Developing criteria and methodology for determining aquaculture zones under Marine Spatial Planning in the EU

Recommendations for MSP planners

Final Draft

October 2019

This study has been prepared by

Marine Atlas Consultants Ltd
Dollar
Scotland, FK14 7PG

in co-operation with

Aquaculture Advisory Council, Brussels.

Recommended citation: Gray, L. (2019). Developing criteria and methodology for determining aquaculture zones under Marine Spatial Planning in the EU. Aquaculture Advisory Council, Brussels.

Contents

Background

Article 34 of the Common Fisheries Policy Regulation requires Member States to prepare multi-annual national strategic plans for aquaculture. The national plans are intended to inform investment priorities for aquaculture under Member States' operational programmes under the European Maritime and Fisheries Fund. They are also intended to identify measures to reduce the administrative burden on operators, to secure sustainable development and growth of aquaculture through coordinated spatial planning, to enhance the competitiveness of the aquaculture sector and to promote a level playing field for EU operators by exploiting their competitive advantages.

The EU's Maritime Spatial Planning Directive has been established to guide Member States in planning their seas in order to deal with competition for maritime space, including for aquaculture areas, enabling the sea to be managed more coherently. Marine Spatial Planning (MSP) has been promoted as an approach for achieving more ecosystem-based marine management, with a focus on balancing multiple management objectives in a holistic way, and a guide to addressing these demands is provided in Gee *et al.*, 2018.

MSP brings a coordinated approach to overall sea use, promising greater accountability and transparency of decision-making by including a wide range of stakeholders from all sectors. It may also increase the effectiveness of investments, reduce duplication of effort, and speed up decision-making (FAO 2013). For example, designating appropriate aquaculture areas and then linking these areas to streamlined licensing procedures could render development less uncertain and increase investor interest (EC 2013). As a strategic tool, MSP can allocate space for aquaculture at sites with both favourable operational characteristics (socio-economic and ecological) as well as lower potential for conflict with other sectors (FAO 2013). MSP would also allow for more structured consideration of co-location of different uses, such as aquaculture taking place around offshore wind structures, providing both a venue for the respective stakeholders to come together and a greater incentive for investment.

The success of an aquaculture project depends on the selection of an appropriate site which entails a complex decision-making process using multiple criteria. Geographical Information Systems (GIS) based data and robust spatial analyses (such as multi-criteria evaluation, MCE) help collate and harmonize spatial data for use at the site selection stage of the planning process (Jay and Gee, 2014 and Shucksmith *et al.*, 2014). GIS is now routinely used in places where an ecosystem-based approach is promoted to zone for the selection of suitable aquaculture sites (Aguilar-Manjarrez *et al.* 2010; Ross *et al.* 2013).

Box 1: Definitions of zoning and Allocated Zones for Aquaculture

Zoning implies bringing together the criteria for locating aquaculture and other activities in order to define broad zones suitable for different activities or mixes of activities. Zoning is a process that countries can use to sustainably and responsibly identify and allocate areas that are biophysically and socio-economically suitable for aquaculture. In broad terms, zoning can be used to identify potential areas for growth where aquaculture is new, and help regulate the development of aquaculture where it is already established (FAO, 2017).

Allocated Zones for Aquaculture (AZAs), a marine area where the development of aquaculture has priority over other uses, and therefore will be primarily dedicated to aquaculture. Identification of an AZA will result from zoning processes through participatory spatial planning, whereby administrative bodies legally establish that specific spatial areas within a region have priority for aquaculture development (Sanchez-Jerez *et al.*, 2016).

According to FAO (2017), the ecosystem approach to aquaculture zoning involves collating essential criteria in the form of:

- biophysical requirements
- environmental carrying capacity
- social carrying capacity
- economic
- governance
- aquatic animal health

The above themes of suitability criteria apply to most aquaculture farming systems and have been the subject of many mapping projects within the EU. The outputs of these projects are typically models (GIS add-ins) which can be adapted for other locations where the criteria are the same, and then overlain with other GIS layers and models. The various criteria under these theme headings have their own degree of importance and their spatial data have been analysed within many zoning models. Each zoning model will have determined "thresholds" that pertain to a desired level of suitability for each criterion. The selection of the thresholds involves interpretation of the data selected, and such interpretation will have been guided with literature research but may not have been scrutinised by opinions from industry, marine planners, and licensing authorities. These zoning models have been reviewed in order to develop a criteria toolkit which has involved consultation with industry and regulators to close the gap between what is reported in the literature and planning precedence.

The MSP Directive states that 'Member States should take into account the precautionary principle and the principle that preventive action should be taken, as laid down in Article 191(2) of the Treaty on the Functioning of the European Union'. This means that, regardless of any zoning output, the competent authority would still need to rely on planning principles to obtain negotiated agreement among affected groups, including the assurance that accurate information has been used. The type of aquaculture and the type of conflict will determine the compatibility levels and risk-based decisions in line with the relevant legal framework will need to be made by regulators.

This Report

A Preliminary Report for this project consolidated known interactions between aquaculture and biodiversity in order to assist the identification criteria for Marine Spatial Planning, including Allocated Zones for Aquaculture (AZAs) and Aquaculture Free Zones (AFZs). These interactions have been developed further in this report by reviewing and analysing how the different Member States have dealt with these within the context of aquaculture suitability.

Aims and objectives

The aim of this work is to develop a criteria/methodology toolkit for identifying AZAs and AFZs under a marine spatial plan.

Through a consultative process with relevant stakeholders and a review of relevant best available science, the objectives are to identify, analyse and advise criteria and methodology that can support determining aquaculture zones for EU Member States. The submission will be used as a guide for the Aquaculture Advisory Council Working Group on Horizontal Issues to develop recommendations for approval by the Executive Committee to be submitted to EU Member States and the European Commission.

Methodology - Approach to Building a Common Framework

Research Approach - Questionnaire and Interviews

The research work resulted in a combination of literature searches and interviews with representatives of the Member States. To focus this research, the FAO have produced a guide to developing a framework to the implementation of aquaculture spatial planning and area management (FAO, 2017), and this has guided the collation of information. Literature searches focussed on Member States processes, activities and tools for determining locations for aquaculture, as detailed in Table 1, which was adapted from the FAO Guide. A questionnaire was created (Annex 1), to quickly gather information from Aquaculture Advisory Council members in order to limit research effort to those Members States that had developed a framework for siting aquaculture within the context of Marine Spatial Planning.

Table 1. Potential framework to guide the implementation of aquaculture spatial planning and area management (adapted from FAO, 2017).

Steps	Process	Tools and activities
National / Subnational efforts	Review national/subnational priorities for aquaculture	Review relevant policy and legal frameworks
	Identification of relevant stakeholders for consultation	Institutional mapping and analysis
	Identification of general issues and opportunities	Aquaculture species/systems review
	Identification of potential for cultured species and farmed systems	Mapping of aquaculture sites
	Assessment of suitability of aquaculture	Set licence production limits within zones or water body carrying capacity
	Detailed estimation of carrying capacity for sites	Nutirent mass balance equation models (e.g. DEPOMOD, ECOPATH)
	Biosecurity planning and disease control	Zoning between aquaculture sites
Zoning approaches	Identification of areas suitable for aquaculture	Site selection and modelling
	Identiifcation of areas suitable for other sectors (e.g. renewables, oil spill response)	SEA and other related approaches

Stakeholder Engagement

To access the wider aquaculture and marine spatial planning community (outside the Aquaculture Advisory Council members), the EU MSP Platform was queried [https://www.msp-platform.eu/countries-overview]. The study was limited to responses from questionnaires within the AAC and coastal Member States have an active aquaculture industry.

Representatives from 17 Member States responded with completed questionnaires and further information via email correspondence (as detailed in Table 2).

Written responses on the first draft of this report were consulted and agreed upon during a webinar with a break-out group held on the 13th September 2019. A second consultation was carried out on the second draft, and comments adopted in the final report. Details of the comments can be found in Deliverable 3: Consultation Report.

Table 2. Authorities consulted in the study.

Member State	Authority
Belgium	FEAP (Federation of European Aquaculture Producers)
Bulgaria	Ministry of Regional Development and Public Works
Croatia	Ministry of Agriculture
Cyprus	Ministry of Agriculture, Rural Development and the Environment, Department of Fisheries and Marine Research
	BirdLife Cyprus*
Denmark	Danish Aquaculture Organisation* **
	Danish Society for Nature Conservation
	Marine Ingredients and EUFishmeal
Estonia	Ministry of Rural Affairs of the Republic of Estonia, Fisheries Economics Department, Market Regulation and Trade Bureau
Finland	Ministry of the Environment, Department of the Built Environment
France	CNPMEM and SFAMN (marine finfish industry)
	CRC Bretagne-Sud (oyster industry)
	Moules de bouchot (mussel industry)
	CIPA (Comité interprofessionnel des produits de l'aquaculture)
	CNC/EMPA**
Germany	Ministry of Energy, Infrastructure and Digitalization Mecklenburg-Vorpommern
Greece	Federation of Greek Mariculture**
	Nireus Aquaculture SA
	Karka Lena, researcher
Ireland	Irish Farmers Association* **
	Coastwatch*
Italy	Associazione Mediterranea Acquacoltori
	FAI-CISL
Netherlands	Stichting Vissan Peschamni
Portugal	Portuguese Society for the Study of Birds*
Romania	National Institute for Marine Research
Spain	APROMAR**
Sweden	Recirkfisk
UK	British Trout Association
	Marine Scotland
	Shellfish Association of Great Britain
Not affiliated with a specific Member State	BirdLife International* **
	European Environment Agency*
	Institute of Aquaculture, University of Stirling*

* Consultees that provided written responses, and ** consultees that provided input through the webinar event.

Research Output

In such an approach requiring the integration of work of international comparison, the construction of a database for all the MS covered by this analysis was an essential step in this work. National plans for aquaculture of the countries studied (from Table 2), were assessed on their efforts in developing criteria for locating aquaculture and these are detailed within Deliverable 1 (Excel): Sheet "Output 1&2. MS Criteria to Locate". This output describes relative efforts in making place-based decisions for aquaculture and allows the identification of gaps between the established national criteria used.

The criteria that Member States have established as standards for which decisions on aquaculture areas can be based on are listed as subject headings. A comparison is made on the criteria thresholds and methods used to consider these. Supplementary information gathered from interviews and research, not directly relevant to criteria to locate aquaculture, are provided in Annex 2.

Where a country has developed an holistic model for zoning using multiple criteria, then the model is assessed further in Deliverable 1: Sheet "Output 3 Model's Criteria to Locate". The analysis of the criteria aims at understanding the weight of interactions with the environment and between activities and the approaches used in GIS to zone.

A comparison between the different approaches to zoning is discussed under the criteria sub-headings, and recommendations are taken forward to developing a methodology for determining aquaculture zones.

Development of a criteria toolkit for identifying AZAs and AFZs under a marine spatial plan

The main aquaculture producers in the EU are (in alphabetical order) France, Greece, Italy, Spain and UK. Of these countries, Greece (Ministry of Environment and Energy, 2011), Spain (Galicia, Murcia, Valencia and Tenerife: Perez *et al.*, 2005) and England (MMO, 2012) have produced suitability maps for locating aquaculture. Other countries that have produced aquaculture suitability maps include Croatia (Oikon and Zjzz, 2003), Cyprus (AP Marine, 2015) and Finland (Ministry of Agriculture and Forestry, 2018). Whilst Germany has not produced suitability maps, they have zoned other activities which exclude aquaculture activities. Thresholds on criteria to locate are discussed under the criteria themes as sub-headings of this section and recommendations concluded at the end of each criterion.

