AQUASPACE

Ecosystem Approach to making Space for Aquaculture

EU Horizon 2020 project grant no. 633476

Deliverable 6.3

CPD Course Manual

'Planning and Managing the Use of Space for Aquaculture'

Lead Beneficiary	**University College Cork (UCC-MaREI)**
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Reviewed by	

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Change log

This section is used to track changes through the review process.

Version	Date	Author	Reason for change
0.1	17/1/2018	AMOH	Initial draft

Review log

Version	Date	Reviewer	Comments
Final	February 2018	J. Gault	Final design and layout

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1. INTRODUCTION

This is a manual intended to accompany the CPD Course on Planning and Managing the Use of Space for Aquaculture. The course is an outcome from Task 6.3 'Research and Develop a Continuing Professional Development (CPD) course'. The CPD course is designed to complement the Masters Module on MSP for Aquaculture, produced as Deliverable D6.1, which is a suite of materials including a syllabus, lectures, practical exercises, presentations, etc. which lecturers and students can use via a self-taught format available online. The CPD Course uses some of the same materials but these have been customised for a professional audience. Both courses utilise materials available from the AquaSpace Toolbox.

The main content of the present report is a manual outlining the possible contents of a Continuing Professional Development course on planning and management of space for aquaculture, tailored to the interests and concerns of professionals from within the aquaculture industry, but also regulators, research professionals, representatives from other maritime industries and interest groups. It is not designed for direct roll-out but rather provides a general framework which can be tailored to suit local conditions and the different levels of knowledge that may exist across the industry, regulatory and research community. The materials referred to in this manual are available on the Aquaspace website (www.aquaspace-h2020.eu).

Course materials benefit from the experience of the AquaSpace consortium coupled with a range of example situations derived from the case study sites in the project, providing real and practical instances of aquaculture site planning and management for different countries, species, environment (marine and freshwater), management issues and potential future challenges. These materials also have the advantage of having had input from the industry partners, such as Longline Environment (UK) and Sagremarisco (Portugal), in the project. Furthermore the tentative course content was discussed with aquaculture producers in Ireland with a view to determining what exactly industry would expect and desire from a CPD module such as this.

2. CONTENT AND TARGET AUDIENCE

This is a web-based, open-access, set of materials for use by:

- any person who, or organisation that, wants to construct, validate and deliver such a CPD Course, or draw on any part of it for teaching purposes;
- any interested person who wishes to learn more about aquaculture planning and management frameworks.

The materials can be used to develop a detailed and critical knowledge of societal and environmental contexts for the use of space by aquaculture, including

- an understanding in principle of how to develop and apply EU, national and regional spatial planning and management frameworks for aquaculture;
- a critical understanding of social and environmental concepts relevant to planning and managing space for aquaculture;
- the knowledge needed to understand and critically select tools from the Aquaspace toolbox and other sources of tools.

One completed, participants will have obtained a broad overview of the management of the marine and coastal resources as well as an awareness of how these can and have been implemented in a variety of spatial contexts. Participants will have an appreciation of the scientific basis underpinning the management of marine, coastal and land based aquaculture resources. This will enable those successfully completing the course to operate within their own professions and be familiar with the emerging and evolving fields of marine governance, planning and management.

3. COURSE STRUCTURE

The lectures are based around 11 topics, representing a course which could be conducted over a two and a half days. A sample timetable is included in Annex 1 for reference. The course is designed so that there is ample discussion time thereby contributing to mutual learning of all participants. Please note that no support can be provided for use of this material. For each topic we provide a set of slides containing exercises and sources of further reading, if required. In other cases we direct users towards resources on the AquaSpace website or external resources. These act as a framework for the content to be covered but with the caveat that material should be added to reflect the local context and specificities of the aquaculture sector in that region/country.

4. LIST OF TOPICS

This material reflects AquaSpace's work on the Ecosystem Approach to Aquaculture (EAA), the issues, tools and case studies that the project utilised and investigated.

1. **Introduction to Aquaculture in a Global Context** (João Ferreira, Longline Environment Ltd.)
2. **Current frameworks for aquaculture planning and management** (Anne Marie O'Hagan, MaREI-UCC)
3. **Maritime Spatial Planning in Europe: Opportunities for Aquaculture** (Lucy Greenhill, SAMS and Anne Marie O'Hagan, MaREI-UCC)
4. **Ecosystem Approach to Aquaculture (EAA)** (Paul Tett, SAMS; Anne Marie O'Hagan, MaREI-UCC and José Aguilar-Manjarrez, FAO)
5. **Introduction to the AquaSpace Tool for use in spatial planning** (Vanessa Stelzenmüller and Antje Gimpel, Thünen Institute)
6. **Tools - Geographic Information Systems** (GIS) (David Miller, Chen Wang, Gillian Donaldson-Selby, Dave Miller, Margaret McKeen, James Hutton Institute; and Antje Gimpel, Thünen Institute)
7. **Tools - Remote Sensing for Marine Spatial Planning** (Sónia Cristina, Bruno Fragoso and John Icely, Sagremarisco Lda)
8. **Tools - Visualisation issues and tools** (David Miller, Gillian Donaldson-Selby and Chen Wang, JHI)
9. **Tools - Social investigation and engagement tools** (Suzi Billings, SAMS)
10. **Tools - Sea lice and salmon aquaculture** (Tom Adams, SAMS)

11. **Forthcoming Issues for Aquaculture and Spatial Planning** (Anne Marie O'Hagan and Jeremy Gault, MaREI-UCC)
12. **Case studies (optional)**

5. TOPIC CONTENT

1. Introduction to Aquaculture in a Global Context

This presentation sets the context for the CPD course in terms of the current status of the aquaculture sector. It provides an overview of global patterns in fisheries and aquaculture production and worldwide consumption and future trends. It also presents the current situation in the EU. Information is presented on the species and technologies utilised as well as carrying capacity and sustainability challenges. The presentation concludes with a synthesis of these topics covering aspects such as production models for the future, approaches to planning in regions that are data poor and how to increase participation in development planning. It should be noted that these slides are a suggested guide only utilising information correct at the time of writing but acknowledging that this information and particularly the statistical data will change regularly as production changes over time.

