use with other industry, increase of production level, complex governance	Developed and applied AquaSpece Tool for site selection and co-use with offshore wind energy industry and mussel culture. Stakeholder interaction show that aquaculture should be explicitly included in MSP.
Norwegian Coast, Norway	R, C	C, O	cold finfish	cages	sea lice connectivity, space availability, co-use	Applied tool for positioning of zones to combat sea-lice impact on wild salmon. Established operational web-based interface simulating sea-lice dispersion representing infection pressure for the entire coast.
Nov Scotia Bays, Canada	B	C	cold finfish	cages	enhancing social licence user/fisheries conflicts	Applied connectivity model to assess disease risk in salmon culture and GIS combined with sea-bed and arial surveys to identify area conflicts with lobster fishery.
Zhangzidao Island and Sangou Bay China	R, C, B	C, O	seaweed, shellfish	suspended	competition for space with other industry; increased production	Developed and applied the tool Aquaculture Planning Decision Support System (APDSS) (derived from AkvaVis). Tool presented for local government.
Argyll and Bute, Scotland, UK	R, C	C, O	cold finfish	cages, suspended	community opposition, space availability, landscape/seascape impacts, sea lice connectivity; increased production	Developed and applied connectivity model for sea-lice treatment management. Explored social licence for finfish aquaculture, and further applied visualization technology to show contribution to coastal landscapes.

						Comparison of tools (MaRS and AquaSpace Tool) for site selection
Pelorus Sound, Marlborough, New Zealand	R	C	shellfish	suspended	Variable production/yield,	Applied a website application forecasting mussel meat yield as a planning tool for the mussel industry.

18. ANNEX 1. DESCRIPTION OF PLANNING AND MANAGEMENT ISSUES OF CASE STUDIES

Case study	**Aquaculture species**	**Aquaculture system**	**Spatial structure**	**Scale of production**	**Aquaculture development trend**	**Management issues**	**Environment issues**	**Aquaculture policy**	**Conflicts between aquaculture activity and EU Directives**	**Socio - Economic perspective**	**Marine Spatial Planning in place? (Y/N) Or is there any spatial management/ordination initiative in place? (including sectoral plans)**
Adriatic sea, Italy	*Mytilus galloprovincialis (Mediterranean mussel)*	Long-lines in open coastal areas	29 companies were operating in 2014, involving approximately 300 employes	About 21,500 tonnes	Mussel production is steady. Farmers are looking for species diversification, i.e. oyster culture, and new materials.	Conflicts with touristic activities are limited, as mussel culture is already perceived as a traditional and environmentally friendly activity. Mussel culture can, however, interfere with fishery and presence of Natura 2000 areas.	The environmental impact due to phytoplankton depletion and enrichment of organic sediment is not very relevant. On the other hand, mussel removal of N and P could be valorized.	The Italian Ministry of Agriculture, Food and Forestry Policies (MiPAAF), has issued a Strategic Plan for the development of aquaculture in the years 2014-2020.	The most severe impact of longline mussel farming is due to the accidental release of plastic socks, presently made of polypropylene, during storm events, as they contribute to plastic macro-litter, which is one the Marine Strategy Framework Directive descriptor.	Increasing aquaculture could be beneficial, as it could help in dealing with the current negative trend of fishery.	In Italy, MSP has not been fully implemented, as yet. At present, the use and protection of marine space is managed by to both national and local authorities, according with the type of use. For example fishing, aquaculture, tourism and coast the defense are entrusted to the "Regioni" (counties), whereas energy uses are managed at national level. The Italian Parliament has only recently, in November 2016, approved a decree for implementing the EU MSP by 2020
Algarve Coast, Portugal	Mussels, oysters	Open water longlines	3 working offshore areas	2000-5000 tons per year	Increase of bivalve production (tons and price)	Conflicts with traditional fisheries operating in the area. Conflict with tourist boat operators, Aesthetic impacts for tourism. Marine litter and shells end up in beaches.	Harmful Algal Blooms; benthic impacts; marine litter from activities end up on beaches.	Government incentives to increase production from bivalve aquaculture	Ensuring that activity does not cause detrimental effects on the environmental. Costs of monitoring have to be met by farmers.	Employment opportunities. Diversification of activities, alternative to fisheries. Regular supply of products.	Yes. POOC – Plano de Ordenamento da Orla Costeira POEM – Plano de Ordenamento Espaço Marítimo POPNSACV – Plano de Ordenamento do Parque Natural do Sudoeste Alentejano e da Costa Vicentina The different stakeholders were not consulted for the newly established offshore areas.

Algarve Coast, Portugal	Seabream, seabass	Land based fish tanks	35 fish aquacultures sites. Ria Formosa Lagoon: 330ha of fish (Seabream, seabass, white bream) Land based tanks; fixed concessions; possible reconversion of inactive salt ponds.		Stable production, slight decrease	Conflicts related to thievery. Water quality from fish sewage	Waste water from fish tanks.			Employment opportunities. Increase and regular supply of products at lower prices than traditional fisheries.	Yes. POOC POEM POPNRF – Plano de Ordenamento do Parque Natural da Ria Formosa
	Clams, oysters, cockles	Intertidal aquaculture	1256 plots: 460ha in Ria Formosa. Land based plots; fixed concession no area to expand; possible reconversion of salt or fish ponds.	2014: Clams 2250t; Oysters 1085t	Stable production of clams; slightly increase of oysters.	Conflicts related to thievery. Illegal capture inside concession areas.	Harmful Algal Blooms. Introduction of sediment into farming plots.		Ria Formosa Lagoon: 460ha within the Natura 2000.	Regular supply of products. Family businesses, activity with very high social importance.	YES. POOC POEM POPNRF
Basque Country; Spain	Mussel	Submerged longline	One licensed site of 567 Ha (3.140 m x 1.400 m). Although the effective area for production is 214 ha, the total area of occupation of DPMT for the project is 290 ha 52 parcels (1 Ha each) Soft substrata Depth range 20-50m.	Average production / ha is 40 tonnes/ year (2080 tonnes/year) •Maximum production / hectare estimated 60 tonnes/year (3120 tonnes/year) • Polygon estimated average production: 2,080 tonnes •Maximum output of polygon: 3,120 tonnes	Development of industrial production	Mainly relate to the displacement of artisanal fishing within the licensed aquaculture site	No relevant environmental issues due to the size and production capacity Environmental monitoring is suggested	Government policy to expand aquaculture according to sustainable production conditions	Not relevant / Not identified	A consensus was reached on the following: (i) the existence of numerous niches and market opportunities linked to local shellfish exploitation; (ii) the potential to involve the local fisheries sector in the shellfish production (iii) the need for commitment, to sustainable (economic, environmental and social) development)	There is no Marine Spatial Plan in place. There is a Territorial Plan for coastal management

