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AQUASPACE

Ecosystem Approach to making Space for Aquaculture

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Guide to the AquaSpace ToolBox

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Summary

This document provides an introduction to the tools that are described in the AquaSpace ToolBox. It includes a summary of each tool texted during the project; a table outlining the main purpose of, requirements for use, and skills needed to use, each tools ; and links to units in the AquaSpace Masters Module that provide background knowledge needed for the tools.

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1. Introduction

Aquaculture is a growing industry worldwide, which already provides over half of the total production of aquatic products for human consumption and is progressively becoming a key component of a sustainable food supply. Currently, the EU aquaculture sector produces approximately 1.2 million tonnes of fish and shellfish with a total value of around EUR 4 billion (EC, 2016a). This is slightly greater than 1% of the global aquaculture production. The sector is composed almost entirely of micro-enterprises and provides employment to approximately 85,000 people (EC, 2016b).

At present, the most important farmed species in the EU are mussel, oyster, salmon, trout, carp, seabass and seabream, using various techniques such as on-bottom as well as off-bottom (rafts and long-lines) cultures for shellfish farming. Relatively small quantities of other species are also produced in freshwater (EC, 2016a).

Between 2000 and 2013, aquaculture registered annual growth rates at a world level of approximately 6%, while it was stagnating, or even decreasing, in the European Union (O´Hagan et al., 2017). Stimulating the growth of aquaculture in the EU is regarded as a key objective of the Blue Growth initiative: its agenda, adopted in 2011, highlights aquaculture as one of five sectors where resources of European coasts, seas and oceans could be a major contributor to jobs and growth opportunity. Furthermore, the Strategic Guidelines for Aquaculture produced by the European Commission (EC, 2013) underline the need to increase aquaculture across the EU and considered the development of spatial planning for aquaculture as a key enabler of that activity. Likewise, the reformed Common Fisheries Policy (CFP; Regulation (EU) 2015/812) places an increased emphasis on the sustainable development of aquaculture, recognising that sustainable solutions should be achieved through integrating the social, economic and environmental dimensions. As a result, following the EC Guidelines, all EU Member States developed their own multi-annual aquaculture plans and set targets to increase aquaculture production. Altogether, EU production is projected to increase to approximately 1.76 million tonnes by 2025, with an annual growth rate of 2.7%. To achieve these results, aquaculture requires access to sufficient space to fulfil favourable operational characteristics, minimise conflicts with existing or planned uses, and utilise locations that could support maximum production within acceptable limits of environmental impact. The aim is to increase global production of aquatic products, while maintaining environmental sustainability.

2. The AquaSpace project

Spatial planning for aquaculture is receiving increased attention globally, with consideration of how best to apply the most equitable use of space for aquaculture in the context of other uses and users, balanced against the need to maintain environmental integrity but increase global production and trade of fish products.

In this context, the central goal of the AquaSpace project was to optimise the available area for aquaculture, in both marine and freshwater environments, by adopting the Ecosystem Approach to Aquaculture (EAA), and spatial planning for aquaculture, within the wider context of EU legislation, such as the Maritime Spatial Planning, Water Framework, and Marine Strategy Framework, Directives, and policies, such as the Integrated Marine Policy and Blue Growth. The core objectives of AquaSpace were to: (i) support increased production; (ii) provide employment opportunities; and (iii) promote economic growth of the aquaculture sector.

The project applied a case study approach, where 17 case studies were used to identify key planning issues for aquaculture development, based on stakeholder requirements, and to develop, fine-tune, test and/or evaluate various tools for facilitating the spatial planning process, thus supporting the industry and investors in selecting new sites. These tools were reviewed in AquaSpace Deliverable 5.1, Galparsoro *et al*. (2018) and are described in detail in a set of factsheets that are the main content of the AquaSpace ToolBox. The tools' application to case studies is presented in detail in AquaSpace Deliverable 4.2, Strand *et al*. (2018) and summarised in Annex 3 of the same report. In the next section, we present the main features of the tools for which factsheets are available, focusing on their potential exploitation beyond the project lifetime.

The Aquaspace ToolBox is part of the AquaSpace website (http://www.aquaspace-h2020.eu/).