Box 2: A brief note on the methods used in GIS to consider criteria

Site selection modelling in GIS can broadly take the form of two approaches of multi-criteria evaluation (MCE), one using a user-defined hard classification scheme and another using a fuzzy classification scheme.

A user-defined classification will have several suitability categories with hard boundaries (e.g. highly unsuitable, unsuitable, intermediate, suitable, and highly suitable). One such model is that of the AquaSpace tool for aquaculture (Gimpel *et al.*, 2018) where trade-offs were weighted through a stakeholder-led, bottom-up approach. This approach has successfully been used in Cyprus for aquaculture and Scotland (with the exclusion of the Shetland Islands) for renewable energy infrastructure (Scottish Government, 2018).

The gradual suitability scale (scores between 0 and 1, representing a scale of not suitable to suitable) for the fuzzy classification method has been successfully applied for aquaculture in Finland and England and for renewable energy infrastructure in the Shetland Islands (Tweddle *et al.,* 2014).

Some decisions on functionality of data are common across both weighting and non-weighting approaches:

- 'Exclusions' are areas that are unavailable to aquaculture, also referred to as Aquaculture Free Zones (AFZs) such as IMO shipping routes and cables and pipelines.
- The intensity of the activity (e.g. fishing) or density of the species (e.g. cetaceans) may be mapped and these can be weighted and a constraint level applied to reflect the intensity/density.
- The use of vector data (points or lines) in spatial analysis and modelling can underrepresent an actual area occupied or being used and so data layers should ideally be expressed as polygons. Where data are not available as polygons, buffers can be applied to point or line data, the size of which was based on legislative guidance, planning precedence or through published evidence of impact threshold distances.

It is not within the scope of this project to determine the MCE approach, as this will be best decided by the GIS practitioner. What has been included in this report is how the different activities have been treated within zoning models for aquaculture.

Baseline criteria - the biophysical requirements

The fundamental factors that determine the viability of a zone for aquaculture are basic biophysical requirements such as:

- substrate type (the EUNIS classification is discussed under 'Seabed Habitats' section)
- depth
- water quantity
- water quality (e.g. salinity, hardness, tendency for eutrophication)
- current velocity
- exposure (wave height and wind strength)
- temperature
- chlorophyll a (surface)
- nitrogen and phosphorus (surface)
- distance from shore

The above criteria are baseline information that determine what species can be cultured efficiently in a particular area and give a broad indication of the production system that is best suited.

Some EU governments have defined acceptable impacts on primary production, sediment oxygen levels etc. which can facilitate the determination of the carrying capacity of an area in terms of number of farms, and total biomass produced.

There are many models that identify biophysical requirements, but one recent roadmap developed for the European Commission is COEXIST, which delivered maps of Europe showing coastal areas with specific characteristics based on physical characteristics and suitability for different activities (Stelzenmüller *et al.*, 2013). At a broad scale, the information provided in the model include search options regarding the aquaculture type to be assessed (finfish, shellfish, macro-algae and Integrated MultiTrophic Aquaculture, IMTA), the species to be cultivated and the culture system (ranching, marine cage, longline, bottom, trestles). This tool has been created for re-use using ArcGIS Model Builder, and can be customised based on the type of production and marine environment (Davaasuren *et al.*, 2013).

→ **Toolkit Recommendation: The mapped outputs from the Coexist project can be overlain with other suitability models and use of these are strongly recommended in any zoning model.**

Environmental Carrying Capacity

The environmental carrying capacity criteria used by Member States to locate aquaculture are broadly similar, and for a detailed review, refer to Deliverable 1 (Excel): Sheet "Output 1&2. MS Criteria to Locate". At consenting stage, most Member States determine the outcome of a planning application at the site-specific scale using simulation models to predict environmental changes with different nutrient loadings from fish cage aquaculture and shellfish aquaculture. It is not within the scope of this study to review these models, but a good analysis is provided by Ross *et al.* (2013).

Natura 2000 network and other conservation protection areas

For marine Natura 2000 sites, the EU Commission Guidelines on Aquaculture and Natura 2000 offer clear advice: only marine aquaculture farms without a detrimental effect on the habitats and species protected under the Birds and Habitats Directive should be permitted in such areas, and these should be assessed on a case-by-case basis (EC, 2012). Aquaculture activities are carried out in many Natura 2000 sites, with over 5% hosting aquaculture activities pre-designation, often under traditional practices or have adapted its operation to the conservation needs of the sites (examples include Arcachon and all oyster parks and marshes in France, the Wadden Sea in the Netherlands, the Sado Estuary in Portugal, Doñana in Spain, shellfish culture in England and Wales and several Lochs in Scotland; EC 2012). A recent report suggests that there are 68 finfish and 58 shellfish sites located within the MPA network (Bolognini *et al*., 2019).

Three of the five Member States studied that modelled aquaculture suitability excluded Natura sites. Croatia, Cyprus and Spain considered aquaculture incompatible with the conservation objectives of the Natura framework.

The AquaSpace tool had a flexible approach to Natura sites in order to incorporate the high variability of MSP implementation processes in different regions. For example, whereas areas designated for marine conservation constituted a constraint in most of the case studies, it was rated as causing a low likelihood of conflict for aquaculture with blue mussel in Germany and seabass in Greece and a medium likelihood of conflict for seabass in Spain.

At a European scale, this variability in likelihood of conflict could be dealt with by acknowledging that Natura sites with a marine element as a designated feature will add complexities and possible delays to obtaining a licence for a new site. Complexities include additional burdens such as Habitats Regulations Assessment (HRA) and potential requirement to carry out an Environmental Impact Assessment (EIA).

The English MMO model applied a defined constraint score (double that of other constraints) to reflect the higher effort required in obtaining a finfish or macro-algae licence (the EIA and HRA burden). Furthermore, a buffer of 250m was applied and fuzzy logic (higher constraint closer to the boundary) based on legislative/historic precedent. One recommendation to future iterations of the model (Franco, 2017) was that this buffer be removed at the England-wide scale. At the local scale, the buffer could be revised taking into consideration differential impacts and hydrodynamic characteristics of a site. This would require analysis on a case-by-case basis given the differences in scales of data.

In the Finnish model, only certain qualifying features of the Natura sites were excluded (bird islands and sandbanks, and these are discussed within their respective section below).

In Greece, Natura sites were included and consents to locate were determined through the planning regime.

→ **Toolkit Recommendation: In general, aquaculture should not be excluded within Natura sites. Exceptions are where data on vulnerable marine features are available at a suitable resolution and confidence level, and there is potential for a significant negative impact from the type of aquaculture.**

Vulnerable Species

Seals

Seals data has not been included in most of the aquaculture zoning models reviewed for this study. Where those models included seals (England and Finland), the format of the data determined how it was dealt with in terms of scoring of constraints:

- Seal protection areas - aquaculture was excluded (Finland)
- Seal density - higher density = higher constraint score (England)
- Species non-specific - a 250m buffer on all Natura sites (England)

Ideally, aquaculture should not be excluded from Natura sites (where seals are a qualifying feature) as species density varies widely within sites given various behavioural needs such as foraging and reproduction. As described above on the section on Natura sites, one of the recommendations to future iterations of the English model was to review the 250m buffer as this was at risk of reducing potential unnecessarily (see note above on local scale hydrodynamic data).

Where there exists site-specific data covering small areas, such as caves for breeding, the seal protection areas of Finland, or seal haul out sites of Scotland, there is a good case for excluding aquaculture. These boundaries further present the opportunity to apply a buffer approach to conserve the integrity of the site. Impacts to seals described in the Preliminary Report can be determined on a dose-response relationship basis, i.e. the noise impact from ADDs or contamination from use of pesticides will decrease with increasing distance to the aquaculture site. Should a zoning model include site-specific local scale data on hydrodynamics and noise propagation, then the case for a fuzzy approach to data should be considered using distance as a constraint factor.

Should data on seal density exist, the higher density areas should be given a low acceptability score. Seals will present operators with additional predator control responsibilities (including shooting and use of ADDs which significantly affects the social acceptability of the industry) and therefore it is in the industry's interests to avoid high density areas.

→ **Toolkit Recommendation: Aquaculture should be excluded within recognised seal haul-out sites. Where the data allow, higher density areas or critical habitats should be treated as a constraint.**

Birds

Bird data has not been included in most of the aquaculture zoning models reviewed for this study. Of those models that did include birds (England and Finland), the format of the data determined how it was dealt with in terms of scoring of constraints:

- Bird habitat - within Natura sites, birds were given a 500m buffer around bird islands during breeding season (Finland)
- Bird population (seaduck and diver species) - presence / absence = fixed constraint score on 1km buffer (England)
- Species non-specific - a 250m buffer on all Natura sites (England)

As for seals, aquaculture should not be excluded from Natura sites where birds are a qualifying feature as species density varies widely within sites. Although the Finnish model included a temporal buffer exclusion within Natura sites, it is unclear how this affected the final potential maps of suitability (i.e. a zoning output is either suitable or not, regardless of season).

The European Seabirds at Sea (ESAS) dataset for seaducks and divers were included in England's zoning model. The model used the "number" column which represents the total number of birds observed (values of "1" were omitted). This data was supplied as point data and a buffer of 1km was applied, with a defined constraint of '1'.

→ **Toolkit Recommendation: Where the data allow, higher density areas or critical habitats for seaducks and divers should be treated as a constraint.**

Migratory Species

Certain types of aquaculture may impact migratory routes of birds, fish and cetaceans in different ways (as discussed in the Preliminary Report of this project) and should consequently be dealt with differently in any zoning model.

Maps showing routes of migratory birds, fish and cetaceans are a key knowledge gap for any zoning model. Although there is not a map of migratory salmon routes on the Scottish Planning Portal (NMPi), policy does exist that prohibit aquaculture over a significant area (north and east coast) where most significant wild salmonid populations are found (Scottish Government, 2015). Studies in Ireland, Norway and Scotland have shown elevated salmon lice levels on wild sea trout particularly within 30km of the nearest farms (as reported in Thorstad and Finstad, 2018). Consideration should be given to a 30km buffer around wild salmon or sea trout river systems in order to protect the outgoing smolts from the effects of sea lice.

No zoning models excluded migratory routes but where the data is available for the relevant species, should be a key consideration in any future model.

→ **Toolkit Recommendation: In general, aquaculture should not be excluded within migratory routes for birds, fish and cetaceans. Where there are high confidence levels in data, high density routes should be treated as a constraint. A 30km buffer around Natura Sites where wild salmon or sea trout are a designated feature should be applied and treated as a constraint.**

Vulnerable Habitats

Spawning and nursery habitats

Finland and Greece exclude aquaculture within spawning and nursery grounds in their zoning models (in Finland, a 100m buffer was applied). These grounds are critical habitats for commercial species, but limitations of the data (too broad scale, therefore representing very large areas) can be restrictive to aquaculture potential in a zoning model.