Case study	Aquaculture species	Aquaculture system	Spatial structure	Scale of production	Aquaculture development trend	Management issues	Environment issues	Aquaculture policy	Conflicts between aquaculture activity and EU Directives	Socio - Economic perspective	Marine Spatial Planning in place? (Y/N) Or is there any spatial management/ordination initiative in place? (including sectoral plans)
Bekes county, Hungary	Polyculture: common carp (*Cyprinus carpio)* and supplementary species	Ponds	Altogether 2010 ha pond sites are distributed over the county: 3 major pond systems (200-800ha) and about 10 smaller (<10ha) farms	1540 tonnes/yr	Annual increase of 8% for carp (result of intensification, not areal expansion)		Inlet water availability; limitations and thresholds for discharged water quality; nature restrictions on timing of filling and draining of ponds	15% increase of pond production by 2023, enhance environmental sustainability		Employment in rural areas	
Carlingford Lough, UK	Blue mussels (*Mytilus edulis*) and Pacific oysters (*Crassostrea gigas*)	Bottom culture and off bottom trestle culture	14 licensed sites on the Northern Ireland side and approximately 41 licensed sites on the Republic of Ireland side.	Northern Ireland aquaculture production figures for 2014 (DAERA) estimate the industry at that time to be worth approximately £4.7 million at point of first sale. Production values for aquaculture species (*Mytilus edulis* and *Crassostrea gigas*) within County Louth (which includes Carlingford Lough) in the Republic of Ireland for the same period (2014) are noted as €1.9 million (BIM 2015).	Applications have been submitted to DAERA for new licensed sites for the culture of Pacific oysters. Due to the conservation status, all applications for new aquaculture sites are subject to assessment under the Conservation Regulations (Northern Ireland) 1995 (Habitat Regulations Assessment (HRA)). This is then followed by a consultation period. It can therefore take many months/years from the date of application until new aquaculture licenses are granted. Whilst the aquaculture industry is trying to expand, this expansion is seriously hampered by nature conservation legislation. The same is true of many other coastal areas .	Issues with trans-boundary nature of site. Conflicts with other uses such as the leisure industry, local harbor authorities and nature conservation.	Reduce impacts of aquaculture activities on nature conservation features.	Government policy (Going for Growth, 2013) to increase aquaculture by 34% by 2020.	Conflicts with the Habitats and Birds directives.		N
Great Bay and Piscataqua	*Crassostrea virginica* (Eastern oyster0	Primarily rack and bag systems	8 growers, 25.5 licensed acres	About 4.8 million oysters	The industry is new and is growing	Current and expanded cultivation	Nutrient degradation is considerable,	NOAA Aquaculture Policy, National	Not Applicable	Increased aquaculture could be beneficial to	Yes, there is a GIS based decision support tool for

Regional Estuaries, USA		on bottom, mesh bags inserted into cages	mostly in Little Bay		rapidly but rate is unknown	suffers from 'social carrying capacity' where land owners, boaters, other users of the waterbody do not what to see, be tangled in, etc. the aquaculture gear	oyster and clam culture would help reduce the symptoms, no negative impacts are anticipated	Shellfish Initiative is supporting expansion of aquaculture for production of sustainable domestic seafood with the recognition of the positive benefits of shellfish		coastal communities in revenue and also nutrient credit payment	permitting shellfish aquaculture leases
Long Island Sound, USA	*Crassostrea virginica* (Eastern oyster); *Mercenaria mercenaria* (quahog clam)	Primarily bottom culture, no gear (90%); floating cages/gear (10%)	About 45 growers/companies; 66,042 acres of leased shellfish growing area within the CT side of the Sound	About 833 million clams, 52 million oysters	As above	As above	Nutrient degradation is very serious, oyster and clam culture would help reduce the symptoms, no negative impacts are anticipated since they are not fed	As above	Not Applicable	As above	As above
Houtman Abrolhos Islands, Australia	Yellowtail Kingfish (Seriola lalandi)	Open water finfish cages	3000 ha of total suitable space (2200 + 800 ha)	Production of Yellowtail Kingfish at the Abrolhos Islands is just beginning and therefore there is currently no annual production statistics	The expected annual tendency is 24 000t	Streamline the licensing approvals and ongoing management of activities. Governmental policy to expand aquaculture on conditions of sustainable production. Assessment of site suitability and carrying capacity to reduce compliance costs	Improve spatial planning to enable better targeting and monitoring requirements in order to ensure sound environmental protection	At the state level, aquaculture is considered a valuable and growing industry: The WA government released a Statement of Commitment in 2015 which recognises aquaculture as a legitimate user of land and resources. In addition, to ensuring that fishing activities are managed consistent with an ecosystem-based approach, to maintain the ecological and cultural heritage values of the Houtman Abrolhos Archipelago	Not Applicable	The development of finfish aquaculture zones is expected to create new jobs (including jobs linked directly to aquaculture and indirectly such as transport of product) as well as economic benefits through economic diversification	While no spatial management plans have been implemented at the case study region specifically, spatial management has been implemented at a state level. The West Australian (WA) government has committed to ensuring that maintenance and development of existing aquaculture industries within WA are considered within the marine planning processes (including development of new marine reserves). This also includes the establishment of aquaculture development zones in suitable areas which provide competitive advantages through streamlined environmental approval processes (Statement of Commitment 2015)

Case study	**Aquaculture species**	**Aquaculture system**	**Spatial structure**	**Scale of production**	**Aquaculture development trend**	**Management issues**	**Environment issues**	**Aquaculture policy**	**Conflicts between aquaculture activity and EU Directives**	**Socio - Economic perspective**	**Marine Spatial Planning in place? (Y/N) Or is there any spatial management/ordination initiative in place? (including sectoral plans)**
Mediterranean Sea Multiple EEZ	Fish: European Seabass (*Dicentrarchus labrax*), Gilthead seabream (*Sparus aurata*), new species (meagre, dentex, red porgy, sharpsnout seabream) Shellfish: Mediterranean mussel -*Mytilus galloprovincialis*, oysters - *Ostrea edulis* & *Crassostrea gigas* etc).	Marine aquacultures: fish farms (near coast and offshore cages) Shelllfish farms (long lines)	About 21,000 farms along the coasts of the Mediterranean mostly in distinct clusters or areas.	756t/year	Except for Greece the major EU Mediterranean producing countries have decreased their production (2013 data), while smaller countries have increased their production	Internal issues: Site selection and licensing; Market issues (no market stability, lack of diversification in cultured finfish); Conflict with other stakeholders and social acceptability issues; Regional issues: no common criteria for aquaculture spatial planning, less space for marine cultures by increasing trend of other activities (offshore platforms, tourism, maritime traffic)	Pressures on sensitive habitats (e.g. seagrass meadows); pressure by lower EQS due to other activities that degrade the marine environment	No common criteria and standards for all countries and even between the different regions of some countries	There are no conflicts. In most Mediterranean EU-States where coastal aquaculture is favoured the marine aquaculture planning follows the WFD recommendations. For the limited offshore aquacultures the MSFD guidelines are followed. MSP directive is not yet implemented in most countries.	Space limitations, market issues (economic crisis) and/or regime conflicts affect the expansion of aquaculture	Diverse management/policy schemes but most countries follow the EC Recommendation on ICZM guidelines.
Normandy, Cancale, France	Pacific oyster (*Crassostrea gigas*)	Intertidal area, culture in bags on tables	About 250 companies	About 34000 tonnes	Decrease	Need to comply with environmental protections, potential conflicts of use with recreational fisheries on intertidal areas, with other uses (fisheries, renewable energy…) in case of development in open waters	Increase water quality and decrease disease outbreaks	Government policy to manage existing areas or to expand on conditions of sustainable production			Initiative under development (DSF)
	Blue mussel (*Mytilus edulis*)	Intertidal area, culture on wooden poles or in bags on tables	About 200 companies	About 29000 tonnes	Increase	Need to comply with environmental protections, potential conflicts of use with recreational fisheries on intertidal areas, with other uses (fisheries, renewable energy…) in case of development in open waters	Increase water quality	Government policy to manage existing areas or to expand on conditions of sustainable production			Initiative under development (DSF)