Most of the text of the present document is taken from AquaSpace deliverable 6.4, which also includes parts presenting a business case for the further development of tools. Those parts remain confidential to the members of the AquaSpace consortium.

3. Innovative tools applied in AquaSpace

In the AquaSpace Case Studies, we developed and tested several tools for supporting the achievement of the project main goals, summarised in Section 2. The term **'Tool'** is used here in a broad sense, and includes legal instruments, guidelines, methodologies for participatory processes, simulation models, methodologies for implementing spatially explicit multi-criteria analysis, as well as other approaches that can be used for supporting regulators, farmers and investors in dealing with issues concerning the optimal use of space in the aquaculture sector. Even though some of these tools were already available at the start to the project (AquaSpace Deliverable D3.1, 2016) their testing in AquaSpace case studies led improvements and enhanced the capacity of project partners of selecting and applying of the most suitable ones, in relation to the issue to be dealt with. Tools are briefly presented, in alphabetical order, below while their main features are summarised and compared in Table 3.1.

"AII" Aquaculture Investor Index: this mobile application for Android provides investors with a synthetic index for ranking the attractiveness of the aquaculture sector in every European country. The Aquaculture Investor Index combines twenty indicators, grouped into five categories, i.e. market, production, legislation, environment and social. The index is designed to rank aquaculture competitiveness for each country, by producing a quantitative, and scalable assessment, for stakeholders to assess and monitor aquaculture attractiveness. Up to now, the Index does not calculate scores for the potential for onshore aquaculture. Additional criteria will be implemented in future to deal with this option. Worldwide data to include additional countries may, in some cases, present challenges due to poor data availability.

"APDSS" Aquaculture Planning Decision Support System: is a GIS based modelling platform that integrates environmental data concerning a given area and support decisions of aquaculture operators and regulators, regarding aquaculture planning and management, based on suitability assessment and the calculation of aquaculture carrying capacity. At present, it can be used for site selection within marine areas, assessment of habitat suitability, risk analysis and environmental impact assessment of aquafarms, supporting aquaculture manager decisions. The tool, however, has technical limitations for spatial analysis (see AquaSpace Milestones 20).

AquaSpace tool: is one of the first GIS-based planning tools empowering an integrated assessment and mapping of 30 indicators reflecting economic, environmental, inter-sectoral and socio-cultural risks and opportunities for establishing marine aquafarms in a given area. The GIS Add-In builds on open source datasets at a European scale, hence aiming to improve reproducibility and collaboration in aquaculture science and research. It supports the planning and management of sustainable aquaculture development and helps to reduce uncertainty in new investments. The tool currently presents a static geo data base and, therefore, results do not fully satisfy real-world requirements for decision making, because there is not comprehensive coverage of open source data at an EU level and the Geo Data Base cannot be regularly updated. This shortcoming could be removed by linking it to Web Feature Service (WFS) datasets, but, in this case, input-output operations are likely to markedly increase the time required for the analysis (see Gimpel *et al*., 2017 and Gimpel *et al*., 2018 for further details).

ArcGIS Visibility Analysis: is a licensed tool that enables the determination of the extent of surface locations (e.g. aquaculture developments) visible to one, or a set of, observers. It can be based upon the analysis of individual fish cages, individual aquaculture sites, or across multiple aquaculture sites. It is used for Environmental Impact Assessment (Landscape and Visual Impact Assessment) of proposed aquaculture development, to assess the potential impacts of aquaculture development on the visual landscape. This is to comply with regulations under the EC Environmental Impact Assessment Directive (85/337/EEC, amended 2014/52/EU; European Union, 2014), as implemented in national or regional legislation.

"ASSETS" Assessment of Estuarine Trophic Status: this model can be used for assessing the overall eutrophic condition of a waterbody and the likely change (worsen, improve) of condition in the future.