→ **Toolkit Recommendation: The resolution of habitat data, the constraint level and the buffer applied should be considered carefully to avoid being too restrictive to potential. Where there are high confidence levels in data, aquaculture should be excluded within and 100m around spawning grounds of fish species of commercial and conservation importance.**

Seabed habitats

Four of the five Member States that carried out aquaculture suitability modelling incorporated exclusions or constraint scores on vulnerable habitats:

- Cyprus and Greece - *Posidonia* meadows given 350m buffer and excluded. Coraligenous seabed habitats are also excluded in Cyprus.
- Finland - within Natura sites where underwater reefs or sandbanks are protected, areas less than 20m depth were excluded.
- England - UKSeaMap (EUNIS codes) with cumulative sensitivity scores excluded. Point data were given buffers and fuzzy logic constraint scoring applied.
- Spain (Tenerife) - Seagrass meadows were given a 300m buffer and a fixed constraint applied.

The buffer distances of 300 – 350m were based on worst-case events published in literature and of a hydrographical nature. Impact zones will vary depending on source and pathway, and hydrographical modelling at the local level will in reality determine impact range. This impact range, combined with knowledge of the type of protected feature and their sensitivity, will determine the compatibility levels and risk-based decisions in line with the relevant legal framework will need to be made by regulators. On this basis, and in order to maximise potential areas at the pre-application stage of zoning, a buffer of 50m was agreed during consultation of this work, as detailed in Deliverable 3: Consultation Report.

The AquaSpace tool (Alkiza *et al.*, 2016) also used the EUNIS code of vulnerable habitats (as did the England model) in order to account for cumulative environmental effects and the risk of impact on ecosystem components from aquaculture. Essential but highly sensitive benthic habitats were scored for their vulnerability to aquaculture. Vulnerability scores (1- 3, 3 = highly vulnerable), combined with the respective EUNIS code of these habitats, are shown in Table 3. All habitats were rated by expert knowledge as being incompatible with aquaculture. However, benthic habitat data are only available for the shallower part of the aquaculture zone and therefore benthic vulnerability scores could only be calculated in shallower areas.

→ **Toolkit Recommendation: Highly vulnerable habitats to aquaculture should be given a buffer of 50m and excluded from potential development.**

Table 3. Habitat (linked to EUNIS coding) vulnerability to aquaculture activity. Vulnerability scores range from 1-3, where 3 = highly vulnerable. Table modified from Alkiza *et al.* (2016).

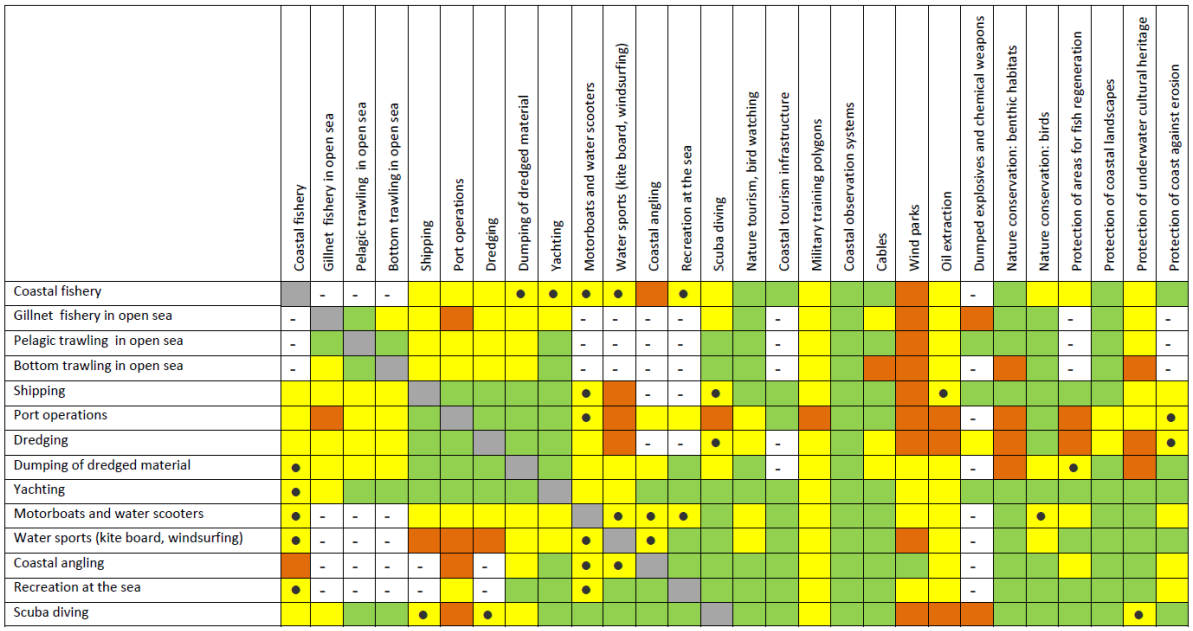
Habitat	EUNIS code	Vulnerability to aquaculture
Infralittoral rock and other hard substrata	A3	2
Atlantic and Mediterranean high energy infralittoral rock	A3.1	1
High energy infralittoral seabed		1
High energy infralittoral mixed hard sediments		1
Atlantic and Mediterranean moderate energy infralittoral rock	A3.2	2
Moderate energy infralittoral seabed		2
Moderate energy infralittoral mixed hard sediments		2
Atlantic and Mediterranean low energy infralittoral rock	A3.3	3
Low energy infralittoral seabed		3
Low energy infralittoral mixed hard sediments		3
Silted kelp on low energy infralittoral rock with full salinity	A3.31	3
Circalittoral rock and other hard substrata	A4	2
Atlantic and Mediterranean high energy circalittoral rock	A4.1	2
High energy circalittoral seabed		2
High energy circalittoral mixed hard sediments		2
Very tide-swept faunal communities on circalittoral rock or mixed faunal turf communities on circalittoral rock	A4.11 or A4.13	3
Sponge communities on deep circalittoral rock	A4.12	2
Atlantic and Mediterranean moderate energy circalittoral rock	A4.2	2
Moderate energy circalittoral seabed		2
Moderate energy circalittoral mixed hard sediments		2
Faunal communities on deep moderate energy circalittoral rock	A4.27	2
Atlantic and Mediterranean low energy circalittoral rock	A4.3	2
Low energy circalittoral seabed		2
Low energy circalittoral mixed hard sediments		2
Brachiopod and ascidian communities on circalittoral rock	A4.31	2
Faunal communities on deep low energy circalittoral rock	A4.33	2
Infralittoral coarse sediment	A5.13	2
Circalittoral coarse sediment	A5.14	2
Deep circalittoral coarse sediment	A5.15	2
Deep circalittoral Seabed		2
Infralittoral fine sand or infralittoral muddy sand	A5.23 or A5.24	2
Infralittoral fine sand	A5.23	2
Infralittoral muddy sand	A5.24	2
Circalittoral fine sand or circalittoral muddy sand	A5.25 or A5.26	2
Circalittoral fine sand	A5.25	2
Circalittoral muddy sand	A5.26	2
Deep circalittoral sand	A5.27	2
Infralittoral sandy mud or infralittoral fine mud	A5.33 or A5.34	2
Infralittoral sandy mud	A5.33	2
Infralittoral fine mud	A5.34	2
Circalittoral sandy mud or circalittoral fine mud	A5.35 or A5.36	2
Circalittoral sandy mud	A5.35	2
Circalittoral fine mud	A5.36	2
Deep circalittoral mud	A5.37	2
Infralittoral mixed sediments	A5.43	2
Circalittoral mixed sediments	A5.44	2

Habitat	EUNIS code	Vulnerability to aquaculture
Infralittoral rock and other hard substrata	A3	2
Atlantic and Mediterranean high energy infralittoral rock	A3.1	1
High energy infralittoral seabed		1
High energy infralittoral mixed hard sediments		1
Atlantic and Mediterranean moderate energy infralittoral rock	A3.2	2
Moderate energy infralittoral seabed		2
Moderate energy infralittoral mixed hard sediments		2
Atlantic and Mediterranean low energy infralittoral rock	A3.3	3
Low energy infralittoral seabed		3
Deep circalittoral mixed sediments	A5.45	2
Deep circalittoral mixed hard sediments		2
Seagrass beds	A5.53	3
Posidonia beds	A5.535	3
Seagrass beds on litoral sediments	A2.61	3
Maerl beds	A5.51	3

Social Carrying Capacity

Social carrying capacity is the amount of aquaculture that can be developed without adverse social impacts. This can include consideration of human activities including fishing and recreational communities, visual impacts and the needs of other resource users.

The concept of developing a matrix of interactions between coastal and marine uses and activities is a crucial step in understanding and analysing the weight of the interactions of the activity with its environment and underpins any zoning framework. A typical matrix is shown in Figure 1, developed for the BaltSeaPlan (2011), but a similar approach was taken by the Transboundary European Planning Project European Atlantic Project (TPEA), and adopted for use in SIMNORAT project (Dilasser *et al.*, 2019). The matrix shown in Figure 1 shows activities ranging in compatibility and includes synergies and spatial efficiencies.



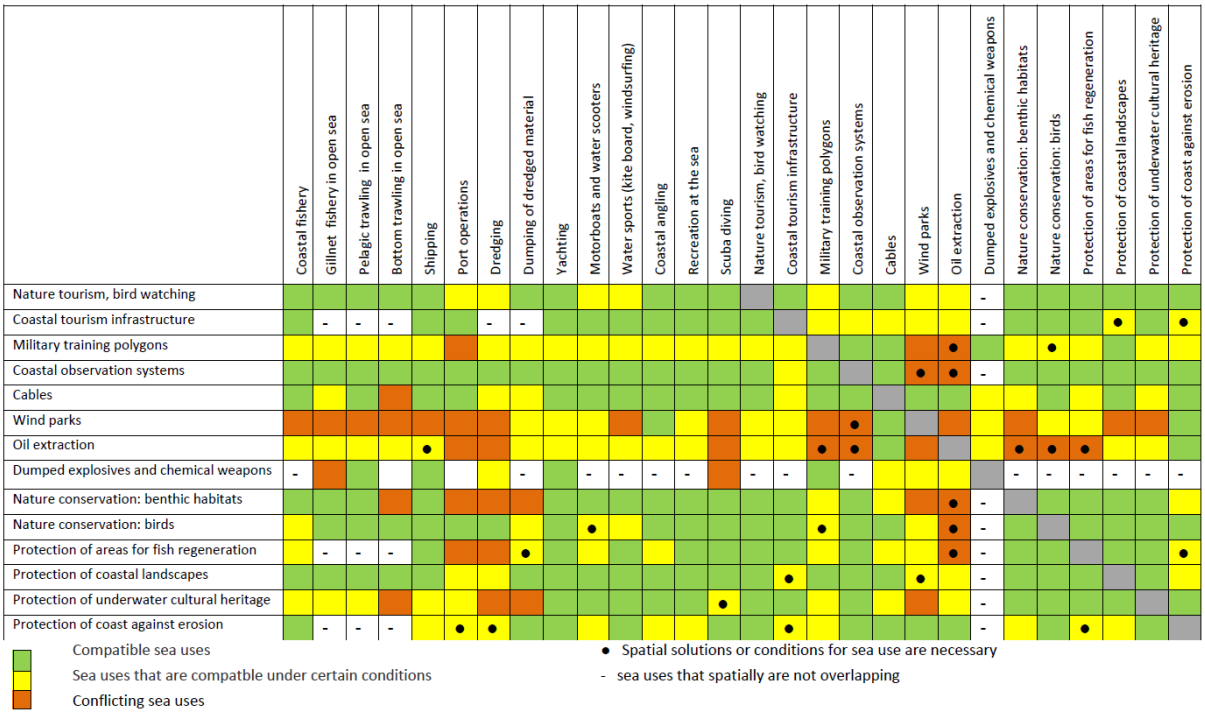


Figure 1: Conflict analysis (BaltSeaPlan Report 16 (2011), download from www.baltseaplan.eu).