	Atlantic salmon (*Salmo salar*)	Fish farming cages in a harbor or in a sea water recirculation system	2 companies	2000 tonnes	Stable	Conflicts of use with civil society related to social license	Find adequate space				Initiative under development (DSF)
North Sea, Germany	Blue mussel (*Mytilus edulis*) and European seabass (*Dicentrarchus labrax*)	Longlines, Cages	Blue mussel: 3.300ha; Seabass: -	Blue mussel: 5000t/y; Seabass: -	Increase blue mussel production (40000 tonnes per year); Co-location of aquaculture with offshore wind farms	A pooling of responsibilities did not happen yet. MSP responsibilities?	No quantification of emissions, High risk potential, Climate change	Complex licensing procedures, Insufficient authorisation competence in authorities, Restrictions discourage Investors, Nature conservation laws hamper aquaculture expansion, High import rates hamper German production		Unfavourable image of aquaculture products, Variable consumer behaviour, Lack of product diversification, High import rates hamper German prices, Production impediments Shortage of qualified professionals in the sector	Y
Norwegian coast, Norway	Atlantic salmon (*Salmo salar* L.) and rainbow trout (*Oncorhynchus mykiss*)	Open water fish farming cages	1067 licenses (2015) for open water cage culture (farms) spread along the western coast	1.38 million tonnes in 2015	Steady increase during the last decades, but stagnation over the last three years due to regulations aimed at reducing salmon lice problems	The Norwegian process is relevant to the Blue Growth policy, advocating the sustainable expansion of aquaculture. Improved environmental control and management Although Norway is not included in the MSFD, the policy is relevant to that directive. Many of the goals of the MSFD are already implemented.	Salmon lice is a growing concern regulating spatial planning issues.	Governmental policy to expand aquaculture on conditions of sustainable production. Policy based on the White paper from 2015 on "Predictable and environmental sustainable growth of the Aquaculture industry" (Anon. 2015)		The Atlantic salmon (*Salmo salar* L.) and rainbow trout (*Oncorhynchus mykiss*) farming industry has grown to become one of the country's largest export industries by economic value, and of significant social importance in many regions along the coast.	Planning for aquaculture activity in Norway are regulated by the Building and Planning Act involving a range of sectors, and ultimately decided at the municipally level. Licenses are regulated by the Aquaculture Act and issued at the regional County Council level. The aquaculture policy, planning process for allocation of space and aquaculture licenses, and the current process leading to the zoning for production regulation, all partially comply to most of the defined processes in MSP.

Case study	Aquaculture species	Aquaculture system	Spatial structure	Scale of production	Aquaculture development trend	Management issues	Environment issues	Aquaculture policy	Conflicts between aquaculture activity and EU Directives	Socio - Economic perspective	Marine Spatial Planning in place? (Y/N) Or is there any spatial management/ordination initiative in place? (including sectoral plans)
Zhangzidao Island, China	Scallop *Patinopecten yessoensis* Sea cucumber *Apostichopus japonicus* Abalone *Haliotis discus*	Sea-ranching (bottom culture) in deep water (>20m) and longline in shallow inshore waters (<20m)	A 1600 km^2 ocean farm, operated by one company	Scallop: 20,000 t Sea cucumbers 200 t, annually	Almost steady in output	Increase productivity per unit area / labour; enhance product quality and safety	Exposure of culture species to extreme weather conditions, e.g. cold water intrusion, is considered one major factor in scallop mass mortality Shortage of food and bottom pollution may result in output reduction etc.	Local MSP and the Conservation Redline system will be implemented soon. Government policy is to stabilise aquaculture by promoting low-carbon, high efficiency and sustainable production methods.	None	Increased labour costs may bring about more mechanisation and less employment per culture area unit; conflicts may also arise where aquaculture overlaps with harbour and navigational uses of the sea.	No clear regional level aquaculture planning, but there are farm level/corporation level aquaculture planning, e.g. the rotation system for bottom cultured scallop for a period of 4 years.
Sanggou Bay, China	Kelp *Laminaria japonica* Oyster *Crassostrea gigas* Scallop *Chlamys farreri* Abalone *Haliotis discus* Finfish （Sea bass *Lateolabrax maculatus* etc.） Sea cucumber *Apostichopus japonicus*	Longline	A 133.3km^2 bay area, operated by more than 20 fish farms/companies	Kelp: 80,000t (dry weight) Abalone: 2,000 t Oyster: 120,000 t Scallop: 10,000 t Finfish: 100 t Sea cucumber: 100t. About 210,000 t annually in total.	Will keep the current level of production	Special marine protected areas are not properly protected, and tend to be compromised by current aquaculture activities Interactions between farms and high culture density affected the overall performance of aquaculture, e.g. kelp rot earlier in warmer season, reduced quality and productivity of bivalves and finfish	Reduced water exchange inside the bay, possibly leading to accumulation of nutrients and pollutants Climate change may reduce kelp growing season Trend of decrease in the N:P ratio in the bay water in recent years	Local MSP will be implemented soon. Governmental policy is to stabilise aquaculture by promoting low-carbon, high efficiency and sustainable production methods.	None	Increased labour costs may bring about more mechanisation and less employment per unit culture area; conflicts may also arise where aquaculture overlaps with harbours and navigation uses.	No clear regional level aquaculture planning, but there are farm level/corporation level aquaculture planning, e.g. the longline IMTA integrating seaweed and bivalves, and the rotation of kelp and *Gracilaria* throughout the year
Argyll and Bute, Scotland, UK	Atlantic salmon (*Salmo salar*)	Cages	Cages (marine) - West Coast and Northern Isles only (approx. 250 sites)	2014 Atlantic salmon: 179,000 tonnes	The general trend has been an increase (e.g. 2014 saw 11.2% increase in Atlantic salmon production) although 2015 was a bad year for Atlantic salmon with a 4% decrease.	Increased mortality and use of medicines in fish farms due to sea lice	Wild fish interaction with fish farms, and therefore sea lice, and sea lice medicines	National targets set by Scottish Government for growth in a sustainable manner across the sector to 2020. Atlantic salmon (to 210,000tn) and mussels (13,000tn) in particular. Application process for licences, leases, and planning permission lies with	N/A	See management issues	Partially – there is sectoral vision for aquaculture. There is also a National Marine Plan. All Scottish Marine Regions are in the process of creating