"BLUEFARM-2": this plug-in, designed for the open source Q-GIS, implements a flexible Spatial Multi Criteria Evaluation methodology, which combines different information layers, provided by users, to generate maps of a single suitability index. It can support policy makers and investors in selecting sites for developing aquaculture activities. The tool was designed for identifying i.e. Allocated Zones for Aquaculture (AZAs) in coastal areas and in AquaSpace, it was tested for shellfish farming. The methodology can be easily applied to fish farm site selection, but such application still needs to be tested in a real world case study. The current version allows one to deal with information layers characterised by different spatial resolutions: at present, a user can select the highest or lowest resolution for mapping the suitability index.

EcoWin.NET framework: this ecosystem-scale ecological model combines a 3D hydrodynamic model with biogeochemical models, shellfish growth models, and a eutrophication screening model for the determination of shellfish production and for the assessment of water-quality changes due to shellfish cultivation. EcoWin can be used to determine production, nutrient removal, changes in environmental variables, and economic value of product and nutrient removal. It requires environmental data measured at the site where analysis takes place. A circulation model should be available at the location where the model is being applied, and a hydrological model is a very useful addition.

"FARM" - Farm Aquaculture Resource Management: is a local-scale carrying capacity model (www.farmscale.org) that combines physical and biogeochemical models, shellfish growth models, and screening models at the farm scale for the determination of shellfish production and for the assessment of water-quality changes due to shellfish cultivation. FARM can be used for site identification of where aquaculture will be most successful, estimate nutrient reduction potential of shellfish-based removal and the economic value of both the shellfish production and the removed nitrogen. This is a local-scale model and cannot be used to determine system-wide production or nutrient removal without several caveats and assumptions.

Lakselus.no (IMR): this model is used for estimating the infestation pressure from salmon lice on wild and farmed salmonid fish along the Norwegian coast. It is also used for locating the "fire brake" areas, i.e. zones of minimal connectivity among farming areas: 11 to 13 such areas are going to be established, based in Lakelus results. Model results are made pubically available through a regularly-updated webpage. Although the model parameters are based on the best available knowledge from scientific literature, processes simulated by Lakeselus.no are still far from being fully understood and more research is required to increase the accuracy of the results in the near future. As for weather forecast models, the embedded chaotic nature of ocean hydrodynamics introduces uncertainty to the results, mainly in the level of absolute numbers, timing of events and small-scale details.

"META" – Maritime and Environmental Thresholds for Aquaculture: this web-based platform (www.longline.co.uk/meta) was designed to provide easy access to data on biological and other thresholds that condition growth of cultivated species in different marine and freshwater areas. It combines physiological data obtained from experimental work with accepted ranges for culture practice, e.g. the depths at which structures can be moored. It allows a user to list all known thresholds for a species and to search for all species that can be cultivated within a particular parameter range. The tool is implemented for 45 species and 16 parameters. The core functionality of some META components extends to site selection and other components which are key for aquaculture development.

Aquaculture conflict analysis and uses reallocation opportunities analysis: is a spatially explicit Bayesian Belief Network (BBN) developed in Netica software package. In AquaSpace, the model was developed to analyse the potential reallocation of artisanal fishing effort to alternative sites due to the introduction of a new, non-take area: an offshore aquaculture site along the Basque continental shelf. The constructed model combined discrete, operational fisheries data, continuous environmental data, and expert judgment to produce fishing activity suitability maps for three different métiers (longlines, nets and traps). The BBN was run with various effort reallocation scenarios for each metier, and the best alternative fishing locations were identified based on environmental suitability, past revenue, and past fishing presence (Coccoli *et al*., 2018). This approach can also be implemented for other purposes related to spatial planning of aquaculture such as the determination of area suitability, risk analysis, environmental impact assessment.

Public comment analysis: this methodology aims at revealing the drivers of complex social interactions between policy, planning, local communities and aquaculture development and can uncover mitigation options/strategies. It involves searching and qualitatively coding statements of support and of objection to proposed marine aquaculture development whenever they available on a local authority planning web-site. It was used for characterising spatially relevant and location-specific social management issues. The application of this analysis takes a significant amount of time and requires public access to information about application for planning permission. It is only available where there is legislation in place for stakeholder engagement during a licensing process.