2. Current frameworks for aquaculture planning and management

This presentation provides information on EU legislation that impacts upon the aquaculture sector as contained in the Regional review conducted under AquaSpace (O'Hagan et al., 2017). Specifically it looks at the legal basis for EU law on environment, fisheries and aquaculture; the key EU legal instruments for marine and coastal management; the main nature conservation instruments and Impact Assessment processes which may apply to aquaculture planning and operation including Strategic Environmental Assessment, Environmental Impact Assessment and Appropriate Assessment under the Habitats Directive. It is suggested that these slides are supplemented with the relevant national legislation and how the various processes work in the country where the course is being held. Some examples from Ireland are included for reference. A discussion on current management frameworks in place and how these facilitate or impede aquaculture development is recommended as an exercise. This will help highlight critical issues for management currently which can then be contrasted with newer approaches to management and the tools recommended later in the course.

3. Maritime Spatial Planning in Europe: Opportunities for Aquaculture

This topic explores the potential opportunities for aquaculture from Maritime Spatial Planning (MSP), a new management approach legally required under EU law and advocated internationally as a means to improve and deliver more integrated marine governance. The lecture outlines what MSP is, how it differs from existing approaches to management, its status of implementation, the requirements of the EU Directive on MSP, the opportunities for aquaculture and possible challenges to the implementation of MSP. This could be supplemented with information on MSP in the country/region where the course is being hosted: if MSP is not implemented, a discussion on how management processes could be more integrated could be facilitated considering alternative approaches such as

integrated coastal management, land-based planning that includes coastal waters, etc. A list of additional recommended reading is provided in the presentation directing users to a wide range of guidance materials and peer-reviewed papers which explore MSP and aquaculture. In addition, course participants can also avail of the Unit Study Guide for this topic available on the AquaSpace Toolbox under the Masters Module, which follows a similar structure to the material presented in this topic.

4. Ecosystem Approach to Aquaculture (EAA)

The Ecosystem Approach to Aquaculture, as developed by the UN Food and Agriculture Organization (FAO), was one of the central tenets of the AquaSpace project, particularly how it could be made operational at different levels of governance. This unit traces the origins of the EAA, how it is related to spatial planning, and the steps that form part of the EAA. Course participants are directed towards the recently published FAO Handbook on aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture (FAO and World Bank, 2017). That Handbook This publication describes the steps related to the various steps in EAA, the rationale for and objectives of each step, together with the ways and tools available to implement it. Recommendations for practitioners and policy-makers are also included in the Handbook. It is advised that material associated with certain AquaSpace case study sites could be useful when covering this topic, depending on where the course is being conducted.

5. Introduction to the AquaSpace Tool for use in spatial planning

During the AquaSpace project, stakeholders identified the need for a spatial planning tool that could integrate over indicators of both risk and opportunity and the AquaSpace Tool was developed. This lecture looks at the tools and methods that could support implementation of the EAA, where there are gaps together with stakeholder opinions on what is needed to support an EAA. This leads to material on the development of the AquaSpace Tool, a GIS-based tool for an integrated assessment of spatial planning trade-offs with aquaculture. This explains how the user can assess individual marine site locations planned for aquaculture in terms of essential biological, ecological, economic, physical and social aspects. All the resources and training necessary to use the tool are available from the AquaSpace website in the Toolbox. Participants are invited to carry out the exercises contained in the lecture and in that way have the opportunity to apply their learning in using the AquaSpace Tool to a specified situation.

The following **five lectures** are focused around different tools that can be used for different aspects of aquaculture planning and management. Whilst the course coordinator may decide to go through each lecture sequentially as part of the CPD Course, an alternative approach would be to focus on specific tools – perhaps those that are least familiar to the participants. This should be decided on a case-by-case basis.

6. Tools: Geographic Information Systems (GIS)

The AquaSpace Tool, referred to in the previous topic, is GIS-based but it is important to learn that GIS has many other potential applications in spatial planning and aquaculture. This lecture is designed to introduce GIS and, therefore, includes definitions and descriptions of basic elements of GIS, clarification of distinctions to be made between commonly used but often misunderstood terms, and examples of its use in AquaSpace. The examples relate to a small set of basic GIS functions and two applications within the AquaSpace project namely the case study areas of Argyll and Bute, Scotland, and the south-east North Sea, Germany. Information is provided in the relevant slides on where to locate more details of these applications. The lecture is not a tutorial on the use of GIS. Some video tutorials are included as reference material.

7. Tools: Remote Sensing for Marine Spatial Planning

This topic sets out what Remote Sensing is providing examples of satellites and sensors, products and their contribution to the selection of aquaculture sites and other applications. The advantages of Remote Sensing for MSP and specifically how it can be used in site selection and management is covered with reference to case studies in the Algarve coast (Portugal); North Adriatic Sea; Mont Saint-Michel bay (France); and the Eastern Passage / Halifax Harbour (Canada). Part of the lecture focuses on SNAP software to explore the application of earth observation for marine aquaculture. Exercises on the use of this software are included covering installation, extraction of imagery and subsequent extraction of data that could be used in site selection. References are provided as a source of additional material.

8. Tools: Visualisation issues and tools

This topic introduces visualisation tools and associated issues including definitions and descriptions of basic elements of visualisations, 3D models, and tools. The examples of its use are as applied in the AquaSpace project particularly relating to consideration of landscapes and seascapes (e.g. landscape concepts of stewardship, naturalness, openness), and the representation of factors in the 3D models and interaction using the visualisation tools (e.g. ephemera of weather, reflections off water, shadows, movement). Information is provided in the relevant slides on where to locate more details of these applications. This is not a tutorial on the development of a 3D model or the use of any specific visualisation tool but rather seeks to inform participants about the potential of such tools in future planning. The evolution of visualisation and mapping tools has contributed to their uptake in relation to assessing consequences of drivers of change in coastal areas, such as aquaculture, renewable energy, housing and transport and, as such, these could be a very important tool in future planning processes.

9. Tools: Social investigation and engagement

An introduction to some of the social investigation and engagement tools that can be used for inquiry into public attitudes to aquaculture and thus to understand the extent to which an aquaculture operation has ‘social licence to operate’ is the focus of this topic. Course participants will become familiar with the two main approaches used in social inquiry as well as some examples of methods for

their use. Benefits of and methods for public engagement within the aquaculture sector are also covered. The example of salmon fish farming in Scotland is presented to provide context. In light of the importance of public acceptance for the development of aquaculture and particularly the expansion of existing operations, special emphasis is placed upon the concept of "Social Licence to Operate" (SLO) and its importance for aquaculture operations. Research on the role of SLO in the aquaculture industry is limited, but there is an increasing recognition that aquaculture's environmental impacts create social costs which can lead to conflict and at the extreme end of the scale, litigation (Kruase et al, 2015). Reading material and possible exercises are included in the Unit Study Guide for this topic available on the AquaSpace Toolbox under the Masters Module.