								government agencies, and Local Authorities respectively.			
	Atlantic Salmon (*salmo salar*), Rainbow Trout (*oncorhynchus mykiss*), Mussel (*mytilus edulis*), Pacific and Native Oyster (*crassostrea gigas and ostrea edulis*), Queen and King Scallop (*aequipecten opercularis and pecten maximus*).	Cages, longlines, trestle tables, lanterns	Cages, long lines and trestle tables – mainly West Coast and Northern Isles, only 3 sites on East Coast.	All 2014 figures: Atlantic salmon: 179,000 tonnes Rainbow trout: 5,882 tonnes Brown trout 48 tonnes Halibut 66 tonnes Mussel: 7,683 tonnes Pasific oyster: 3,392,000 shells Native oyster: 242,000 shells King scallop: 40,000 shells Queen scallops: 18,000 shells	As above	--The current policy and planning regime means that there may be a disconnect between national policy and local decision-making. This could reduce investor confidence and ability of smaller producers to soak up the cost of expansion/start-up due to this often lengthy process (3-6 years). For larger producers this creates issues relating to time, resources, and cost. --Spatial planning and co-existence of aquaculture withother sectors and interest is necessary. Space is currently being used less than optimally which means that there are concerns regarding conflict with other marine users (potentially including marine tourism as it is a rapidly expanding sector). --Accountability in aquaculture in terms of policy and enforcement (government/regulators) and the industry (producers) is limited. The line between governmental and corporate responsibility is		As above			MSPs but are at different stages (e.g. Argyll and Bute has formed a Marine Planning Partnership but will take time to develop the plan due to limited resources, whereas the Clyde and Shetland are on their way to having a fully functioning MSP)

						blurred, which can contribute negatively to public perception and social licence to operate. --Public perception of aquaculture (related to accountability) is mixed due to misconceptions/lack of enforcement, and corporate social responsibility. --Business development strategies are affected by planning and policy issues. Development of novel techniques and approaches is limited by investment. --Consideration of changes in seascape character due to aquaculture and associated infrastructure (e.g. aesthetics and other cultural services)					
Pelorus Sound, New Zealand	Green mussel *Perna canaliculus*	Long-line farms, suspended culture	About 645 licenses (farms) spread along the coast	Nationally, in 2011 over 100,000 tonnes green weight was harvested with export value of 218 M NZD and domestic value of 35 M NZD	Average annual increase from 1998 to 2016 stable	Variable production/yield, uncertain spat supply/survival Biosecurity biotoxin-producing microalga	Plankton depletion, benthic effects Habitat creation	National Aquaculture Strategy is the blue print to becoming a billion-dollar sector by 2025		Twenty percent of allocated aquaculture space is reserved for the Māori (the indigenous Polynesian people of New Zealand)	Yes: sectoral plans – by region either preselected for potential investment or more usually allocation on application. Approval is dependent on EIAs and possibly regional/environmental court hearings to resolve conflict usage issues.
	Chinook salmon *Oncorhynchus tshawytscha*	Mostly coastal water cages: some in freshwater hydroelectric canals	About 13 licenses (marine farms) and 2 in freshwater	4,122 tonnes a year	As above	Variable production/yield: issues = sea temperature and oxygen	Pelagic and Benthic impacts	As above	-	As above	As above
	Pacific oyster	Estuarine intertidal racks	About 230 licenses	1,868 000's dozens a year	As above	Spat supply; Biosecurity; biotoxin-producing microalga	Benthic impacts and diseases; habitat creation	As above	-	As above	As above

19. ANNEX 2. DESCRIPTION OF THE STAKEHOLDER WORKSHOPS, FEEDBACK AND OUTPUT

Case study	Stakeholders	Stakeholder workshop	Feedback and output	Recommendations from stakeholders
Adriatic sea, Italy	Industry representatives and consultants; Regulators and public servants involved in the implementation of environmental legislation and food safety monitoring; Scientists involved in shellfish research.	The worskhop was held on November 7th 2015 in Chioggia, near Venice. In total, we registered 47 participants, namely 19 from the industry, 18 from the regulators group and 10 scientists.	Bluefarm and other experts presented some tools for maritime spatial planning which are being developed in different projects, including Aquaspace, and some preliminary results. The feedback was positive. Industry representatives and regulators pointed out that the identification and classification of areas suitable for shellfish farming based on a set of criteria, including biomass productivity and access/proximity to markets, could be a key for simplifying the current legislation and making the licensing process faster and more transparent.	Simplifying the legislation in order to make the licensing process fast and transparent. - Establishing a unique reference contact point, at a national level, for helping farmers in the licensing process and in complying with the current legislation. Establishing a stakeholder platform, for involving them in decision making. -Promoting Continuous Professional Development -Providing economic support to face adverse events, Making data concerning environmental variables and food security, publicly.
Algarve Coast, Portugal	Meeting at the DRAPAlgarve, Regional Directorate for Agriculture and Fisheries, Patacão, Algarve. Entities present DGRM (General Directorate for Natural Resources and Maritime Security), APA (Portuguese Environmental Agency), DGAV (General Directorate for Veterinary and Food Security) and IPMA (Portuguese Institute for Sea and Atmosphere); inshore and offshore aquaculture producers of bivalves (around 40 people)	29th June 2016	Provided information about the exceptional mortality of oysters, clams and cockles that occurred, particularly, in the Ria Alvor along the Algarve Coast during the Autumn of 2015.	
	Representatives of DGAV at DRAPAlgarve, Regional Directorate for Agriculture and Fisheries, Patacão, Algarve	21st July 2016	Provided detailed information about the licensing procedure and governance of aquaculture activities in Portugal. There was also clarification about the governance hierarchy within the different institutions involved in the licensing process	
	Interview with a producer in Ria Alvor	22nd July 2016	Concerning his specific problems with bivalve culture at this location. Apart from the mortality which has fortunately been somewhat limited for him, he has several issues with the licensing and subsequent monitoring activities with the governing institutions.	
	Interview with consultant /manager of Aquasacrum	4th August 2016	Comments are similar to those of the producer interviewed from Ria Alvor. Aquasacrum was one of the companies with substantial mortality of oysters in Autumn 2015.	It is notable that they sent samples to a laboratory that specialised in bivalve diseases: they received an identification of what was causing the mortality, but this was not acknowledged officially by the Portuguese institutions.
	Finisterra SA	Regular contact	Detailed information on the day to day issues affecting the use and management of the 60 hectare offshore concession for mussel culture	Overarching issues relate to slow response times of the State institution responsible for monitoring toxic algae, which has substantial economic consequences for the company.
Basque Country; Spain	Administration (government): 11 Conservation: 3 Education: 1 Research: 3 Promoters: 7 Fishermen Associations: 2	10th December 2015/ Bilbao / 27 participants / 10 questionnaires answered	- current state of open sea aquaculture in the Basque Country from the stakeholder perspective identify those limitations stakeholders and promoters were facing	Measures proposed to solve the conflicts with other uses and sectors: -Maritime Spatial Planning is seen by stakeholders as a good framework that would help the promotion of aquaculture activity -Spatial Planning should be developed to take into account social, environmental and economic criteria, aiming, if possible, to achieve consensus among users.