Seascape visualisation: virtual reality and visualisation tools enable the exploration, interpretation, design and dialogue about aquaculture developments in seascapes with different types of stakeholder. An interactive 3D model for creating seascapes can be used to enable options for aquaculture, renewable energy and tourism related activities to be selected and located within the area of relevance. The development of options for locating aquaculture developments enables the exploration of choices made by members of the public with respect to uses of coastal waters and reasons for their choices.

"SNAP" - Sentinel Application Platform: combines all the toolboxes used to process images from the ESA Sentinel satellites, offering the most complete processing platform for these missions. The satellite images from the Sentinel programme can be accessed, and the data extracted, with this software. The platform provides data and output maps, but they must be developed and customised. One of its limitations is the confidence of the estimated values based on global algorithms not validated or calibrated with *in situ* observations, which is essential to ensure the optimal quality of the data. Additionally, satellite-derived products can only make estimates for the surface layer of the ocean, and spatial and temporal coverage is only possible during cloud free conditions. It is also important to recognise that uncertainties for satellite products increase close to the coast due to land adjacency, bottom reflection in shallow waters, and high amounts of suspended matter from river outlets, etc.

"SISAQUA": is an interactive web portal based on the free and open source software QGIS, hosted by an Infrastructure of Geographical Data (Sextant), which can be used for site selection of aquafarms. It is originally derived from the Norwegian demonstrator AkavaVis. SISAQUA allows the integration and visualization of different types of spatial data relevant for aquaculture as well as constraints, due to regulatory frameworks, including environmental protections, and other conflicting usages. A module treatment was implemented to allow the generation of indicators based on the combination of different layers of information. The number of indicators is, at present, still limited: however, the flexible structure of the module allows one to expand SISAQUA indicator portfolio. Dynamic modelling tools are not included: SISAQUA output is based on the results of predefined model simulations. The superimposition of constraints is possible but there is no direct cross-spatial analysis. At present, there is no economic module.

"SMILE": the model was developed in 2007, enabling the application of an integrated framework for the determination of sustainable carrying capacity within the shellfish production areas for which it was developed. The SMILE model framework includes a 3D hydrodynamic model, a shellfish growth simulation model, a biogeochemical model, and an aquaculture-specific ecological model, and can include detailed catchment modelling for analysis of pressure, state, and response. Primarily, it is used primarily to provide data to help inform management decisions regarding at stocking density and potential areas for the expansion of aquaculture based on food availability. SMILE is also used as an ecosystem health tool, providing data from scenarios to indicate potential impacts of changes in the ecosystem, e.g. impacts on water quality due to changes to shellfish cultivation in the system. When the outputs of SMILE are coupled with other environmental data sources in the AkvaVis model, it can be used for site identification for aquaculture sites.

EAF toolbox (SGM): this toolbox was developed to support stakeholder consultation on the implementation of an Ecosystem Approach to Fisheries. It includes various tools to assist and facilitate input from stakeholders: Project meetings, Community and Stakeholder meetings, Stakeholder workshops, EAF presentation materials, Surveys and Questionnaires, Focused Conversation, Team Building Methods, Facilitation-online guides, Facilitation courses, Conflict management, negotiation and consensus building, Consensus workshop method.

WATER Where Can Aquaculture Thrive in EuRope (LLE): is a web-based model for aquaculture based on observed and modelled data of parameters that condition the feasibility of aquaculture at the EEZ level. WATER (www.longline.co.uk/water) is designed to identify best placement for new aquaculture sites in Europe. Ranked suitability is presented for each of the requested exclusive economic zones and area per suitability class. Due to its current 1 km^2 resolution, this analysis should be made at the EEZ scale and not at the local scale.

Web-based tool for forecasting mussel yield (NIWA): This is a web-based tool for forecasting greenlip mussel yield for the Pelorus Sound Greenshell™ mussel industry. The forecasts were created from the NIWA research, made in conjunction with the mussel industry. Currently, access to the tool is restricted to mussel growers who contributed to the project. The tool can forecast three levels of historical mussel yields (above, mean and below), based on climate forecasting scenarios.