10. Tools: Sea lice and salmon aquaculture

Disease is an ongoing challenge for aquaculture operators and also for planning of future operations. This lecture covers sea lice and salmon aquaculture covering the life cycle and dispersal of sea lice in the water column, how they infect and affect wild and farmed fish. Approaches to reducing their abundance, including efforts to model their spread, is also included. Management of sea lice, covering both site management and cage treatments, are discussed. This also deals with resistance to chemicals as well as new approaches to lice management like the use of cleaner fish and barrier technologies. Finally a synopsis of mathematical and computational models used to understand the dynamics of sea lice populations, and spatial management approaches, are presented as tools to help address this challenge. It is suggested that someone with a background in aquaculture disease, parasitology or another relevant discipline is utilised to deliver this component of the course.

11. Forthcoming Issues for Aquaculture and Spatial Planning

This topic draws out the emerging policy and other issues relevant to future spatial planning for aquaculture, building on the key messages put forward in earlier topics. Emerging policy trends are presented which also captures the challenges already identified by the EC in relation to spatial planning of aquaculture. There is scope to discuss new governance approaches such as those more based on economics or community-based management. A synthesis of the key challenges surrounding the implementation of the EAA are explained together with suggestions for examples of good practice from around the world. A list of possible future needs is included to stimulate further discussion capturing the various pillars of sustainability, technical and policy requirements.

6. CASE STUDIES

A set of slides are available for each Aquaspace case study site, supplemented by more comprehensive reports authored by Strand and Bergh (2017) as Aquaspace Deliverable 4.2. The following list gives location, type of aquaculture and main issues investigated. These case studies provide an evidence-base for the topics, approaches and issues covered in the lecture topics. It is intended that these examples could be used in conjunction with the PPT files to demonstrate a particular issues, how it was managed and learning transferable to that particular set of circumstances.

1. **Adriatic Sea, Italy:** bottom and suspended cultivation of bivalves; issues were proximity to protected area and conflicts with tourism and fisheries
2. **Algarve Coast, Portugal:** cage and pond cultivation of finfish and suspended and bottom culture of shellfish; issues were co-use, optimising space allocation, and disease connectivity
3. **Basque County, Spain:** suspended culture of shellfish; issues were making space for, and changing social attitudes to, aquaculture
4. **Békés County, Hungary:** freshwater shellfish cultivation in ponds and tanks; issues were proximity to bird reserves, availability of clean water
5. **Carlingford Lough, Ireland/UK:** shellfish (trestles, bottom); issues were: complex governance, co-use by several sectors.
6. **Great Bay (Piscataqua, New Hampshire) and Long Island Sound (Connecticut), USA:** shellfish (trestles, bottom); issues were: legal constraints and use conflicts
7. **Houtman Abrolhos Islands, Western Australia:** shellfish (suspended), finfish (cages); issues were: conservation area, co-use, potential for disease spread
8. **Mediterranean Sea:** cage culture of warm-water finfish; issues were: co-use with other sectors; complex governance; Multiple EEZ
9. **Normandy and Cancale (the Bay of Seine and the Normandy-Brittany Gulf), France:** shellfish (bottom, suspended); issues were: multiple conflicting uses, complex governance
10. **North Sea (Helgoland Bight), Germany:** shellfish (bottom), finfish (cages); issues were: co-use with other industry, increase of production level, complex governance
11. **Norwegian (western and northern) Coast, Norway:** cold-water finfish (in cages); issues were: sea lice connectivity, space availability, co-use;
12. **Nova Scotia Bays, Canada:** cold-water finfish (in cages); issues were: enhancing social licence; user/fisheries conflicts
13. **Zhangzidao Island and Sangou Bay, China:** seaweed, shellfish (suspended); issues were: competition for space with other industry; increased production
14. **Argyll and Bute, Scotland, UK:** cold water finfish in cages; community opposition, space availability, landscape/seascape impacts, sea lice connectivity; increased production;
15. **Pelorus Sound, Marlborough, New Zealand:** shellfish (suspended); Variable production/yield.

7. THE AQUASPACE TOOLBOX

Figure 1 shows the relationships between the several parts of the Aquaspace toolbox website. This document is related to the CPD course but utilises material from the Masters course. Users may need to access other pages of the toolbox to download, for example, materials relating to specific tools, videos, reports and papers of interest. The Toolbox page includes:

- factsheets relating to tools tested, and in some cases, developed by Aquaspace,
- examples of applications of a range of tools in the Aquaspace case studies.

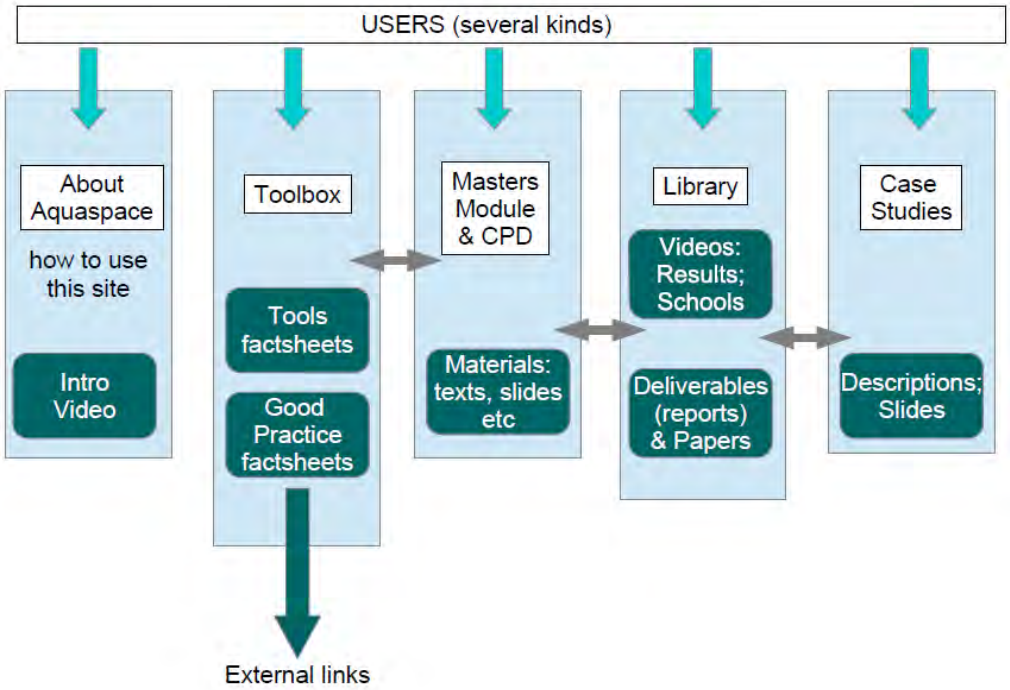


Figure 1: Overview of AquaSpace toolbox

8. ATTRIBUTION

These materials were developed as part of the AquaSpace project (2015-2018) and constitute project Deliverable 6.1. They may be used under a Creative Commons Attribution-ShareAlike 4.0 International License, with attribution as follows:

- ATTRIBUTION FOR USE OF MULTIPLE PARTS OF THE MATERIAL: Aquaspace (2018). Material from a Masters Module on `Planning and Managing the Use of Space for Aquaculture', prepared as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture), which received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement no. 633476.
- ATTRIBUTION FOR THE USE OF ANY SINGLE DOCUMENT: Author(s) name(s) and their Organisations (2018) Document title. Prepared as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture), which received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement no. 633476.

9. 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.
- Krause, G., Brugere, C., Diedrich, A., Ebeling, M.W., Ferse, S.C.A., Mikkelsen, E.I., Pérez Agúndez, J.A., Stead, S.M., Stybel, N. and Troell, M. (2015). A revolution without people? Closing the people-policy gap in aquaculture development. Aquaculture, 444, pp 44-55.
- O'Hagan, A.M., Corner, R.A., Aguilar-Manjarrez, J. Gault, J., Ferreira, R.G., Ferreira, J.G., O'Higgins, T., Soto, D., Massa, F., Bacher, K., Chapela, R. and D. Fezzardi. (2017). Regional review of Policy-Management Issues in Marine and Freshwater Aquaculture. Report produced as part of the Horizon 2020 AquaSpace project. 170pp.
- Strand, Ø. and Bergh, Ø., editors (2017). Deliverable 4.2: Case Study Final Report. H2020 project 633476 Aquaspace, Oban.

10. SUGGESTED TIMETABLE

DAY 1	
Time	**Session Title and Information**
09:00 – 09:15	**Welcome / Introduction / Aims of Module**
	Local Module Co-ordinator
09:15 – 10:00	**National MSP Context**
	20 mins presentation - Government/Regulatory Representative 25 mins facilitated discussion - Local Module Co-ordinator
10:00 – 10:45	**Industry Perspective / Understanding of MSP**
	20 mins presentation - Industry Representative 25 roundtable discussion - Local Module Co-ordinator
10:45 – 11:00	**Coffee**
11:00 – 12:30	**Topic 1: Introduction to Aquaculture in a Global Context**
	• 45 mins presentation - Based on Ferreira presentation - augmented with national, local examples • 45 mins facilitated discussion - Local Module Co-ordinator – context of participants operation
12:30 – 14:00	**Working Lunch:** Initial thoughts / share experiences on MSP for aquaculture
14:00 – 15:30	**Topic 2: Current frameworks for aquaculture planning and management**
	• 45 mins overview presentation - Based on O'Hagan presentation - augmented with national and local examples • 45 mins facilitated discussion - Local Module Co-ordinator – legal requirements under MSP (and other legislation)
15:30	**Coffee**
16:00 – 17:30	**Topic 3: Maritime Spatial Planning in Europe: Opportunities for Aquaculture**
	• 45 mins presentation - Based on Greenhill & O'Hagan presentation – augmented by local case studies • 45 mins facilitated discussion - Local Module Co-ordinator – MSP opportunities and issues

DAY 2	
Time	**Session Title and Information**
09:00 – 10:30	**Topic 4: Ecosystem Approach to Aquaculture (EEA)**
	• 45 mins presentation - Based on Tett / O'Hagan / Aguilar-Manjarrez presentation - local, national and international examples • 45 mins facilitated discussion - Local Module Co-ordinator – using the approach in practice
10:30 – 11:00	**Coffee**
11:00 – 12:30	**Topic 5: Introduction to the AquaSpace Tool for use in Spatial Planning**
	• 40 mins overview and examples - Based on Stelzenmüller & Gimpel presentation • 50 mins hands-on use of tools - Local Module Co-ordinator / demonstrators – examples of application
12:30 – 13:00	**Working Lunch: use of tools**

DAY 2	
Time	**Session Title and Information**
13:30 – 15:00	**Topic 6: Tools: Geographic Information Systems (GIS)** **Topic 7: Remote Sensing for Marine Spatial Planning**
	• 30 mins overview presentation on each topic - Based on Millar et al. and Cristina et al. presentations but augmented with national, local examples of application • 30 mins hands-on exercises - Local Module Co-ordinator / demonstrators – applied examples
15:00 – 15:30	**Coffee**
15:30 – 16:30	**Topic 8: Tools - Visualisation issues and tools**
	• 40 mins overview presentation - Based on Millar et al. presentation but augmented with locally available technology and expertise • 20 mins practical exercises - Local Module Co-ordinator / demonstrators – applied examples
16:30 – 17:30	**Topic 9: Tools - Social investigation and engagement tools**
	• 30 mins presentation - Based on Billing presentation – with relevant local, national and international examples • 30 case study examples - From industry AND other marine users (+ve and –ve experiences)

DAY 3	
Time	**Session Title and Information**
09:00 – 10:30	**Topic 10: Tools - Sea lice and salmon aquaculture**
	• 40 mins presentation - Based on Adams presentation – augmented with national, local examples of application • 50 mins facilitated discussion - Local Module Co-ordinator – the use of MSP for disease control
10:30 – 11:00	**Coffee**
11:00 – 12:30	**Topic 11 Forthcoming Issues for Aquaculture and Spatial Planning**
	• 15 mins research perspective - Based on O'Hagan & Gault presentation – with facilitated discussion / HEI / Research Centre • 15 mins regulator perspective - Government official • 15 mins industry perspective - Local / National industry • 45 mins facilitated discussion - Local Moderator
12:30	**CLOSE**

11. APPENDIX

Topic 1: Introduction to Aquaculture in a Global Context

AquaSpace

CPD Course
PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 1: Aquaculture in a Global Context

Joao G. Ferreira
New University of Lisbon

Horizon 2020

• The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.