Multi-user synergies and spatial efficiencies

The social licence for IMTA will be more publicly acceptable, where shellfish and macro-algae production can have a positive effect on water quality when co-produced with finfish and shellfish respectively (i.e. recycling wastes nutrients from higher trophic-level species) (Holmer, 2012).

Synergies might also emerge where technical development in one sector supports another such as locating shellfish lines within wind farms. Various IMTA scenarios were tested in the southwest European area by the Coexist project (Stelzenmüller *et al.*, 2013), and this model can be adapted for other areas to map biophysical requirements (which are then overlain with other constraint models).

→ **Toolkit Recommendation: Multi-user synergies and spatial efficiencies can be dealt with in GIS through applying a negative scoring (that counteracts the positive scoring of constraints).**

Wastewater and other controlled discharges

A wastewater or controlled discharge will be a stronger constraint to aquaculture developments at the source than at a given distance away from the source. All of the models studied based suitability on proximity to discharges. Where point data was supplied for the English model, a 100m buffer was applied and fuzzy logic approach taken (the constraint score of '1' reduced with distance from source). Aquaculture was excluded within a 200m buffer of discharges in the Tenerife model in order to avoid damage from mooring lines of aquaculture.

Sources of pollution were combined with current and wave data in the Cyprus model, with graduated constraint scores (in order of reduced suitability):

- >3km, exposed and no sources of pollution;
- <3km exposed and no sources of pollution;
- <3km, sheltered no sources of pollution;
- exposed and polluted;
- sheltered and polluted were excluded.

The water quality indicator in the AquaSpace tool was parameterized by expert opinion, assuming that a distance > 1.8km indicates a low risk of pollution and therefore a high water quality (3 = high), a distance of < 1.8km indicates medium water quality and a distance of < 100m indicates a low level of water quality (1 = low).

During consultation of this work, as detailed in Deliverable 3: Consultation Report, it was recognised that water testing at the local level will be a requirement prior to a licence being granted. In order to pre-empt this requirement, at the same time as maximising potential areas, it was agreed to include a conservative buffer of 100m around wastewater and other controlled discharge points.

→ **Toolkit Recommendation: A buffer of 100m around wastewater and other controlled discharge points should be applied and treated as a constraint.**

Recreation and tourism

Shipwrecks

Information on sites of interest for their significance or contribution to cultural heritage should be incorporated in any zoning model, and were included in all of the zoning models studied. Some Member States designate a restricted area surrounding a wreck to protect from looting, but the majority of shipwrecks do not have some form of protected status. The Finnish model applied a buffer of 100m around wrecks and aquaculture was excluded from this area.

→ **Toolkit Recommendation: Unless a shipwreck is considered to be of historical importance and vulnerability, aquaculture should be excluded within 50m of all wrecks.**

Recreational activities

Another indicator which reflects socio-cultural impacts is based on spatially explicit information about areas used for recreational activities. The range of data will vary between Member States. Croatia had previously designated intensive areas of recreation and excluded any potential for aquaculture. Aquaculture is excluded through policy in some local areas in the Shetland Islands (Shetland Marine Regional Marine Planning Partnership, 2019). The AquaSpace tool and Cyprus approach used distance to Blue Flag beaches as a factor for suitability (i.e. short distance = high impact, long distance = low impact). In addition to visual impact from beaches in Tenerife (described below), the model included maps of varying activities (scuba-diving, scuba-diving in particular marine habitats, shipwrecked boats, spearfishing, windsurfing and near-shore sailing) and applied a fixed constraint

score to a 500-1000m buffer surrounding the activity. Data on diving and yachting was used in the English spatial model and a fixed constraint score was applied. The Finnish model excluded aquaculture within a 500m buffer zone around all holiday homes.

Such data on recreation is not available for many areas (e.g. the German coast), but is extensive in others (e.g. for Scotland available data include dive sites, historic MPAs, sailing areas for cruising, racing, and sailing, and anchorage sites).

During consultation on this project, it was agreed that buffer distances should vary depending on the activity (as detailed in Deliverable 3: Consultation Report). Sports such as surfing, windsurfing, sailing, sail boat / yacht racing and rowing have large spatial requirements that would conflict with aquaculture, and therefore require larger buffers such as 500m. Whereas sports will little spatial requirements such as kayaking, climbing, coasteering, scuba diving and angling have limited spatial conflict with aquaculture.

→ **Toolkit Recommendation: Where data exists, aquaculture should be excluded from intensively used areas for recreation. Where there are no exclusions, various buffer distances appropriate to the activity should apply and be treated as a constraint.**

Visual impact

Visual impacts can be difficult to quantify and measure as they will vary depending on the system and the sensitivity of the area to visual change. The visibility of the system and the aesthetic value of a seascape will vary spatially.

From the models studied, only the Tenerife model used visual impact criteria, where visibility from important tourist resources and visibility from beaches (visible = totally unsuitable) were mapped and used. This is very labour-intensive, but a key consideration where tourism is important economically.

An alternative approach was carried out by Falconer *et al.* (2013), who used a two-stage GIS based modelling approach to assess the visual impact of marine aquaculture and associated land-based structures in the Western Isles of Scotland.

To account for spatial expressions of some socio-cultural effects and impacts of aquaculture, the AquaSpace tool enabled inputs relating to visual impacts and is quantified by local population (>10,000) within a 5.5km radius (as quantified by Miller and Morrice, 2002).

During consultation on this project, it was agreed that visual impact could not be quantified at European-scale and should be open to interpretation through the local planning regimes in place (as detailed in Deliverable 3: Consultation Report).

→ **Toolkit Recommendation: Visual impact should be considered during the planning process. Where data exists, visual impact should be treated as a constraint.**

Marine Traffic and Maritime Safety

All models excluded aquaculture from IMO ship routing measures (including traffic separation schemes and inshore traffic zones), in accordance with The International Regulations for Preventing Collisions at Sea 1972, COLREGS.

The Tenerife model applied a 200-400m buffer with a fixed constraint score to fairways to ports. The English model applied an exclusion to port administration areas, as well as recognised offshore anchorage and areas used for ship-to-ship transfers. The English model also used additional data on shipping intensity, where low density areas were given a lower constraint score. The Mecklenburg-Vorpommern MSP (Germany) excluded Priority Areas of Shipping defined in the EEZ Plan as well as a site-specific buffers on traffic separation areas, ranging from 16.5m to 3.5NM (full list in the Governance section and Deliverable 1: Sheet "Output 3 Model's Criteria to Locate").

Other boat routes, outwith the statutory ship routing measures, should be included. Whilst anecdotal evidence from an aquaculture operator in Greece suggested there were too many areas committed for navigation (*questionnaire response from Leonidas Papaharisis*), ferry routes provide lifeline links to remote populations, and tourist craft encourage and educate visitors as well as providing a valuable source of income.

→ **Toolkit Recommendation: Aquaculture should be excluded within IMO ship routes, recognised anchorage, port administration areas and where relevant, ship-to-ship transfer areas. Fairways to ports should be considered using buffers and varying constraint levels. Ferry routes and tourist craft should be treated as a constraint.**

Fisheries

The importance of individual fishing areas changes considerably over time and therefore Good Practice in the UK recommends a 5-year history of data to be used for EIA, and this approach was adopted in the English zoning model. Fishing intensity data was ranked into five categories ranging between high intensity and low intensity fishing effort. Similarly, the AquaSpace tool offers the opportunity to distinguish between high and low fishing effort per country.

In Greece, aquaculture is excluded within a buffer zone of 50m of fishing grounds to allow for fishing gear to avoid the mooring lines of caged aquaculture. The Tenerife model also applied proximity ranges, but of a less strict threshold than Greece, where a lower suitability score was applied closer to a fishing ground.

A time-series of data may not be possible for inshore fisheries where there is a widespread lack of evidence-base across the EU. There is a high degree of conflict for space with aquaculture, and capturing fisher knowledge is crucial in pre-empting objections to planning applications.

→ **Toolkit Recommendation: Fishing intensity data should be ranked for suitability. Consideration should be given to a 50m buffer that allows for fishing gear to avoid the mooring lines of caged aquaculture. A key gap across Member States will be inshore fishing data and efforts to map and rank this should be priority before zoning is carried out.**

Renewable Energy Infrastructure

Renewable energy may still be considered a growth industry, where Member States may have allocated space, which may or may not have infrastructure in place. These suitable areas should be considered when zoning for aquaculture.

The opportunities for aquaculture sites in the middle of offshore wind farms is well recognised, however no type of such synergies has yet been implemented (Dilasser *et al.*, 2019).

The models used in Cyprus and Greece excluded aquaculture from sites of renewable energy infrastructure, the latter model applying a 500m buffer. The English model applied an exclusion to caged (fish and macro-algae) aquaculture only, allowing for the possible synergy for shellfish (rope and bottom culture). The AquaSpace tool also offers the possibility for spatial synergies with aquaculture for nearly all case studies, except the Mediterranean mussel in Spain. It is unclear why this species is excluded for synergy potential, but it appears to be the exception to the rule.

→ **Toolkit Recommendation: Only caged aquaculture should be excluded from within renewable energy infrastructure permit areas, including potential areas identified through zoning. A buffer should be carefully considered as it may be that permitted areas (for renewables) already factor in the risk to safety and navigation.**

Oil and Gas Infrastructure

UNCLOS has set exclusion zones around oil and gas platforms, well heads and guard vessels of 500m, and this exclusion area is adopted in all the zoning models (where relevant). For pipelines, the recommended distances vary between member states: the UK oil and gas industry recommend a 250m buffer on either side of the centre line of the pipeline (as adopted in the English zoning model), and in Belgium, a 500m exclusion on both sides exists. For the purposes of a generic European-wide model, the more conservative distance of 250m on either side of the pipeline will be adopted.

→ **Toolkit Recommendation: Aquaculture should be excluded 500m around oil and gas exploration areas and 250m either side of the central line of pipelines.**

Electricity and Telecommunications Cables

As with oil and gas infrastructure, for safety reasons, the use of any aquaculture equipment cannot coexist with cables. Whilst the International Cable Protection Committee (ICPC) recommends that existing cables in shallower waters (up to a depth of 75m) are given a default 500m exclusion zone on either side, Belgium, Denmark, Netherlands and the UK all adopt much shorter distances (Belgium: 250 m and 50m either side; Denmark: 200m either side; Netherlands: 500m; UK: 250m either side, as adopted in the MMO model). For the purposes of a generic European-wide model, an exclusion area of 500m will be taken for the recommendation.

→ **Toolkit Recommendation: Aquaculture should be excluded 250m either side of the central line of cables.**

Other interactions

Aquaculture was excluded where data existed on the following activities:

- Aggregate extraction and dredge disposal grounds
- Military Use

- Desalination units - a 3km buffer (Cyprus) or 1km buffer (Greece)

Current direction may permit aquaculture within range of desalination units, and therefore a 1km buffer should be applied and treated as a constraint.