WestLice (SAMS): this model predicts the spread of sea lice between defined locations. This allows the estimation of spread patterns and “connectivity” between salmon aquaculture sites, the identification of distinct self-contained units for management, and the assessment of potential impacts from new sites, coherent area management strategies, and strategic spatial planning for the industry. Lice count data are required to fully validate model. There is the potential to predict lice metapopulation dynamics, but at present this is not well developed or validated.

4. Features of the Aquaspace tools (in a table).

The table will be found on the next page.

Tool	IPR own/shared by at least one beneficiary	Beneficiaries who own IPR	Tool type	Management dimension				Main functionality							Skills needed to operate the tool			
				Policy / management	Environment	Economic / Market	Other sectors	Site identification	Modelling	Mapping	Stakeholder engagement	Economic analysis	Ecosystem services Ass.	Scenario analysis	No customization and training	Requires minimum customization	Requires short training	Requires skill at research level
Aquaculture Investor Index	Y	LLE	Spatial analysis model	X	X	X	X	X			X	X		X	X			
Aquaculture Planning Dec. Support System (APDSS)	Y	YSFRI	GIS based mo-delling platform	X	X	X	X	X	X	X				X		X		
AquaSpace tool	Y	TI-SF	Arc GIS AddIn	X	X	X	X	X		X		X		X			X	
ArcGIS Visibility Analysis	Y	JHI	Arc GIS AddIn	X	X			X	X	X	X		X	X			X	X
Assessment of Estuarine Trophic Status (ASSETS)	Y	LLE, NOAA	Model	X	X			X	X	X	X			X			X	
BLUEFARM 2	Y	BF	Plug-in for QGIS free software	X	X	X		X		X	X			X		X		
EcoWin.NET	Y	LLE	Ecological model	X	X	X	X	X	X	X	X	X	X	X				X
FARM	Y	LLE, NOAA	Production Model	X	X	X	X		X			X		X		X		
Lakselus.no	Y	IMR	Model	X	X	X	X	X	X					X				X
META	Y	LLE	Online platform	X	X	X	X	X			X	X		X	X			
Aquaculture conflict analysis and uses reallocation opportunities analysis	Y	AZTI	Model (Bayesian belief network)	X	X	X	X		X	X				X				X
Public comment analysis	N		Procedure	X	X	X	X	X			X							X
Seascape visualisation	N		Simulator	X	X			X	X		X		X	X			X	
Sentinel Application Platform (SNAP)	N		Processing of satellite data	X	X	X	X	X	X	X			X	X				X
SISAQUA	Y	IFREMER	Web based dynamic GIS	X	X		X	X	X	X				X				X
SMILE model	Y	LLE, AFBI	Dynamic mod. framework	X	X	X			X		X		X	X				X
Stakeholder consultation (EAF toolbox)	Y		Process	X	X	X	X	X			X		X	X			X	
WATER - Where Can Aquaculture Thrive in EuRope	Y	LLE	Spatial analysis model	X	X	X	X	X		X	X	X	X	X	X			
Web-based tool for forecasting mussel yield	Y	NIWA	Production Model	X	X	X	X		X		X				X			
WestLice	Y	SAMS	Model (Biophysical connectivity)	X	X			X	X	X				X				X

5. Links to Masters' Module and other Resources

The AquaSpace Masters' Module, Planning and Managing the Use of Space for Aquaculture, can be found on another page on the AquaSpace website.

Several of the units of the Masters' Module provide introductions to tool theory and practice. They are listed below.

Unit	Title	Relevant for
5	Introduction to Geographic Information Systems	All GIS tools: AquaSpace Tool, ArcGIS Visibility Analysis, BlueFarm2, WATER, plus AkvaVis and the tools derived from it: APDSS and SISAQUA
6	Introduction to AquaSpace integrating tools	Aqua Investor Index, AquaSpace Tool, META and WATER
7	Remote Sensing for Marine Spatial Planning and Aquaculture	SNAP
8	Sea lice and Salmon Aquaculture	Laxselus and WestLice
9	Introduction to Visualisation Issues and Tools	ArcGIS visibility analysis, SeaScape visualisation
10	Social Investigation and Public Engagement Tools	Public comment analysis, Stakeholder consultation (EAF toolbox),

In addition, the older ECASA ToolBox provides information on physical-biological models.

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