Aquaculture in a Global Context

Overview

1. Global patterns in fisheries and aquaculture production
2. Worldwide consumption and future trends
3. The European situation in perspective
4. Species and technologies
5. Carrying capacity and sustainability challenges
6. Synthesis

Aquaculture in a Global Context

1 - Global patterns in fisheries and aquaculture production

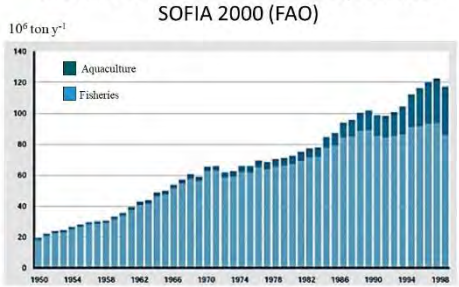
- Overview of world production
- Decadal trends in fisheries and aquaculture
- Production of main wild-caught fish species
- Capture fisheries by country
- Relevance of world aquaculture
- Development of world aquaculture

World capture fisheries and aquaculture (2016)

	2009	2010	2011	2012	2013	2014
			(Million Tonnes)			
PRODUCTION						
Capture						
Inland	10.5	11.3	11.1	11.6	11.7	11.9
Marine	79.7	77.9	82.6	79.7	81.0	81.5
Total capture	**90.2**	**89.1**	**93.7**	**91.3**	**92.7**	**93.4**
Aquaculture						
Inland	34.3	36.9	38.6	42.0	44.8	47.1
Marine	21.4	22.1	23.2	24.4	25.5	26.7
Total aquaculture	**55.7**	**59.0**	**61.8**	**66.5**	**70.3**	**73.8**
TOTAL	**145.9**	**148.1**	**155.5**	**157.8**	**162.9**	**167.2**
UTILIZATION*						
Human consumption	123.8	128.1	130.8	136.9	141.5	146.3
Non-food uses	22.0	20.0	24.7	20.9	21.4	20.9
Population (billions)	6.8	6.9	7.0	7.1	7.2	7.3
Per capita food fish supply (kg)	18.1	18.5	18.6	19.3	19.7	20.1

Note: Excluding aquatic plants. Totals may not match due to rounding.
* Data in this section for 2014 are provisional estimates.

The state of world fisheries and aquaculture SOFIA 2000 (FAO)



FAO, 2001. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

The state of world fisheries and aquaculture SOFIA 2014 (FAO)

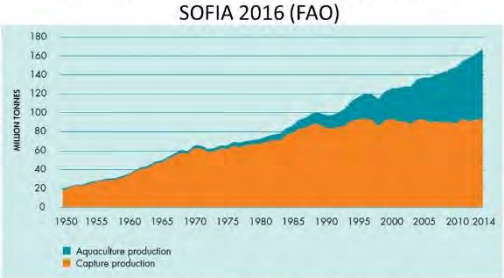
FAO, 2014. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

Fisheries are declining, growth in aquatic products is driven by aquaculture.

Return to Timetable

Appendix – Presentation Content

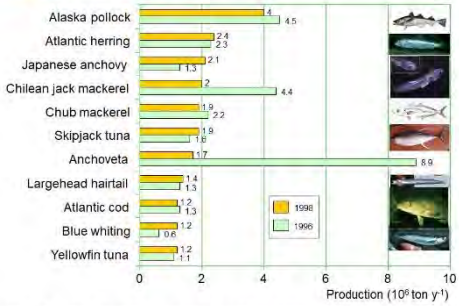
The state of world fisheries and aquaculture SOFIA 2016 (FAO)



FAO, 2016. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

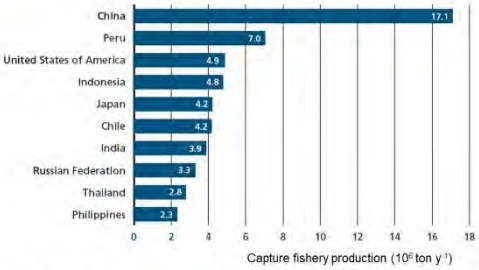
Aquaculture continues to grow at an APR of 6% per year.

Distribution of production among major fish species



FAO, 2001. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

Capture fishery production by country SOFIA 2008 (FAO)



FAO, 2008. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

Relevance of world aquaculture

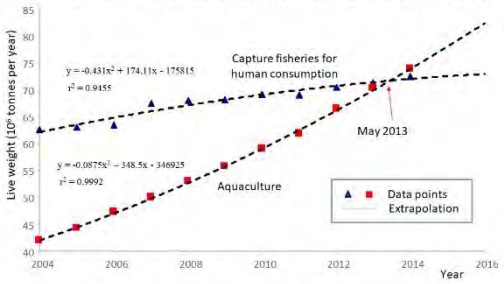
Volume and value

FAO Global Aquaculture Conference 2010

- 50% of aquatic products originate from aquaculture (SOFIA, 2010)
- 90% of the 68 million tonnes of aquaculture products (105 billion USD) originate from Asia (Sorgeloos, 2010)
- Production of striped catfish *Pangasius* in the Mekong delta is >1 Mt y^{-1}, highest yields in the world, 350-400 tonnes ha^{-1} per crop (Sena da Silva, 2010)
- 30 Mt y^{-1} of extra aquatic products required to feed the planet by 2050 (Swaminathan, 2010)
- US predicted expansion from 0.5 to 1.5 Mt y^{-1} (Olin, 2010)
- Europe: production is 4.2% by volume, 9.1% by value (Sorgeloos, 2010)

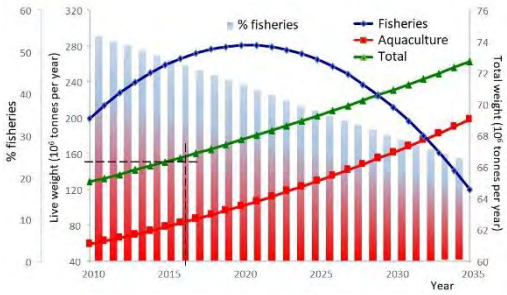
Growth of both population and aquaculture will take place in developing nations

Trends in fisheries and aquaculture – SOFIA 2016



Equivalent to the emergence of agriculture 10,000 years ago in the Neolithic period.

Trends in fisheries and aquaculture : 2010-2035



For projected APR growth in aquaculture and fisheries, 155 million tonnes in Sept 2016.