	Administration (government): 5 Conservation: 0 Education: 2 Research: 2 Promoters: 7 Fishermen Associations: 0	11th November 2016 / Renteria / 16 participants / 10 questionnaires answered	- Applicability, willingness to use new tools and identification of new functionalities of tools developed in AquaSpace	-It is necessary to declare zones for aquaculture interest in which the activity could be prioritized. -Use of aquaculture facilities as limits for strictly protected areas, where fishing activity is banned. E.g. the use of longlines as barriers to limit the entrance of fishermen into protected areas. -Better coordination among sectors. -Spatial Planning should be developed with good communication and promotion of the plans. -Coordinated actions and decisions should be promoted where the negatively affected sectors could be identified at an early stage and become involved in the project to minimize the negative impacts of decisions, and if possible, profit from it. -Involvement of the fishing sector in the business and compensation measures with an important income from aquaculture. -Aquaculture activity should be located away from ports and recreational zones where it may interfere with bathers. -Allocation of aquaculture activity within inner waters in order to limit the use of fishing gear in this area. -Strict protection of the marine environment in accordance with international commitments and environmental assessment. It is agreed that a good environmental status of marine waters are necessary for any existing and future activity.
Bekes County, Hungary	Industry representatives, water management and environmental authorities, national parks, NGOs, academic institutes, local and national decision makers	1st stakeholder workshop 13th January 2016, Biharugra, Hungary Participants: farmers, environmental and water management authorities, governmental institutes, national parks, NGOs for nature protection, academic institutes, local and national decision makers 2nd stakeholder workshop 4th May 2017, Szarvas, Hungary Participants: farmers, governmental institutes, regional national park, NGO for nature protection, academic institutes, national decision makers	An important milestone in the cooperation between different sectors and interests. A SWOT analysis was finalised based on the opinions of the participants. Progress of the project was presented Consultation process between sectors was supported. Legal harmonisation, licensing and regulatory process should be simplified	Better cooperation between aquaculture producers and nature conservation agencies. Calculate compensation for ecosystem services. Increase the economic competitiveness of aquaculture products. Improve social and consumer communication.

Case study	Stakeholders	Stakeholder workshop	Feedback and output	Recommendations from stakeholders
Carlingford Lough, UK	Local Harbour Authority Aquaculture producers Fishermen Conservation agencies Government Departments NGOs Local sailing clubs Anglers Foods Standards Agency Local business owners	No official workshop was undertaken as part of this case study. However, AFBI have had meetings with several stakeholder groups. These include; The Harbour authority, aquaculture producers, and government department officials.	Two of the main concerns amongst stakeholders are; • concerns regarding the impacts of aquaculture activities on designated features of European sites (Natura 2000 sites) and • concerns regarding the licensing process for aquaculture sites and the time taken for this.	
	Industry representatives – we were unable to connect (see text) but did have the President of the East Coast Shellfish Grower Association on our project team State resource managers and permitting agencies Federal NOAA National Marine Fisheries Service scientists involved with research to support aquaculture University scientist partners	We presented our findings to about 60 growers on May 15th, 2015 at the Connecticut Shellfish Industry Spring Workshop in Bridgeport, CT. We had 20+ phone calls to 8 growers from April 1st - 17th, 2014. We had a former grower on our project team who provided repeated advice during the course of the project. We were advised, had repeated interaction and consultation over the project duration with 2 people from the CT Division of Aquaculture. We had repeated interaction and consultancy for the duration of the project with a SeaGrant Aquaculture Extension agent – state personnel in a nationally funded position. There were 10 federal employees involved in the project. There were 4 university partners on the project team.	Industry representatives were not helpful; they have refused to interact with us. At the workshop, we received little feedback. The growers provided some information on culture practices, what percentage of the lease they cultivated but did not provide harvest or income information. The growers on our project team provided confirmation of the practices used and helped determine the areas under cultivation. The state personnel helped us to calculate a range of possible areas under cultivation, estimates of maximum potential expansion, helped estimate a range of harvested product. We received confirmation of the number of leases and culture practices from the resource managers, provided data and information about water quality and pollution management plans. Federal employees coordinated the project, conducted phone interviews, conducted some of the modelling and research, spoke at conferences about project results. University people conducted some of the modelling and research of the project.	None, they would not speak to us On the phone they did provide some information as described, but no recommendations. Recommended we use previous harvest to estimate current harvest since it had not been reported in several years. Recommended the means to make better estimates of current areas of cultivation, current harvest and maximum potential areas that could be cultivated. Recommended that we use a 'work around' to estimate cultivated areas and harvests since the growers were not forthcoming and had also not reported in several years. Recommended using a range of cultivated areas and harvests to make the best possible results to inform about aquaculture in Long Island Sound given obstacles to getting actual data / information on harvest, income, cultivated areas, density of planting, etc. Recommended the best use of models and model input from the little data provided by growers.
Great Bay and Piscataqua Regional Estuaries, USA	Industry representatives – President of the East Coast Shellfish Grower Association, one of our scientist partners is also a grower State resource managers and permitting agencies	We had a current and former grower on our project team who provided repeated advice during the course of the project.	The growers on our project team provided confirmation of the practices used and helped determine the areas under cultivation. The state personnel helped with determination of the state of water quality, areas of lease, pollution management plans.	Growers in Great Bay Piscataqua were forthcoming using our project partner/grower to represent them and their practices, harvest, income and cultivated areas. Their industry was so new that there was little harvest to evaluate.

	Federal NOAA National Marine Fisheries Service scientists involved with research to support aquaculture University scientist partners	We had one state employee as a project team member providing continual advice during the project. There were 10 federal employees involved in the project. There were 4 university partners on the project team.	The federal people were less helpful in Great Bay than Long Island Sound since the industry was so small and new. University partners helped confirm water quality status and data availability and contributed to modelling efforts.	
Houtman Abrolhos Islands, AU	The Western Australian Department of Fisheries South Metropolitan TAFE Aquaculture Council of Western Australia (ACWA) BMT Oceanica (Consultancy)	We have had six in person meetings with the aquaculture manager at the WA Department of Fisheries regarding exchange of data and information related to the case study region. We have had three meetings with the director of the TAFE and the principal research scientist. They provided advice on Yellowtail Kingfish physiology and growth. Two meetings have taken place at the University of Western Australia and one meeting at the South Metropolitan TAFE in Fremantle WA. One meeting between UWA and ACWA to discuss possibility of collaboration in one of the projects aiming to get funding (application unsuccessful). Together with major aquaculture stakeholders in Western Australia and Australia in general, UWA attended a state forum on aquaculture which took place in Perth, WA, on the 25 May 2016 (http://www.pdc.wa.gov.au/our-focus/pilbara-blueprint/who-we-are). Three-five meetings took place (in person and skype) with BMT Oceanica and UWA (skype meeting also attended by AquaSpace partner Longline Environment Ltd) to discuss potential collaboration through contribution of BMT Oceanica's hydrodynamic modelling results. Collaboration did not go forward as BMT Oceanica needed payment and UWA had no funds from AquaSpace to buy the existing hydrodynamic modelling results needed to run the tool from Longline Environment Ltd.	Provided data from the Houtman Abrolhos Archipelago, including oceanographic data (wave height and speed, tidal patterns and bathymetry), water quality data (temperature, dissolved oxygen, pH), sediment quality data (phosphorus, nitrogen, trace metals, particle size distribution) and benthic habitat descriptions. Providing advice based on experiments conducted at the facility for yellowtail kingfish growth and physiology parameters for input into a growth model. The current state of the aquaculture industry was discussed, and the networking enabled through those discussions will assist in targeting future avenues for knowledge exchange and discussion regarding the impacts of the AquaSpace outcomes.	Recommended to concentrate on the modelling the release of biochemicals into the water column (e.g. nitrates and phosphates).