→ **Toolkit Recommendation: Aquaculture should be excluded within existing aggregate extraction and dredge disposal grounds and military use areas. A 1km buffer should be applied to desalination units and treated as a constraint.**

Economic criteria

Distance to port

All of the zoning models studied included proximity to suitable ports as a strong economic driver in locating aquaculture sites. Locations within a distance of 500m of port were most suitable. Beyond this, Cyprus and England models created distance ranges from port and scored accordingly, with the least acceptable range being >12NM.

→ **Toolkit Recommendation: Distance ranges from port should be scored accordingly, within 500m being most suitable, to least acceptable range being >12NM.**

Distance to processing facilities

The ability to factor in distance to processing facilities will depend on the availability of the relevant data. For the purpose of zoning, this distance can be restricted to limited facilities i.e. it includes just cleaning and packaging for fin fish, and depuration for shellfish. This criterion was only considered by English and Cyprus models, using distance ranges scored accordingly with the greatest distance being least favoured. In Greece, processing facilities and markets are ideally within a radius of 10NM (*Personal Communication, Leonidas Papaharisis, producers questionnaire response*).

→ **Toolkit Recommendation: Distance ranges from processing facilities should be scored accordingly, within 500m being most suitable, to least acceptable range being >12NM.**

Distance to market

The distance to market will depend on the species cultured and will vary country to country: one government may focus on the supply of cheaper species to local markets, whilst another country may focus on high revenues with high-value species for export by large corporations. Generally, local markets will be more abundant and accessible (20 - 40NM away in Greece), whilst bigger European markets could be located 1,000 - 3,000NM away. Vivier trucks transport live shellfish and fish throughout Europe in specially modified trailers, and these should be accessible at landing port. Therefore, distance to port is the key limiting factor here and distance to market does not have to necessarily be included within any zoning model.

Invasive Non-Native Species (INNS)

The English model recognised the economic impacts of INNS in terms of the burden on cleaning equipment and smothering species. Proximity to INNS was used as a limiting factor (i.e. negative scoring on suitability was applied closer to INNS). The ability to factor in distance to INNS will depend on the availability of the relevant data.

→ **Toolkit Recommendation: Where data is available, proximity to INNS should be a limiting factor (i.e. less suitability closer to INNS).**

Proximity of onshore aquaculture to the marine area

Some aquaculture systems (closed systems such as saltpans and lakes, and land-based hatcheries) are dependent on the marine area, either for tidal influence or for use of saltwater. Using bathymetry data within the Coexist GIS add-in will resolve the depth-dependent resource requirement. For land-based hatcheries, the Valencia model used 500m as a limiting factor, however siting of onshore hatcheries and is outwith the scope of this project.

→ **Toolkit Recommendation: The mapped outputs from the Coexist project will resolve the depth-dependent resource requirement and can be overlain with other suitability outputs.**

Governance – restrictions and opportunities

There are criteria that limit the potential for aquaculture based on government priorities and legislation. Those areas where aquaculture would be excluded in a zoning model, includes, but is not limited to:

- Regulation (EC) 854/2004 and (EC) 853/2004): classification of Shellfish Production Areas (SPAs) are the official type of classification based on results from an extensive number of sampling occasions and a sanitary survey to ensure that potential seasonal and annual variability has been fully covered. Bivalve mollusc species harvested from SPAs classified as “B” and “C” have restrictions before being placed on the market for human consumption, and therefore can be included in a zoning model as a constraint (“B” is a lower constraint than “C”).
- Baltic Sea: Denmark have increased finfish aquaculture opportunities in the Kattegat (outside WFD waters only).
- Croatia: unfavourable hydrodynamics, and areas at-risk areas of phytoplankton blooms.
- Cyprus: Moni Vassilikos area (unofficially considered as an existing aquaculture zone due to the high number of units) and west of the Cava Gata (highly affected by strong wind currents).
- England: potential opportunities for aquaculture exist in zoned areas of the East and South Marine Plan Areas. Elsewhere, restrictions include prohibited areas for harvesting shellfish.
- Finland: Gulf of Finland. The Archipelago Sea (waters off Finland) are in poor condition and aquaculture should be avoided, and as a rule, larger production proposals should be directed to areas over 20m deep.

- France: regulation restriction on Bonne Anse in Gironde; sites/habitats/nature conservation species within the Nature Reserve in the Marennes-Oléron Basin; Yves Nature Reserve; Niges Islet Nature Reserve on D; sites classified Oléron, Brouage, Ré and Charente Aval.; and PNM of the Gironde estuary and Charentais pertuis (*Personal Communication, CRC Charente-Maritime, producers questionnaire response*).
- Germany: regulations exclude other activities from many areas (full detail is provided in Deliverable 1: Sheet "Output 3 Model's Criteria to Locate").
- Scotland: North and East Scotland (migratory fish); recreational area exclusions within the Shetland Islands Marine Plan; Category 1 areas (based on nutrient carrying capacity).

Aquatic animal health

Risk of disease spread

The siting of finfish cages is critical since the environmental conditions under which the fish are grown can influence their welfare as well as the production efficiency of the farm. Whilst this is a key consideration, this aspect is considered to be too site- and time- specific to model in a GIS environment; equally the evidence is not available in a way that would be appropriate for this study.

Gap Analysis and Recommendations

The recommendations on dealing with criteria to locate aquaculture (summarised in Table 4) should be reviewed as new information emerges. In particular, when the EU TAPAS (Tools for Assessment and Planning of Aquaculture Sustainability) project outputs are published, this report should be reviewed for any gaps.

It should be recognised that the output of any zoning model is only as good as the input data, and significant data gaps and limitations were identified during the course of this study. Depositional models for finfish cultivation and nutrient capacity models for shellfish cultivation exist for assessing the environmental effects, but these would require site and development-specific information.

Biophysical requirements have been comprehensively modelled within the Coexist project Stelzenmüller *et al.* (2013) and this tool can be used across other areas of Europe. Even when the essential environmental conditions for aquaculture are identified (bullet point 1 below), the required datasets to map areas of suitable conditions might not be readily available, which will be a significant challenge to its application in the Coexist model. Generally, biophysical datasets can be prioritised as follows:

- Essential datasets that can be collated with ease: substrate type, depth, distance offshore, energy/current speed, wave and tidal exposure.
- Datasets that may be difficult to collate at an EU scale: spat availability, predation, biofouling, disease risk.
- Consider including only adverse conditions for the following data: temperature, salinity, water quality, and primary productivity.

Nutrient carrying capacity measures the resilience of the natural environment to the aquaculture activities and therefore it is essential to estimate the rate at which nutrients can be added to the water, the rate of organic flux to the benthos, and the rate of dissolved oxygen depletion that can be accommodated without negative effects the ecosystem (Pillay & Kutty 2005). Some EU governments have defined carrying capacities of areas, and whilst these are key indicators for industry needs, the methods used to calculate them are outwith the scope of this work. Guidance has been developed in the UK by the Aquaculture Stewardship Council (2012a, 2012b) and could be easily incorporated, to give a broad assessment of the variation of carrying capacity across different areas of the Europe.

MSFD criteria include nutrient concentration, chlorophyll concentration, water transparency, abundance of opportunistic algae and shift in micro-algae concentration and HABs, DO and abundance of perennial seaweeds/seagrasses. HABs and biotoxins are of particular relevance to shellfish aquaculture.

Caution in the interpretation of the model outputs is advised when considering the interaction between aquaculture developments and mobile species. The sensitivity of mobile species to particular activities is likely to be temporally variable, and the timing of noisy operations would still need to be considered through the planning process, rather than through a zoning model.

Furthermore, whilst attempts should be made to represent areas used by mobile species for breeding and migration in a zoning model, an absence of constraint may reflect data gaps generated through the use of non-systematic survey data, rather than a true absence of this constraint. It is for this reason that zoning should not replace the planning process that would have an obligations to anticipate potential adverse effects on the environment before they occur and to take all precautionary measures so that an activity will not result in significant harm.

Nevertheless, critical habitats for mobile species (such as, but not limited to, migratory routes for fish and cetaceans, seal haul-out sites, spawning grounds of commercial and protected fish species) are a key data gap when assessing the impacts of aquaculture.

Table 4. Recommendations on dealing with criteria to locate aquaculture.

Criteria	AZA – data-dependent conditions	AFZ – examples of what data would be treated as an exclusion	Toolkit Recommendation	Data source*
Biophysical	Substrate type, depth, distance offshore, energy/current speed, wave and tidal exposure.	Species- and equipment-dependent. For comprehensive European thresholds, refer to Stelzenmüller *et al.* (2013).	The mapped outputs from the Coexist project can be overlain with other suitability models and use of these are strongly recommended in any zoning model.	EMODnet
Natura 2000 network and other conservation protection areas	Effects should be demonstrated through EIA and HRA, with mitigations negotiated through the planning regime.	Where there is potential for a significant negative impact.	In general, aquaculture should not be excluded within Natura sites. Exceptions are where data on vulnerable marine features are available at a suitable resolution and confidence level, and there is potential for a significant negative impact from the type of aquaculture.	EMODnet
Seals	• Higher densities should be treated as a constraint (i.e. less suitability). • Any critical habitat or area used for behaviours such as foraging and reproduction should be treated as a constraint. • Effects should be demonstrated through EIA and HRA, with mitigations negotiated through the planning regime.	Designated haul-out sites.	Aquaculture should be excluded within recognised haul-out sites. Where the data allow, higher density areas or critical habitats should be treated as a constraint.	Limited data: EMODnet
Birds	• Higher density = higher constraint score (less suitability). • Any critical habitat or area used for behaviours such as foraging and reproduction should be treated as a constraint. • Effects should be	Designated areas or habitats for breeding or foraging.	Where the data allow, higher density areas or critical habitats for seaducks and divers should be treated as a constraint.	EMODnet

Criteria	AZA – data-dependent conditions	AFZ – examples of what data would be treated as an exclusion	Toolkit Recommendation	Data source*
	demonstrated through EIA and HRA, with mitigations negotiated through the planning regime.			
Migratory routes for birds, fish and cetaceans	• High density routes should be treated as a constraint. • Effects should be demonstrated through EIA and HRA, with mitigations negotiated through the planning regime.	None.	In general, aquaculture should not be excluded within migratory routes for birds, fish and cetaceans. Where there are high confidence levels in data, high density routes should be treated as a constraint. A 30km buffer around Natura Sites where wild salmon or sea trout are a designated feature should be applied and treated as a constraint.	Negligible data
Spawning and nursery habitats	Effects should be demonstrated through EIA and HRA, with mitigations negotiated through the planning regime.	Where high confidence levels exist.	The resolution of habitat data, the constraint level and the buffer applied should be considered carefully to avoid being too restrictive to potential. Where there are high confidence levels in data, aquaculture should be excluded within and 100m around spawning grounds of fish species of commercial and conservation importance.	ICES
Seabed habitats	EUNIS habitats with vulnerability score 1-2, according to Alkiza *et al.*, 2016.	EUNIS habitats with vulnerability score 3, according to Alkiza *et al.*, 2016.	Highly vulnerable habitats to aquaculture should be given a buffer of 50m and excluded from potential development.	EMODnet
Synergies and spatial efficiencies	Co-producing different aquaculture species and types (IMTA).	Shellfish lines are possible within wind farms where technologies exist.	Multi-user synergies and spatial efficiencies can be dealt with in GIS through applying a negative scoring (that counteracts the positive scoring of constraints).	Negligible data
Wastewater and other controlled discharges	Constraint: 100m buffer on point data.	None.	A buffer of 100m around wastewater and other controlled discharge points should be applied and treated as a constraint.	EMODnet
Shipwrecks	None.	Exclusion within 100m buffer.	Unless a shipwreck is considered to be of historical importance and vulnerability, aquaculture should be excluded within 50m of all wrecks.	EMODnet
Recreational activities	Constraint: a 500m buffer on point and line data.	Exclusion within intensively used areas.	Aquaculture should be excluded from intensively used areas for recreation. Where there are no exclusions, various buffer distances appropriate to the activity should apply and be	Bathing waters: EMODnet