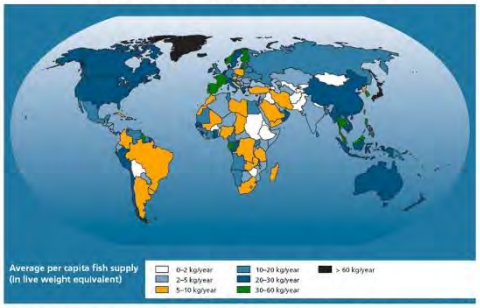
Aquaculture in a Global Context

2 - Worldwide consumption and future trends

- Patterns of fish consumption
- The challenge of aquatic food security

Fish as a food

World per capita supply (average 2003-2005)



FAO, 2009. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

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Fish as a food

World per capita supply (average 2011-2013)

FAO, 2016. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

The state of world fisheries and aquaculture SOFIA 2016 (FAO)

FAO, 2016. The State of World Fisheries and Aquaculture (SOFIA). Food and Agriculture Organization of the U.N.

Balance of supply and demand. Non-food uses are decreasing.

Aquaculture in a Global Context

3 - The European situation in perspective

- European production framework
- Import of aquatic products to Europe and the US
- Breakdown of production by country
- Legal frameworks

Aquaculture in the European Union

Sustainability and legislation

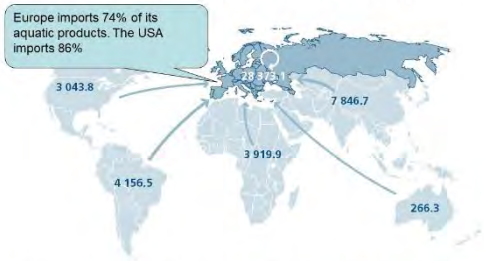
Environmental, legal, and social pressures

- Aquaculture is the most heavily regulated food production sector in Europe (Varadi, 2010)
- Competition for space, access to capital, availability of special services, limited authorised veterinary products (Varadi, 2010)
- Water Framework Directive (2000/60/EC) – no reference to aquaculture. Benthic biodiversity, fish (in transitional waters); Good Ecological Status in Europe by 2015
- Marine Strategy Framework Directive (2008/56/EC) – Fish and Shellfish Quality Descriptor (QD3). Aquaculture is seen only as a pressure. Good Environmental Status by 2020
- Many other parts of the world don't come close to the EU regulatory panorama

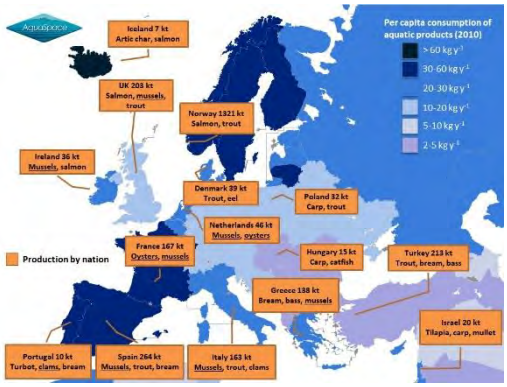
The EU faces a huge aquatic food security challenge in the next years.

Imports to Europe

All numbers in millions of USD (SOFIA 2012)



If European consumption was at the level of Portugal (57.4 kg y^{-1} per capita) an extra 27 million tonnes of fish products would be required annually.



Legal frameworks for aquaculture

Asia 90%. Rest of the world: 10% of production

Country	Basic Legislation	Authorisation System	Environmental Impact Assessment (EIA)
EU	Horizontal directives, MSFD, WFD, shellfish directives	Licensing, water quality permitting	Required
USA	Federal and state level	Registration with state authorities. May vary among states	Usually required, may vary among states
Canada	Oversight by federal, provincial and local authorities.	Federal and provincial governments issue licences	Required
Norway	- Aquaculture Act (2005). - EEA agreement	Licence. Regulators may limit number of licences	Required for large aquaculture installations
Chile	- Fisheries and Aquaculture Law	Permit	Required for large aquaculture installations
New Zealand	- Resources Management Act (RMA)	Resource consent	Required

Asymmetry in regulatory instruments and requirements for environmental compliance on a global scale.

Aquaculture in a Global Context

4 - Species and technologies

- What is grown and how
- Examples from four continents
- Species combinations (integrated culture)

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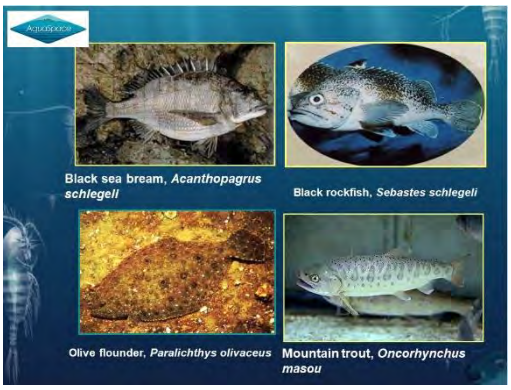
Types, species, and structures

Aquaculture type	Group	Example species	Cages	Ponds	Bottom	Lines/ rafts	RAS*
Fed aquaculture	Finfish	Atlantic salmon	X				X
		Rainbow trout	X				X
		Tilapia		X			X
		Carp		X			
		Seabass	X				X
		Gilthead	X				X
	Shrimp	White shrimp, tiger shrimp		X			X
Organic extractors	Filter-feeders	Oysters, mussels, scallops			X	X	
		Clams			X		
	Deposit feeders	Sea cucumber, abalone			X		
Inorganic extractors	Seaweeds	*Porphyra* (nori)				X	
		Saccharina, Alaria, Undaria				X	

*RAS: Recirculating Aquaculture System

FAO provides a complete database of species and production volumes worldwide.



Aquaculture in Thailand - Mae Tak reservoir, Chiangrai

Tilapia, *Oreochromis niloticus*

Chiangrai pond culture, Thailand

Tilapia, *Oreochromis niloticus*

Aquaculture in Brazil – Santa Fé do Sul, São Paulo

Tilapia, *Oreochromis niloticus*

World's largest offshore fish farming site (Atlantic salmon)

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Nori in Fujian, China - *Porphyra yezoensis*

Worldwide production of 600,000 tonnes, feeds demand for Sushi.

Integrated Multi-Trophic Aquaculture
Vancouver Island, Canada

Scallop lanterns as part of an IMTA setup that includes sablefish, kelp, and sea cucumbers.

Sanggou Bay – December 2016
Aquaculture on a different scale

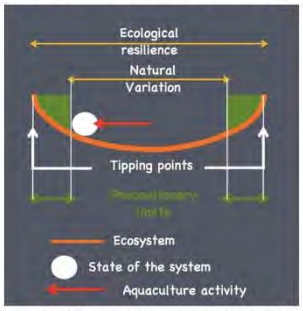
Seaweed, abalone, sea cucumber, oysters, scallops...