Case study	Stakeholders	Stakeholder workshop	Feedback and output	Recommendations from stakeholders
Mediterranean Sea Multiple EEZ	Scientists, regulators/planners and industry members from a wide range of Mediterranean countries (Spain, Greece, Cyprus, Turkey, Malta, Croatia, Morocco, Tunisia, Montenegro, Albania, Italy, Israel).	27/11/2015 / Catholica-Italy / 13 participants	Evaluation (discussion and questionnaire) of the SHoCMed and update about the current state of aquaculture and other sector issues	1) An MSP framework at national level is not implemented. 2) IUCN and ICZM concepts are embedded in most countries 3) AZA adopted in a number of countries 4) Other than spatial limitations, a number of policy and economic factors limit aquaculture expansion
Normandy (France)	National, regional and local authorities Industry representatives Technical centers/Applied research Non-governmental organisations Public institutions	2016 March 2nd Caen 28 persons, 18 organisations	- Identification of data required to implement spatial planning for aquaculture in the case study area - Identification of issues related to aquaculture development in the case study area - Necessity to work around the question of social licenses for aquaculture development	- Simplify the procedures for aquaculture installation - Clarify the decision making process and make the information required to do it available - Simplify the consultation process and improve communication with civil society Create communication tools between stakeholders
North Sea, Germany	Experts from: Business sector National or federal states politics County administrations Environmental protection	April, 14th 2016 / Thünen Institutes of Sea Fisheries and Fisheries Ecology in Hamburg, Germany / 22 experts and stakeholders from the fields of nature conservation, politics, economy, science and administration	Discussed issues include: authorisation and obligations, company organisation, consumer behaviour, differentiation, federalism, location factors, image, predators and climate change	Central coordination of aquaculture authorisations. Upscaling of enterprises/farms to use economies of scale advantages. Training of authority's employees at county level. Highlighting the differences between species and production systems. Standardisation and simplification of regulation frameworks and authorisation procedures. Standardised and continuous communication towards consumer. Emphasize the product environment (e.g. tradition, regionalism). Enhance the traceability of products. Demand-orientated product development. Defining space for aquaculture in spatial planning. Improving national scientific networking and networking between business and science. Duties for imported products with lower environmental, consumer or hygienic standards. Consequently, cultivation of image to reach prerogative of interpretation. Enhance cooperation between producer's associations. Compensation payments. Subsidise defence actions.
Normandy and Cancale, France	National, regional and local authorities Industry representatives Technical centers/Applied research Non-governmental organisations Public institutions	2016 March 2nd Caen 28 persons, 18 organisations	- Identification of data required to implement spatial planning for aquaculture in the case study area - Identification of issues related to aquaculture development in the case study area - Necessity to work around the question of social licenses for aquaculture development	- Simplify the procedures for aquaculture installation - Clarify the decision making process and make the information required to do it available - Simplify the consultation process and improve communication with civil society Create communication tools between stakeholders
	Public institution	2016 May 10th Rouen 4 persons, 2 organisms : CEREMA & Ifremer	- Listing of data managed by CEREMA and of interest for aquaculture planning in the case study	
	Public institution	2016 December 16th Rouen 5 persons, 2 organisms : CEREMA & Ifremer	- Discussion on priority data identified after the first meeting	

North Sea, Germany	Experts from: Business sector National or federal states politics County administrations Environmental protection	April, 14th 2016 / Thünen Institutes of Sea Fisheries and Fisheries Ecology in Hamburg, Germany / 22 experts and stakeholders from the fields of nature conservation, politics, economy, science and administration	Discussed issues include: authorisation and obligations, company organisation, consumer behaviour, differentiation, federalism, location factors, image, predators and climate change	Central coordination of aquaculture authorisations. Upscaling of enterprises/farms to use economies of scale advantages. Training of authority's employees at county level. Highlighting the differences between species and production systems. Standardisation and simplification of regulation frameworks and authorisation procedures. Standardised and continuous communication towards consumer. Emphasize the product environment (e.g. tradition, regionalism). Enhance the traceability of products. Demand-orientated product development. Defining space for aquaculture in spatial planning. Improving national scientific networking and networking between business and science. Duties for imported products with lower environmental, consumer or hygienic standards. Consequently, cultivation of image to reach prerogative of interpretation. Enhance cooperation between producer's associations. Compensation payments. Subsidise defence actions.
Norwegian coast, Norway	Industry representatives from two producer organisations Salmon farming enterprises Management – Norwegian Food safety authorities, Directorate of Fisheries and others Research communities, national and international	Internal meeting at IMR (9 participants) on the coordination of spatial planning tools in line with the objectives of AquaSpace. 8th - 19th of November 2015. A meeting between IMR, the Norwegian Food Safety Authority and industry representatives was held on the 25th of November 2015. Related meetings on the zoning issue leading up to the meeting was hosted by the Norwegian Seafood Federation on the 16th of October and 10th of November 2015. 57 participants, 10 from industry, 13 from government, 21 from research and 13 from NGOs. As a follow up from this meeting, IMR representatives participated in the following meetings with unregistered attendance. Aquaspace co-hosted an international meeting on salmon lice dispersion modeling from the 20th – 22nd of April 2016, at Finse, Norway. 14 participants from research; 5 from Canada, 3 from Scotland, 5 from Norway.	Feedback from the industry is characterised by strong involvements ranging from support, to opposition and confrontation affecting the implementing process. This opposition also links to opinions from the public, research communities, management and politicians. The industry feedback can be regarded as • The large companies operating in several zones are supporting the production regulations • The small companies operating in one-two zones are more affected and show partly strong resistance to the suggested zoning In the scientific community the debate focusses on the methodology and use of models; opposition suggests empirical salmon lice incidence models to be superior to the salmon lice dispersion and connectivity approach. In the management community the concern is about the feasibility to manage the traffic-light system for production regulation.	Collaboration and efficient decision making The national process demonstrated in this case study include elements at all stages of Maritime Spatial Planning (MSP) and the Ecosystem Approach to Aquaculture (EAA). There is a need to further develop governance issues for efficient decision making.