Criteria	AZA – data-dependent conditions	AFZ – examples of what data would be treated as an exclusion	Toolkit Recommendation	Data source*
			treated as a constraint.	
Visual impact	Visual impact is a constraint where mitigations can be negotiated through the planning regime.	None.	Visual impact should be considered during the planning process. Where data exists, visual impact should be treated as a constraint.	Negligible data
Marine Traffic and Maritime Safety	Buffers around fairways to ports, ferry routes and tourist craft should be considered and varying constraint levels applied.	IMO ship routes, recognised anchorage, port administration areas and where relevant, ship-to-ship transfer areas.	Aquaculture should be excluded within IMO ship routes, recognised anchorage, port administration areas and where relevant, ship-to-ship transfer areas. Fairways to ports should be considered using buffers and varying constraint levels. Ferry routes and tourist craft should be treated as a constraint.	Vessel density: EMODnet
Fisheries	Varying constraint levels dependent on data.	None.	Fishing intensity data should be ranked for suitability. Consideration should be given to a 50m buffer that allows for fishing gear to avoid the mooring lines of caged aquaculture. A key gap across Member States will be inshore fishing data and efforts to map and rank this should be priority before zoning is carried out.	Aggregated to FAO areas: EMODnet
Renewable Energy Infrastructure	Potential for shellfish and macroalgae lines to coexist dependent on technologies.	Aquaculture should be excluded within existing renewable energy sites unless there is a coexist scenario.	Only caged aquaculture should be excluded from within renewable energy infrastructure permit areas, including potential areas identified through zoning. A buffer should be carefully considered as it may be that permitted areas (for renewables) already factor in the risk to safety and navigation.	EMODnet
Oil and Gas Infrastructure	None.	500m around oil and gas exploration areas and 250m either side of the central line of pipelines.	Aquaculture should be excluded 500m around oil and gas exploration areas and 250m either side of the central line of pipelines.	EMODnet
Electricity and Telecommunications Cables	None.	250m either side of the central line of cables.	Aquaculture should be excluded 250m either side of the central line of cables.	EMODnet
Other interactions	Constraint: a 1km buffer around desalination units.	Aggregate extraction and dredge disposal grounds; and military use areas.	Aquaculture should be excluded within existing aggregate extraction and dredge disposal grounds; and military use areas. A 1km buffer should be applied to desalination units and treated as a constraint.	Aggregate extraction and dredging: EMODnet
Distance to port	Varying constraint levels.	None.	Distance ranges from port should be scored accordingly, within	EMODnet

Criteria	AZA – data-dependent conditions	AFZ – examples of what data would be treated as an exclusion	Toolkit Recommendation	Data source*
			500m being most suitable, to least acceptable range being >12NM.	
Distance to processing facilities	Varying constraint levels.	None.	Distance ranges from processing facilities should be scored accordingly, within 500m being most suitable, to least acceptable range being >12NM.	Negligible data
Invasive Non-Native Species (INNS)	Varying constraint levels.	None.	Where data is available, proximity to INNS should be a limiting factor (i.e. less suitability closer to INNS).	Negligible data
Proximity of onshore aquaculture to the marine area	Restricted to within 500m of onshore equipment.	None.	The mapped outputs from the Coexist project will resolve the depth-dependent resource requirement and can be overlain with other suitability outputs.	EMODnet

* It is not within the scope of this project to review the quality of data (in terms of scale, timeliness, granularity and completeness). Data sources are based on EU-wide databases and better quality data may be best sourced from national databases.

References

Aguilar-Manjarrez, J., Soto, D., and Brummett, R. (2017). Aquaculture zoning, site selection and area management under the Ecosystem Approach to Aquaculture. A handbook. Report ACS18071, Food and Agriculture Organization of the United Nations, and The World Bank, Rome. Available at: www.fao.org/3/a-i6834e.pdf (part 1 only) and www.fao.org/3/a-i6992e.pdf (full report).

Alkiza M., Galparsoro I., Uyarra M.C., Muxika I., Borja A. Vol. 23. Revista de Investigación Marina, AZTI; 2016. Mapeo de la sensibilidad ecológica de los hábitats bentónicos frente a las actividades humanas en el noreste Atlántico; pp. 9–22. [Google Scholar]

AP Marine Environmental Consultancy Ltd and Atlantis Consulting Cyprus Ltd. 2015. Study on the siting of aquaculture areas / zones within the marine are under the control of the Republic of Cyprus and a strategic environmental study impacts. Tender number: 24/2015. Available online: [http://www.moa.gov.cy/moa/dfmr/dfmr.nsf/All/E327D560F41AA0E64225811E003F0A75?OpenDocument].

Aquaculture Stewardship Council (2012a). ASC Bivalve Standard Version 1.0 [pdf] Utrecht: Aquaculture Stewardship Council. Available online http://www.asc-aqua.org/upload/ASC%20Bivalve%20Standard_v1.0.pdf

Aquaculture Stewardship Council (2012b). ASC Salmon Standard version 1.0, [pdf] Utrecht: Aquaculture Stewardship Council. Available online http://www.asc-aqua.org/upload/ASC%20Salmon%20Standard_v1.0.pdf

BaltSeaPlan. 2011. BaltSeaPlan Report 16. Available online www.baltseaplan.eu.

Bolognini L., Grati F., Marino G., Punzo E., Scanu M., Torres C., Hardy P.Y., Piante C. (2019). Safeguarding Marine Protected Areas in the growing Mediterranean Blue Economy. Recommendations for Aquaculture. PHAROS4MPAs project. 52 pages. [https://pharos4mpas.interregmed.eu/fileadmin/user_upload/Sites/Biodiversity_Protection/Projects/PHAROS4MPAs/AQUACULTURE_31july_single_page.pdf].

CRC Charente-Maritime, 2019. Producers questionnaire response to Aquaculture Advisory Council.

Dilasser, J., Ganne, M., Campillos-Llanos, M., Murciano Virto, C., Plaza Arroyo, M., Lloret, A., Cervera-Núñez, C., Gómez-Ballesteros, M., Marques, M., Sousa, L., Quintela, A., Lopes Alves, F. 2019. Support Members States implementation of Marine Spatial Planning. C1.3.2. Spatial demands and future trends for maritime sectors.

Davaasuren, N., Brunel, T., Bolman, B., Jak, R., and Corso, S. Deliverable D1.1 Maps of Europe showing coastal areas (marine ecosystems) with specific characteristics based on physical characteristics and suitability for different activities. Coexist Consortium, IMARES. [https://www.coexistproject.eu/images/COEXIST/Tools/SuitabilityMaps.pdf].

European Commission. 2012. Guidance on Aquaculture and Natura 2000 Sustainable aquaculture activities in the context of the Natura 2000 Network. Available online [http://ec.europa.eu/environment/nature/natura2000/management/guidance_en.htm].

European Commission. 2013. Strategic Guidelines for the sustainable development of EU aquaculture. Available online https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0229&from=EN

Falconer, L., Hunter, D.C., Telfer, T.C., Ross, L.G. 2013. Visual, seascape and landscape analysis to support coastal aquaculture site selection. Land Use Policy 34, 1–10.

FAO. 2010. Ecosystem approach to aquaculture. FAO Technical Guidelines for Responsible Fisheries. Rome, FAO.

FAO & World Bank. 2017. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. http://www.fao.org/documents/card/en/c/4c777b3a-6afc4475-bfc2-a51646471b0d/

Franco, S. 2017. Mapping areas of aquaculture potential for marine spatial planning in the UK - analysis of the MMO 1040 aquaculture model and recommendations for future improvements.

Gimpel, A., Töpsch, S., Stelzenmüller, V., Gubbins, M., Murray, A.G., Watret, R., Galparsoro, I., Murillas, A., Pınarbaşı, K., Miller, D., Brigolin, D., Pastres, R., Porporato, R., Roca Carceller, G., Marba, N., Moraitis, M., Papageorgiou, N. 2018. AQUASPACE Ecosystem Approach to making Space for Aquaculture EU Horizon 2020 project grant no. 633476 Deliverable 3.3 AquaSpace tool to support MSP.

Gee, K., Lukic, I., Schultz-Zehden, A., Ooms, E., Onwona Ansong, J., Passerello, C. 2018. Addressing conflicting spatial demands in MSP Considerations for MSP planners. Pro-sustainable projects GmbH, Germany. https://publications.europa.eu/en/publication-detail/-/publication/8971ab22-8285-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-98582084

Ministry of Environment and Energy, Greece. 2011. Special Framework for Spatial Planning and Sustainable Development for Aquaculture. http://www.ypeka.gr/LinkClick.aspx?fileticket=63fqgg7cbug%3d&tabid=367&language=el-GR

Jay, S., & Gee, K. (Eds.) (2014). TPEA good practice guide: Lessons for cross-border MSP from transboundary planning in the European Atlantic. Liverpool: University of Liverpool.

Ross, L.G., Telfer, T.C., Falconer, L., Soto, D., Aguilar-Manjarrez, J. 2013. Site selection and carrying capacities for inland and coastal aquaculture, pp. 19–46. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 282 pp.

Ministry of Agriculture and Forestry, Finland. 2018. National Aquaculture Location Control plan. Available online https://mmm.fi/documents/1410837/1801200/Kansallinen+vesiviljelyn+sijainninohjaussuunnitelma/55a022d6-054b-4136-b8b3-bcae09e53379/Kansallinen+vesiviljelyn+sijainninohjaussuunnitelma.pdf

MMO. 2013. Future trends in fishing and aquaculture in the South inshore and offshore marine plan areas. A report produced for the Marine Management Organisation. MMO Project No: 1051. ISBN: 978-1909452-20-6. Available online https://webarchive.nationalarchives.gov.uk/20140305103940/http://www.marinemanagement.org.uk/evidence/documents/1040.pdf

Oscar M Perez, O.M., Telfer, T.C., Ross, L.G. 2005. Geographical information systems-based models for offshore floating marine fish cage aquaculture site selection in Tenerife, Canary Islands. Aquaculture Research, 2005, 36, 946-969.

Oikon and Zjzz. 2003. Studija korištenja i zaštite mora i podmorja na području Zadarske županije. Pokretanje procesa integralnog upravljanja obalnim područjem Zadarske županije. Sažetak. OIKON and Zavod za javno zdravstvo Zadar. Zadar. 21pp.

Personal Communication, CRC Charente-Maritime, producers questionnaire response. Aquaculture Advisory Council.

Personal Communication, Leonidas Papaharisis, producers questionnaire response. Aquaculture Advisory Council.