Aquaculture in a Global Context

5 - Carrying capacity and sustainability challenges

- Tipping points and real-life examples
- What is carrying capacity?
- Different world visions of carrying capacity
- The FAO Ecosystem Approach to Aquaculture

Sustainability criteria:
foundation in classical ecology



Filgueira et al., 2013. Aquaculture Environment Interactions 4, 117-133.

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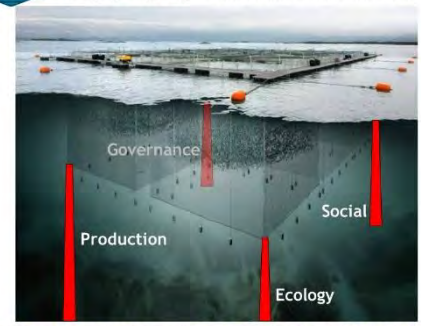
Tilapia cage culture
Laguna de Bay, Philippines

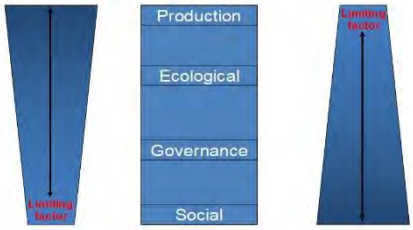
Overstocking and slow water turnover can lead to excess organic material.

Carrying Capacity – a Multidimensional Problem



Four pillars for sustainable aquaculture. In the West, the social pillar is limiting.

Different types of carrying capacity for aquaculture



Different parts of the world see carrying capacity in very different ways.

In China, social licence for aquaculture is very different from Europe

Ecosystem Approach to Aquaculture - FAO

Three principles

- Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience;
- Aquaculture should improve human-well being and equity for all relevant stakeholders;
- Aquaculture should be developed in the context of other sectors, policies and goals.

Soto, 2010

EAA: ecosystem balance, social equity, multiple uses

Aquaculture in a Global Context

6 - Synthesis

- Production models for the future
- Planning approaches for data-poor nations
- A blueprint for participative development
- Synthesis

Offshore production platform idea 2015 – launched in 2017-2018

Nordlaks : An Ocean ship/cage solution to be tested

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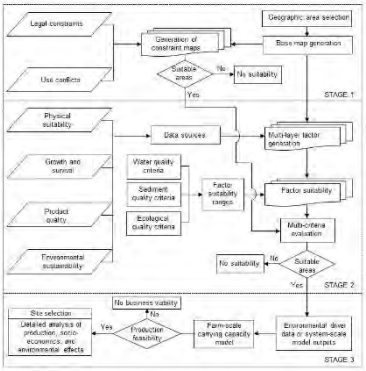
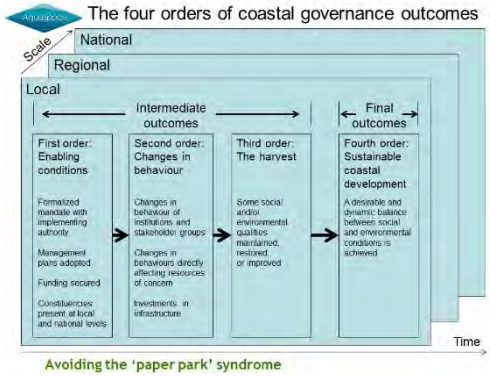
Systems approach for site selection



Silva et al., 2011.

The four orders of coastal governance outcomes



Avoiding the 'paper park' syndrome

Summary

- Fisheries are an important and traditional human activity;
- Aquaculture has replaced fisheries as the main source of aquatic protein, but fishing (like hunting) will not disappear;
- Aquaculture, like agriculture, needs to be sustainable. Probably only a few species will be cultivated at scale;
- Different technologies are used worldwide for cultivating aquatic organisms;
- Carrying capacity and site selection are key for sustainable and harmonious growth of the economy of the sea;
- The distinction should not be between wild and farmed fish, but between good and bad fish;
- A good fish is nutritious and tasty, environmentally friendly, and raised with due consideration for animal welfare.

For more information about the AquaSpace CPD Course and spatial planning toolbox, visit our website:
www.aquaspace-h2020.eu

Horizon 2020

The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.

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Topic 2: Current frameworks for aquaculture planning and management

AquaSpace

CPD Course
PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 2: Current Frameworks for Aquaculture Planning and Management

Anne Marie O'Hagan
MaREI, ERI, UCC

Horizon 2020

- The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for AquaculTure, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.

Overview

- Legal basis for EU law on environment, fisheries and aquaculture
- Key EU legal instruments for marine / coastal management
- Conservation
- Impact assessment processes

EU Legal basis

- Article 3(3) TEU defines the objectives of the EU:
  "The Union shall work for **sustainable development** of Europe based on balanced economic growth and price stability (…) and a high level of protection and improvement of the quality of the **environment**"
- Art. 191 TFEU: defines objectives and principles of EU environmental policy (+ new legal basis for **climate change** and Art. 194 sets a new legal basis for EU **energy policy**)
- Transboundary effects in third countries: international treaties/agreements

Legal Principles

- Article 5 TEU defines general principles/mechanisms of EU law:
  - Proportionality
  - Subsidiarity
- Article 191(2) TFEU defines environmental principles: "Union policy on the environment shall aim at **high level of protection** taking into account the **diversity of situations** in the various regions of the Union. It shall be based on the **precautionary principle** and on the principles that preventive action should be taken, that **environmental damage** should as a priority be **rectified at source** and that the **polluter should pay**"

Areas of Competence

Exclusive Competence	Shared Competence	Competence to support, coordinate or supplement MS action	Competence to provide arrangements within which EU member states must coordinate policy
Conservation of marine biological resources under Common Fisheries Policy	Agriculture and fisheries, excluding the conservation of marine biological resources	Human health	Economic policy
Concluding international agreements	Economic, social and territorial cohesion	Industry	Social policies
Non-exhaustive	Environment	Culture	Employment
	Energy	Tourism	
	Research, Tech. dev.	Education & training	
		Civil protection	
		Administrative cooperation	

EU Directives

- Over 200 relevant to the marine environment
- Horizontal (Cross cutting) – **Environmental Assessment**; Environmental Justice and Information
- Sectoral
  - Bathing water quality (revisions), Shellfish water (revisions), Waste water treatment, Nitrates, Water Framework Directive
  - Marine Strategy Framework Directive
  - Birds Directive, Habitats Directives
  - Floods Directive
  - Maritime Spatial Planning Directive