Case study	Stakeholders	Stakeholder workshop	Feedback and output	Recommendations from stakeholders
Zhangzidao islands and Sanggou bay, China	Research institutes and industry representatives	December 8th 2015 at Sanggou Bay 1. Øivind Strand Institute of Marine Research (IMR), Norway 2. Samuel Rastrick Institute of Marine Research (IMR), Norway 3. YOU Jun-Yong Christian Michelsen Research AS (CMRAS), Norway 4. LI Xiao-Bo Xunshan Fisheries Group (XS), PR China 5. BIAN Da-Peng Xunshan Fisheries Group (XS), PR China 6. XIAO Lu-Yang Xunshan Fisheries Group (XS), PR China 7. GUO Wen-Xue Xunshan Fisheries Group (XS), PR China 8. TANG Xiao-Yang Xunshan Fisheries Group (XS), PR China 9. WEI Hao Tianjin University, PR China 10. FANG Jian-Guang Yellow Sea Fisheries Research Institute (YSFRI), PR China 11. JIANG Zeng-Jie Yellow Sea Fisheries Research Institute (YSFRI), PR China 12. FANG Jing-Hui Yellow Sea Fisheries Research Institute (YSFRI), PR China LIU Hui Yellow Sea Fisheries Research Institute (YSFRI), PR China	Based on earlier ecological and physical oceanography studies, the current layout and density of aquaculture longlines has reduced the water exchange in Sanggou Bay to a certain extent, which may have affected the growth of the seaweed. The aquaculture companies are under strong pressure to increase aquaculture productivity via optimised spatial planning, so as to maintain the companies' economic balance (return) while the labour costs keep rising. The current level of mechanization of seaweed culture and harvest is relatively low, and labour costs may comprise 40% of the total production cost.	A science-based carrying capacity evaluation and spatial planning is vital to tackle current productivity bottle-necks, in both Sanggou Bay and Zhangzidao aquaculture waters.
	Research institutes and industry representatives	November 29-December 1 2016 at Rongcheng City 1. Øivind Strand Institute of Marine Research (IMR), Norway 2. Rolf Engelsen Institute of Marine Research (IMR), Norway 3. Lars Asplin Institute of Marine Research (IMR), Norway 4. Pia Kupka Hansen Institute of Marine Research (IMR), Norway 5. YOU Jun-Yong Christian Michelsen Research AS (CMRAS), Norway 6. Jan Wilhelm Grythe Counsellor, Development, Royal Norwegian Embassy in Beijing 7. Joao Ferreira Universidade Nova de Lisboa, Portugal 8. Jeffrey Ren NIWA, New Zealand 9. FANG Jian-Guang Yellow Sea Fisheries Research Institute (YSFRI), PR China 10. JIANG Zeng-Jie Yellow Sea Fisheries Research Institute (YSFRI), PR China 11. LIU Hui Yellow Sea Fisheries Research Institute (YSFRI), PR China	The policy framework for implementing ecosystem based spatial planning for aquaculture in China and in EU countries, and Norway in particular, was discussed; industry concerns regarding sustained production and profitability were presented; and modelling of carrying capacity in China, Norway and New Zealand was discussed, including the MOM model, AkvaVis, DEB model and FARM model. Future collaboration between AquaSpace project partners in the development of spatial planning tools for Chinese aquaculture was also discussed.	Ecosystem-based aquaculture planning is highly needed in decision making for the industry, in order to maintain sustained output and profitability. Issues regarding project implementation plans and specific technical questions for developing the Chinese Aquaculture Spatial Planning Decision Support System (APDSS) were discussed.

		12. Zhang Jihong Yellow Sea Fisheries Research Institute (YSFRI), PR China 13. Lin Fan Yellow Sea Fisheries Research Institute (YSFRI), PR China 14. Gao Yaping Yellow Sea Fisheries Research Institute (YSFRI), PR China 15. Du Meirong Yellow Sea Fisheries Research Institute (YSFRI), PR China 16. Jiang Weiwei Yellow Sea Fisheries Research Institute (YSFRI), PR China 17. Cai Biying Yellow Sea Fisheries Research Institute (YSFRI), PR China 18. Yu Liangju Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences 19. Shang Weitao Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences 20. Jiang Xiaopeng Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences 21. Zhou Feng Second Institute of Oceanology, State Oceanic Administration 22. Xuan Jiliang Second Institute of Oceanology, State Oceanic Administration 23. Zhu Changbo South China Sea Fisheries Research Institute (YSFRI), PR China 24. Liang Jun Zoneco Group Co Ltd, Dalian 25. Zhang Yuan Zoneco Group Co Ltd, Dalian 26. BIAN Da-Peng Xunshan Fisheries Group (XS), PR China 27. GUO Wen-Xue Xunshan Fisheries Group (XS), PR China Zhang Yitao, Chudao Marine Scientific Company		
Argyll and Bute, Scotland, UK	Aquaculture industry (8) Governing agencies (5) Research (9) Other industry (e.g. fishermen's associations) (3)	Workshop was a full day, held at SAMS January 18th 2016, which involved discussing what the barriers are to aquaculture expansion in Argyll. Breakout sessions allowed an exploration of the issues and possible measures for addressing them.	Output was a synthesis of the issues which was sent to the participants for feedback/ clarification. This directed the research questions and research design, which were also sent out to stakeholders for feedback.	6 issues were identified; 1 – Planning and policy regime (long process), 2 – Spatial planning and co-existence of aquaculture with other sectors and interests (renewable energy, for example), 3 – Developing accountability (linked to public perception and including both governing agencies and industry), 4 – Public perception (lack of social licence), 5 – Business development (uncertainty in planning and its implications for investment) 6 – Development of novel techniques and approaches for expansion (such as going off-shore)
Pelorus Sound, New Zealand	Aquaculture New Zealand and Marine Farming Association (both , Sanford Ltd, Seafood Innovation Ltd (SIL))	Zeldis J, Booker D, Mullan B, Greenwood M, Hadfield M (2015). Forecasting Pelorus Sound mussel aquaculture yield. 2015 New Zealand Aquaculture Conference Technical Session Nelson, September 2015.	We have received positive responses to the website from industry users.	None

20. ANNEX 3. DESCRIPTION OF THE TOOL(S) IMPLEMENTED IN THE CASE STUDIES.

Case study	Scale	Site identification	Environment	Tools currently in use	Level of numerical modelling	Integration with external sources	Multiuse	Investment decision support	Licensing module
Adriatic sea, Italy	Regional, National	Shellfish are farmed along the entire Adriatic coast line, from Trieste, in the North, to Taranto, in the South, as the trophic level of the Adriatic is higher than that of the other Italian seas, due to the nutrients delivered by the river Po and other major Italian rivers. The Emilia-Romagna region, which was selected as case study, in 2014 produced about 40.000 tonnes of shellfish per year, accounting for about 1/3 of the national mussel production, and about 60% of the clam one.	Open coastal areas	"Bluefarm 2", which is a GIS based tool for implementing a Spatially Explicit Multicriteria Analysis., The output is a suitability map.	The main input layers are obtained from , remote sensing, eco-physiological and transport models	Different model ouputs are made interoperable in the open sorce programming environment Q-GIS. A plug-in is being designed and tested, in order to enhance the transferability of the tool	Mainly aquaculture, but the methodology can be used in a participatory forum involving stakeholders form other sectors	Some input layers concern the potential production, i.e. biomass at harvest, and could therefore be used for estimating revenues.	Italy, Northern Adriatic sea
Algarve Coast, Portugal	Regional	http://eaquicultura.pt/navegue-pelo-mapa-da-aquicultura-em-portugal/	Offshore	GIS/ Remote Sensing (BLUE-FARM-2)			Aquaculture		
Basque Country, Spain	Farm	Multi-criteria decision process and spatial analytical modelling: environmental conditions (physical characteristics and water quality), biosecurity (harmful algal blooms, pathogens), legislation, minimisation of conflicts of use, Economic sustainability	Offshore	GIS Numerical modelling	Hydrodynamics Biological carrying capacity	Integration of spatial layers generated by other models and tools	No	Based on the background analysis	No
	Regional	AquaSpace tool implementation in the Cantabrian Sea	Offshore (entire coast within the baseline)	None (first time for the entire area)	AquaSpace tool, extended cost-benefit analysis	Integration of publically available information layers	No	No	No
Bekes County, Hungary	Regional (NUTS-3)	Available datasets Representative farm characteristics	Pond (fresh water)	GIS Ecosystem services Stakeholder consultation		Integration of excess water hazard and water catchment management planning layers	Aquaculture Water management, Nature conservation	Selection of suitable sites for aquaculture	
Carlingford Lough, UK	Regional	GIS	Coastal/ Sea Lough	GIS, SMILE model	SMILE model is comprised of a Hydrodynamic model (Delft 3D), a shellfish growth model (AquaShell), and an ecosystem model (EcoWin.net).		Aquaculture		
Long Island Sound, USA	Farm, regional, w national implication		Coastal - estuarine	GIS, hydrologic/circulation modelling, aggregated / integrated modelling	Circulation, hydrodynamics, ecosystem for shellfish modeming and eutrophication assessment, farm scale	Integration with other models	Aquaculture, nutrient management, shellfishery management		