Pillay T. V. R. & Kutty M.N. (2005). Aquaculture: principles and practices. Fishing News Books.

Shucksmith, R., Gray, L., Kelly, C., & Tweddle, J. F. (2014). Regional marine spatial planning—The data collection and mapping process. Marine Policy, 50, 1–9.

Sanchez-Jerez, P., Karakassis, I., Massa, F., Fezzardi, D, Aguilar-Manjarrez, J., Soto, D., Chapela, R., Avila, P., Macias, J.C., Tomassetti, P., Marino, G., Borg, J.A., Franiˇcevi, V., Yucel-Gier, G., Fleming, I.A., Biao, X., Nhhala, H., Hamza, H., Forcada, A., Dempster, T. 2016. Aquaculture's struggle for space: the need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability. Aquaculture environment interactions, Vol. 8: 41–54.

Scottish Government. 2015. Scotland's National Marine Plan. Available online https://www.gov.scot/publications/scotlands-national-marine-plan/pages/8/

Scottish Government. 2018. Scoping 'Areas of Search' Study for offshore wind energy in Scottish Waters. Available online https://www.gov.scot/binaries/content/documents/govscot/publications/consultation-paper/2018/06/scoping-areas-search-study-offshore-wind-energy-scottish-waters-2018/documents/00536637-pdf/00536637-pdf/govscot%3Adocument/00536637.pdf

Shetland Marine Regional Marine Planning Partnership. 2019. Shetland Islands Regional Marine Plan. NAFC Marine Centre UHI pp 158. https://www.nafc.uhi.ac.uk/t4-media/one-web/nafc/research/document/marine-spatial-planning/sirmp/Shetland-Islands-DRAFT-Regional-Marine-Plan-June-2019-compressed.pdf

Stelzenmüller, V., Schulze, T., Gimpel, A., Bartelings, H., Bello, E., Bergh, O., Bolman, B., Caetano, M., Davaasuren, N., Fabi, G., Ferreira, J.G., Gault, J., Gramolini, R., Grati, F., Hamon, K., Jak, R., Kopke, K., Laurans, M., Mäkinen, T., O'Donnell, V., O'Hagan, A.M., O'Mahony, C., Oostenbrugge, H., Ramos, J., Saurel, C., Sell, A., Silvo, K., Sinschek, K., Soma, K., Stenberg, C., Taylor, N., Vale, C., Vasquez, F., Verner-Jeffreys, D. 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, 79pp. Printed. doi 10.2788/189662. http://www.coexistproject.eu/images/COEXIST/Guidance_Document/Best%20practices%20guidelines_FINAL.pdf

Thorstad, E.B. & Finstad, B. 2018. Impacts of salmon lice emanating from salmon farms on wild Atlantic salmon and sea trout. NINA Report 1449: 1-22. [https://www.salmon-trout.org/wp-content/uploads/2018/01/Thorstad-Finstad-2018-Impacts-of-salmon-lice-NINA-Report-1449-2.pdf].

Tweddle. J.F., Gray, L., Kelly, C., Shucksmith, R. 2014. Developing regional locational guidance for wave and tidal energy in the Shetland Islands. Marine Policy 50, 53-66.

Annex 1 – Sample Questionnaire

Name:	
Organisation and role:	
Member State:	
Are you the most appropriate person to be contacted in future? If not, please provide other name(s)?	
Contact email and telephone:	

On the table below, please highlight (with a tick) efforts (processes and/or activities) that your Member State has completed / started:

Steps	Process	Yes, No, Don't know	Tools and activities	Yes, No, Don't know
National / Subnational efforts	Review national/subnational priorities for aquaculture		Review relevant policy and legal frameworks	
	Identification of relevant stakeholders for consultation		Institutional mapping and analysis	
	Identification of general issues and opportunities		Aquaculture species/systems review	
	Identification of potential for cultured species and farmed systems		Mapping of aquaculture sites	
	Assessment of suitability of aquaculture		Set licence production limits within zones or water body carrying capacity	
	Detailed estimation of carrying capacity for sites		Nutirent mass balance equation models (e.g. DEPOMOD, ECOPATH)	
	Biosecurity planning and disease control		Zoning between aquaculture sites	
Zoning approaches	Identification of areas suitable for aquaculture		Site selection and modelling	
	Identiifcation of areas suitable for other sectors (e.g. renewables, oil spill response)		SEA and other related approaches	

Please write down or send relevant links you think relevant:

Annex 2 – Supplementary Information on Selected Member State Efforts in Aquaculture Zoning

Bulgaria

The Executive Agency of Fisheries and Aquaculture (EAFA) at the Minister of Agriculture and Foods administers the planning regime for aquaculture and the Act on fisheries and aquaculture determines criteria for zoning [http://iara.government.bg/wp-content/uploads/2016/07/ZAKON_za_ribarstvoto_i_akvakulturite-ENG.pdf]. The Act has as objective to "ensure the sustainable development of the fish resources, including the restoration and preservation of biological equilibrium and enrichment of the diversity of the fish resources in the water ecosystems" and this is reflected in the criteria for locating aquaculture:

- Aquaculture is excluded around the mouths of the rivers (radius 200 m) for reproduction of the fish and the other aquatic organisms.
- Sites must be located within the zone determined in the permit for use of water site issued by the order of the Waters Act
- Aquaculture is excluded from fishing and sailing routes.

Croatia

In the Republic of Croatia, spatial planning is within the competence of regional self-governing counties, and since each county has its own development strategy, spatial Plans vary from county to county.

In line with the National Strategic Development Plan for Aquaculture for period 2014-2020 [https://ribarstvo.mps.hr/UserDocsImages/akvakultura/NSPA%202014-2020_hrv.pdf], aquaculture zoning has been defined in regulations and the Ordinance on Criteria [https://narodne-novine.nn.hr/clanci/sluzbeni/2018_11_106_2070.html]. This Ordinance on Criteria includes specific biophysical criteria, exceptional and special areas, and ground infrastructure requirements.

Not all counties have zoned aquaculture: the best example of planning areas for marine aquaculture is the Zadar County Plan, which determined four zone types in accordance with the Ordinance:

- Areas designated for aquaculture (where there will be a presumption against any other activity should it be harmful for growing conditions);
- Areas where farming has a high priority, but other activities are allowed;
- Areas restricted to certain varieties of cultivation and production limits are set based on other dominant activities; and
- Areas not suitable for aquaculture.

The Zadar County has applied this method because the County's aquaculture development strategy has been recognised as the driver for economic development of the county. Across the remaining Republic of Croatia, in general, there is a lack of port infrastructure for fisheries and the needs of aquaculture.

Cyprus

Under the 2014-2020 Fisheries and Aquaculture Operational Program, government policy in the aquaculture sector is aimed at balancing increased production and sustainable development. Over the last 10 years, aquaculture in Cyprus shows a growth rate of 7-10%. 25-30% of aquaculture products are channelled to the local market while the remaining 70% is exported. A small percentage (5%) is exported into various European market countries. Marine finfish is the biggest sector of highest potential.

Web-GIS services for Cyprus and Greece were one of the main outputs of THAL-CHOR project (http://www.mspcygr.info/webgis/), and include the location of aquaculture sites. In line with the 2020 vision, Cyprus is now in the process of establishing marine aquaculture zones with public participation playing an important part of the conflict analysis process. The Site Study (AP Marine, 2015) was developed with stakeholder input and is currently going through a voluntary SEA appraisal (as it falls outwith the regulations given its pilot status), to be complete by the end of the year (*Personal communication with Vassillis Papadopoulos, 08 July 2019*).

The method used for the spatial study was a MCE analysis for socioeconomic and environmental features that were weighted on a point-scoring basis in order to identify the most suitable areas. Acceptability from competent authorities and other stakeholders was taken into consideration during two consultation rounds during the evaluation, one to agree the scoring system, another to determine the degree of acceptance on the zoned areas.

Natural resource requirements were mapped based on depth, wind frequency and substrate type. Temperature and currents were not included because the local environmental conditions do not vary significantly. Production carrying capacities were outwith the scope of the study, and therefore production limits have not been set.

One potential gap is that species and habitats protected by the Birds and Habitats Directive (outwith the Natura framework) appear not to have been considered (with the exception of Posidonia meadows).

Denmark

The capacity for Denmark to increase production for finfish aquaculture will be difficult given the Ministerial announcement that there will be no more or larger aquaculture [http://www.regeringen.dk/nyheder/miljoeminister-jeg-oensker-ikke-flere-og-stoerre-havbrug-i-danmark/]. There are currently 19 sea farms in Danish waters and production is currently under review, including the requirement for current licences to be revoked and applied for again [http://www.dr.dk/nyheder/indland/rapport-fra-kammeradvokaten-danske-havbrug-opdraetter-fisk-uden-tilladelser]. Mussel and seaweed industries are favourable in the coastal area, creating issues in terms of resource and space.

The Danish Maritime Authority is responsible for establishing Denmark's first maritime spatial plan, which was initiated in January 2017 and will continue until March 2021, when the plan enters into force.

Estonia

The Ministry of Rural Affairs administers the locating of aquaculture sites using water based criteria: fish farming developers have to apply for a permit for the special use of water, in accordance with the Water

Act (https://www.riigiteataja.ee/en/eli/526022019001/consolide). The main conditions are that the aquaculture area should not be planned on the areas of national defence, on maritime traffic fairways or on nature conservation areas. When deciding the location of aquaculture facilities and the technological solutions at permit or EIA level the impact on fish spawning areas must be assessed and necessary mitigating environmental measures must be defined. Collaboration between competent authorities is necessary when defining aquaculture sites, especially regarding national defence, maritime traffic, cultural monuments and environmental conditions.

Finland

The objective of the Aquaculture Strategy 2022 is that Finland enhances the competitiveness of the sector, supports its continuous renewal and ensures the ecological, economic and social sustainability of aquaculture. Quantitative indicators include the production volume in Mainland Finland increasing to 20 million kilograms and its value exceeding €100 million.

In line with the Strategy, new aquaculture facilities will be directed to suitable waterbodies that can withstand the nutrient load caused by the activity and where they cause minimal harm to other users or features. To help achieve this, the Ministry of Agriculture and Forestry, in cooperation with the Finnish Game and Fisheries Research Institute and the Ministry of the Environment, have identified suitable areas for aquaculture in a National Location Management Plan (Ministry of Agriculture and Forestry, 2018).
[https://mmm.fi/documents/1410837/1801200/Kansallinen+vesiviljelyn+sijainninohjaussuunnitelma/55a022d6-054b-4136-b8b3-bcae09e53379/Kansallinen+vesiviljelyn+sijainninohjaussuunnitelma.pdf].

The following criteria were used to identify areas suitable for aquaculture (see Deliverable 2, Excel sheet for specific rules):

- The water area is well suited for aquaculture and the socio-economic needs of the area.
- The water area is in good condition for water quality and there is no threat to nutrient loading (analyzed with the BEVIS ecosystem and water quality model and incoporated into the suitability maps).
- The water area is located on the open sea, in the outer archipelago or in the inner archipelago in particularly good flow conditions (some exclusions apply).
- The water body has adequate depth and water flow, and provides for good dilution.
- There is no significant leisure time in the immediate vicinity of the production area (holiday homes), habitat (specific exclusions apply to underwater reefs, sandbanks and breeding birds); or other current use of the water for which the activity would be caused essential disadvantage (nature reserves, including seal protection areas, fish spawning grounds, protected ship wrecks).
- Area mapping takes into account, in particular, areas where the natural state of human activity has already been clearly changed (eg wind farms and heavily built waterways) and industrial activities that can benefit farming activities (waste heat).
- Aquaculture activities can exploit the infrastructure in the area or area is located near markets (operations carbon footprint).

As it stands, the Location Management Plan gives clear guidance to planners and industry in site selection based on water quality:

- the Gulf of Bothnia is suitable;
- the Archipelago Sea is in poor condition and should be avoided, and as a rule, larger production proposals should be directed to areas over 20m deep;
- aquaculture is excluded in the Gulf of Finland.

Significant effort has been made to map environmental and socioeconomic criteria (which have been configured to consider zone of impacts) but it is left up to the developers to use the these maps within their licensing applications, i.e. there is not one final map of suitability that considers all criteria. Not all opportunities or constraints have been quantified, for example, renewables, fishing, and proximity to ports have been considered (by providing maps), but whether there would be a conflict of interest would be left to the planning regime to negotiate.

The plan is currently implemented on a voluntary basis, with no legal obligation to use it. Instead, permission will continue to be done on a case-by-case basis, but applicants will have less success outside the identified waters. Based on the outcome of the maps, the author concedes that an increase in production will be challenging because only a few percent of the identified waters are so sheltered that they are capable of supporting the current technology. The report identifies that the constraints could be refined in the future to increase the potential production.

The situation within the Archipelago Sea area differ in that the government's aim is to relocate and concentrate farms here, which should lead to reduced conflicts with recreational use and the environmental impact of activities in general. The planned concentration of production would reduce over 80% of the holiday properties that are within a half-mile radius of farms. Should the plan be implemented, the volume and value of production could increase by about 60%, which would increase employment in the sector over 20%. The share of aquaculture in the total phosphorus load would increase by 1.9 and the total nitrogen load to 0.8%. The new load would be controlled in sea areas that can withstand the increase in load well and do not significantly impair breeding birds and other users of the sea.

France

The EU MSP Directive has been transposed into the National Strategy for the Sea and the Coastline (2012 Decree). Implementation has been prioritised for 4 maritime regions through strategic documents, the Regional Plans for Marine Aquaculture Development. The government uses web based mapping http://sextant.ifremer.fr/ which has incorporated SISAQUA for shellfish suitability modelling.

Aquaculture production is dominated by the shellfish sector, and government priorities focus on tools and initiatives to promote production levels, specifically the need to designate (secure) existing sites and diversify production.

Maintaining production space on land as well as at sea: to defend shellfish growing areas ashore:

- Guarantee access to the coast.
- Reinforce the place of professional structures in planning documents of the territory.
- Strengthen and affirm the strategy of shellfish culture in coastal development policies.

- Halting changes in the destination of shellfish farming establishments (demands for maintaining the shellfish growing area)

and, to guarantee a good management of the zones conceded on the Public Maritime Domain:

- Define the development potential of shellfish culture (SRDAM) and include these potentialities in territorial planning documents
- Ensure that the shellfish activity is taken into account in the development projects of existing or new activities in the maritime area (offshore wind, for example).
- Assist in the installation (request for extension of the shellfish area)

Germany

Whilst the government have not mapped the potential for aquaculture, the State Development Programme Mecklenburg-Vorpommern 2016 explains various zoning approaches https://www.regierung-mv.de/serviceassistent/download?id=1576266 The government uses mass balance equation models for determining suitability of sites, but does not set production limits for shellfish and finfish.

The Federal State Government of Mecklenburg-Vorpommern has an aquaculture strategy, http://www.aquaculture-mv.com. Due to the eutrophication status of the Baltic Sea, the focus is on aquaculture on land (as it is with other Baltic countries). Mariculture or sea ranching is supported as far it does not worsen the water quality of the Baltic Sea.

Greece

The Special Framework for Spatial Planning and Sustainable Development for Aquaculture provides guidelines, rules and criteria for spatial organization of the aquaculture management areas and units both at sea and inland waters and for spatial organization of the aquaculture activity by type (species of marine aquaculture, shellfish, freshwater species, fish farming in lagoons etc.). The Special Framework for Spatial Planning and Sustainable Development for Aquaculture prescribes a zoning system for locating aquaculture activities. Specific areas are defined for the development of aquaculture by evaluating spatial, environmental, social and development aspects as well as carrying capacity criteria. These designed aquaculture zones are defined as Suitable Areas of Aquaculture Development (ΠΑΥ).

The system's main provisions regarding sea areas for the location of the farms are the following:

- Areas Suitable for the development of aquaculture
- Allocated Zones organized and managed by a special authority, similar to industrial estates
- Informal zones in places with existing concentrations
- Individual location: a) within Suitable Zones b) outside the provided zones. Individual locations are also permitted for experimental farms and small parks accompanying agrotouristic units.

For Greece the aquaculture zones were distributed along the coastline. The spatial planning of the fishfarms is based on the carrying capacity of the installation area, determined by parameters such as distance from shore, depth and currents.

Italy

Priorities, including reviewing relevant policy and legal frameworks for aquaculture have been addressed within the context of Marine Spatial Planning.

Consultation with stakeholders is established and aquaculture sites are mapped. No other mapping efforts have begun in terms of site selection (i.e. zoning). No tools for estimation of carrying capacity appear to be used for shellfish or finfish planning / licensing. Biosecurity measures and disease control is practised, but no zoning is specified between sites.

Shape for the Adriatic Sea has resources including online mapping, including aquaculture sites and marine habitats http://www.shape-ipaproject.eu/Default.asp?p=home There are many exclusion zones for tourism priorities http://www.shape-ipaproject.eu/download/listbox/WP4%20action%20%204.2/Definition%20of%20the%20Adriatic%20ecosystem%20quality%20as%20basis%20for%20MSP.pdf

Portugal

Financing technological improvements, together with the zoning effort and simplification of the licensing regime reflect the strategic vision for the sector included in the Strategic Plan for Portuguese Aquaculture 2014-2020. Aquaculture is designated a priority activity by the Portuguese government and a number of initiatives have been aimed at increasing production:

- Community funds were allocated through the Operational Program Mar 2020 and the focus is on developing technologies to withstand production further offshore.
- Zones have been allocated based on the characterisation of the environment (derived from modelling, physical-chemical parameters and biological characteristics of the water column).
- Licensing procedures were simplified in 2017, but despite this, location suitability is still hampered by conflicts with other activities (fishing, shipping, tourism, conservation). The government department DGRM (Direção-Geral de Recursos Naturais), have established an online mapping tool, GeoPortal da Aquicultura [https://www.dgrm.mm.gov.pt/en/geoportal-dos-estabelecimentos-de-culturas-marinhas], which may further make the licensing procedure more efficient.

The number of active aquaculture sites in the marine area is small relative to other countries in the EU and is concentrated in the Algarve region, where the focus is offshore for bivalve longlines. Production levels have been constrained by environmental conditions that have caused long periods of closure due toxins from Harmful Algal Blooms (HABS), or fluctuations in the settlement of natural bivalve spat.

Romania

In Romania the National Agency for Fishery and Aquaculture [http://www.anpa.ro/] has published a Strategy for the Fishery and Aquaculture for 2014-2020 [http://www.madr.ro/docs/fep/programare-2014-2020/Strategia-Nationala-a-Sectorului-Pescaresc-2014-2020-update-dec2013.pdf].

Spain

Spain is a major producer of aquaculture products in Europe. Aquaculture is managed primarily by the Autonomous Communities, some of which have their own strategic plans, while others have adopted the National Strategic Plan. The Sustainable Development Strategy for Spanish Aquaculture (https://www.mapa.gob.es/es/pesca/temas/acuicultura/estrategia_desarrollo_sostenible_marcadores_tcm30-77602.pdf) aims to increase Spanish aquaculture production, based on investments and improvement of sectoral planning underpinned by Integrated Coastal Zone Management (ICZM) and the designation of Allocated Zones for Aquaculture (AZA).

The spatial management of aquaculture is detailed in the Multiannual Strategic Plan of Spanish Aquaculture 2014-2020 and the development of an online mapping tool, ACUIVISOR [https://servicio.pesca.mapama.es/acuivisor/]. This tool enables the user to view the distribution of aquaculture activity, access site information, and perform spatial analysis for the site selection process.

In Andalusia, the Ministry of Agriculture and Fishing, through the Public Company Agrarian and Fishing Development, have adopted the 'Protocol for the identification of suitable areas for the installation of Cages of culture in the sea ' (2008), published by the National Marine Aquaculture Advisory Board (JACUMAR).

United Kingdom

England

The spatial potential for aquaculture in the East and South Marine Plan Areas was carried out in 2013 and suitable areas are now adopted as policy by the Marine Management Organisation.

The fuzzy logic multi-criteria evaluation (MCE) modelling approach was applied using data layers describing the technical, environmental, socio-cultural and industrial opportunities and constraints to finfish and shellfish development (as described in reports MMO 2013a and 2013b). The outcomes of three separate models were overlain: natural resource requirements for different aquaculture types; environmental; and economic information specific to the anticipated level of interaction with each aquaculture type.

Gaps and future recommendations have been reported (Franco, 2017) and include the following:

(i) water quality requirements and feeding requirements,
(ii) disease management,
(iii) wild spat availability, collection and hatchery seed production, and
(iv) effects of climate change on culture performance and habitat alteration.

Other gaps include aquaculture-environment interactions, competition with other species and improvement of culture methods. Though it can be argued that some of these gaps are not only hard to assess, but their resolution might also not provide a considerable improvement to the model's capacity to predict suitable aquaculture sites, they are of relevance to stakeholders and marine planners in the broader sense.

Scotland

Although there is no one-zoning-one-policy approach like the English devolved administration, there is some exclusions and place-based guidance based on the following:

- Areas are created based on environmental risk from nearing capacity limits - upper thresholds for standing stock set for environmental purposes by Locational Guidelines.
- Some exclusions apply and are enforced through ICZM plans and Regional Marine Spatial Plans (Shetland for recreation and tourism)
- Some areas are set for disease management purposes (very few areas).
- Some no take zones for seal licensing are in operation if shooting is proposed within 50km or 25km of a Natura Site (although this is not dealt with at the pre-application stage: the seal license is considered after planning licences have been granted).

The approach used by government bodies to determine licensing (i.e. the first bullet point above) is based on two models to assess nutrient enhancement and benthic impacts. Mass balance calculations have been used to estimate the amounts of nitrogen in dissolved and particulate waste from farms producing “new” species. The primary variables in such calculations are the Food Conversion Ratio (FCR), the composition of the feed, the bulk composition of the fish, the proportions of feed lost as waste pellets and the digestibility of the feed. The potential degree of nutrient enrichment for each loch is therefore assessed and the systems most at risk of overexploitation can be identified. The second model used for the categorisation predicts the cumulative areal extent of impact on the seabed due to the carbon deposited from all the finfish sites in each loch.

A zoning approach that uses spatial modelling has been created for renewable industry. The Crown Estate’s Marine Resource System (MaRS) GIS based MCE tool has been applied to all of Scottish coastal and offshore waters, where data has been analysed according to weights and scores specific to anticipated level of interaction with each renewable type (Scottish Government, 2018).