Great Bay and Piscataqua Regional Estuaries	Farm, regional, w national implication		estuarine	aggregated / integrated modelling	Farm scale, system for eutrophication assessment		Aquaculture, nutrient management, shellfishery management		
Houtman Abrolhos	Regional		Offshore - in the Zeewijk Channel, between the Pelsaert and Easter island groups.	Hydrodynamic model – TUFLOW FV (BMT WBN) Used prior to the AquaSpace involvement in the case study area to assess the suitability of the region to finfish aquaculture. Therefore, UWA was not directly involved in the implementation of these models.	Hydrodynamics		Aquaculture		
	Regional			Regional Ocean Modelling System – ROMS (UWA)	Hydrodynamics				
	Farm			Sediment diagenesis model – FABM-AED (UWA) Used prior to the AquaSpace involvement in the case study area to assess the suitability of the region to finfish aquaculture. Therefore, UWA was not directly involved in the implementation of these models.	Ecosystem		Aquaculture		
	Site			GIS – mapping of bathymetry and multiple uses in the region	Ecosystem		Aquaculture		

Case study	Scale	Site identification	Environment	Tools currently in use	Level of numerical modelling	Integration with external sources	Multiuse	Investment decision support	Licensing module
Mediterranean Sea Multiple EEZ	Multinational	GIS	Entire coast to 10 km offshore	GIS-based model (ArcGIS)	Different pressures/activity layers, changes in time	Integration with updated and older data on aquaculture locations from Google Earth	Aquaculture, renewable energy, shipping routes	Mediterranean Sea Multiple EEZ	Multinational
				Emodnet portal	Ecosystem: depth data				
				National Aquaculture Sector Overview (NASO) maps collection	Ecosystem: Historical fish farm locations				
				GIS-Fish	Ecosystem: Historical data on farms and production data/country				
Normandy and Cancale, France	Regional	GIS	Coastal (with estuaries) and off-shore	Web-based application based on GIS, includes results of numerical modeling and remote sensing	Hydrodynamic and ecophysiological growth models – offline use	Possible visualisation of data coming from external sources through web standard protocols of communication	Aquaculture with a focus on shellfish culture at this time	no	no
North Sea, Germany	National	GIS-based MCA	Coastal, Offshore	AquaSpace tool	Ecosystem	yes	Fisheries Offshore Wind farm Platforms Cables Pipelines Sediment extraction Marine traffic Coastal discharge Marine protected areas Tourism	Yes, but just for 2 species/ qualitative analysis	no
Norwegian coast, Norway	National	GIS	Entire coast within the baseline	Zoning based on connectivity analysis determining the position of borders	NORKYST800 hydrodynamic model (ROMS), sea lice dispersion model	Farm site specific data on sea lice abundance, sourced from the Directorate of fisheries monitoring of the salmon industry	Aquaculture and wild salmonid stock management		
Zhangzidao Island, China	Regional	GIS-based	Coastal and offshore	AkvaVis, and Aquaculture Planning Decision Support System (APDSS)	Growth model, Hydrodynamics and ecosystem model	Aquaculture / fisheries	Aquaculture/ fisheries/harbour	None	None
Sanggou Bay, China	Farm	GIS-based	Coastal bay	sinoAkvaVis, and Aquaculture Planning Decision Support System (APDSS)	Growth model, Hydrodynamics and ecosystem model	Aquaculture / fisheries / tourism (small)	Aquaculture/harbour / fisheries / tourism (small)	None	None

Argyll and Bute, Scotland, UK	Local, regional	West coast, islands and shelf waters	Coastal, fjord, estuary, island	Hierarchy of: FVCOM hydrodynamic model.	Sea lice dispersal model. Population dynamic model	Potential to be used in conjunction with MaRS tool through data layer sharing	Aquaculture	New site parasite impacts on local water body, site network and existing management unit definitions	Open Source. FVCOM is open source, but implementation depends on forcing data help by SAMS. All models run by SAMS upon request for particular scenarios.
	Regional	Specific cases on the in Argyll and Bute county	Coastal, fjord, estuary, island	Public comment analysis	N/A	Can be used for more in-depth understanding of spatial conflict identified by spatial models	Aquaculture Renewable Energy Other developments which require planning permission	Report; Analysis of reasoning and motivations around objections to aquaculture expansion. Create list of criteria where objections might occur and suggest options for mitigation.	N/A
	National	All Scottish coastal and offshore waters	Coastal, fjord, estuary, island	Marine Resource System (MaRS)	N/A	Can be used in conjunction with the AQUASPACE tool.	All sectors mapped for interactions with finfish and shellfish farming	Produces locational guidance (maps) of opportunity and constraint to assist with planning and site selection	Tool owned by Crown Estate and run for Marine Scotland on request rather than under licence
	Regional	Argyll Scottish Marine Region	Coastal, fjord, estuary, island	Augmented reality tool	N/A	Uses Google Earth visual data and locational data from Marine Scotland	Multiple sectors for representation of interactions, impacts and potential multiple benefits	Provides a tool for assessing public understanding of aquaculture, and engagement with all the types of target stakeholders	Augmented reality tool owned by James Hutton Institute, data layers available through Google Earth
	National	Entire coastline	Coastal, fjord, estuary, island	Viewshed analysis using GIS mapping	N/A	Can be used in conjunction with the AQUASPACE tool	Multiple sectors for representation of interactions, impacts and potential multiple benefits	Provide tool for assessing marine areas which are highly visible from terrestrial buildings.	ArcGIS licence
Pelorus Sound, New Zealand	Regional	Map layer	Coastal protected sounds	Tool is implemented in password-protected Web application	Climate forecasts incorporated in multiple regression production model	Climate forecasting from NIWA Climate models and International Ensemble forecasts	Aquaculture		