Integrated Maritime Policy

"All matters relating to Europe's oceans and seas are **interlinked**, and that sea-related policies must develop in a joined-up way if we are to reap the desired results"

Cross-cutting policies:

- Sea-basin strategies
- Blue Growth
- Marine data and knowledge
- Maritime Spatial Planning
- Integrated maritime surveillance

Marine Strategy Framework Directive (2008/56/EC) [1]

- Establishes a **framework** within which Member States take measures to achieve or maintain Good Environmental Status in the marine environment by 2020
- First attempt at an **Ecosystems-based Approach**
- Applies to 'marine waters' from baseline to 200M
- First EU legal instrument with an objective to maintain **marine biodiversity**
- Implementation on a **Regional** basis: Marine Strategies
- **Integrated** the concepts of environmental protection and sustainable use

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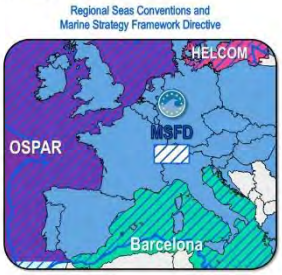
MSFD – Marine Strategies [2]

MSFD – Regional Implementation [3]

Four European marine regions

- Baltic Sea,
- North-east Atlantic Ocean,
- Mediterranean Sea and
- Black Sea



MSFD - Descriptors [4]

1. Biodiversity is maintained
2. Non-indigenous species do not adversely alter the ecosystem
3. The population of commercial fish species is healthy
4. Elements of food webs ensure long-term abundance and reproduction
5. Eutrophication is minimised
6. The sea floor integrity ensures functioning of the ecosystem
7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
8. Concentrations of contaminants give no effects
9. Contaminants in seafood are below safe levels
10. Marine litter does not cause harm
11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Water Framework Directive [1]

- Objectives:
  - Protection of aquatic ecosystems;
  - Promotion of sustainable water use based on a long-term protection of available water resources;
  - Improvement of the aquatic environment through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances;
  - Reduction of pollution of groundwater, and,
  - Mitigation of the effects of floods and droughts.

Water Framework Directive [2]

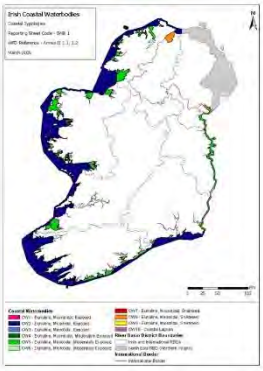
- Aim is to prevent the deterioration of ecological quality and the restoration of polluted surface and groundwaters by the end of 2015
- Implemented through River Basin Management Plans
- River basins which cross national frontiers must be assigned to an international River Basin District (RBD)
- Addresses inland surface waters, estuarine and **coastal waters** and groundwater.

Water Framework Directive [3]

- Transitional waters = estuarine waters, precise technical details for characterisation set out in Annex II;
- Coastal waters defined as "surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters."

- Note definition of coastal waters
- How will this align with MSFD and MSP? Local specificity?

- Coastal waters must be assigned to the nearest or most appropriate river basin district or districts;
- Member States are obliged to appoint an authority responsible for applying the rules of the Directive **within each RBD.**



Common Fisheries Policy [1]

- Four main pillars

1. Fisheries Management e.g. Technical Conservation Measures, Total Allowable Catch (TACs)
2. Structural Policy: funds for infrastructure and fleet (e.g. EMFF)
3. Market and Trade Policy: consumer information (labelling), pricing,
4. External Policy: international agreements, access to waters

Also separate rules on Aquaculture and Stakeholder Involvement (Advisory Councils)

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Common Fisheries Policy [2]

- Reform package sought to boost aquaculture production
- EC published the Strategic Guidelines for the sustainable development of EU aquaculture (2013)
- Four priority areas identified:
  - Reduce administrative burdens
  - Improve access to space and water
  - Increase competitiveness
  - Exploit competitive advantages due to high quality, health and environmental standards
- Member States requested to produce Multi-annual National Strategic Plans to promote aquaculture
- 27 Plans produced

EU Strategic Guidelines on Aquaculture [1]

Multi-annual National Strategic Plans

Member States encouraged to define their own **national targets** based on their:
- Current positions,
- National circumstances and
- Institutional arrangements.

Four priority areas:
1. **Administrative procedures**
2. **Coordinated spatial planning**
3. Competitiveness and
4. A level playing field

Challenges identified at MS level

Marine:
- Lack of available space in inshore, sheltered waters
- Complex administrative procedures
- Competitiveness of products
- Use of Research & Development outputs
- Environmental conditions

Freshwater:
- Credit, investments and costs
- Fragmented structure of sector
- Lack of available space

EU Strategic Guidelines on Aquaculture [2]

Exercise
- Critique your National Strategic Plan for Aquaculture
- Possible considerations:
  - Links to other regulatory frameworks
  - Approaches to spatial planning
    - Recommended tools?
  - Environmental monitoring
  - Mention of EAA
- Is their scope to include EAA in total/part?
  - Barriers
  - Opportunities

Impact Assessment: SEA, AA and EIA

Impact Assessment

- Needs to answer:
  - what the problem is,
  - what the objectives to be pursued are,
  - what the options are,
  - what their possible impacts are and
  - how the options compare.
- Must ensure the **balanced** assessment of economic, environmental and social impacts of proposals and avoid unintended and unexpected side effects.

Types of Impact Assessment

SEA	EIA	Appropriate Assessment
Strategic level	Site level	Natura 2000 site and its conservation objectives
Takes place at early stages of decision-making cycle: aims to prevent impacts	Takes place near the end of decision-making cycle: aims to minimise impacts	Takes place early in the process (screening)
Emphasis on meeting environmental objectives, maintaining natural systems	Emphasis on mitigating and minimising impacts	Emphasis on possible nature conservation implications of any plan or project on Natura 2000 site
Broad perspective, lower level of detail	Narrow perspective, high level of detail	High level of detail specific to site

Strategic Environmental Assessment (SEA) Directive [1]

- Involves the systematic identification and evaluation of the impacts of a strategic action (e.g. a **plan** or **programme**) on the environment
- ALSO the effects of the environment on the PPs
- Operates **in conjunction** with the EIA Directive
- Still uncertainty around what plans and programmes are subject to SEA.... does apply across a wide range of sectors

SEA Directive [2]

- Prepare an **Environmental Report** - likely significant environmental effects are identified and evaluated
- **Consult** the public, environmental authorities and any MS affected on the ER and draft P/P
- Take account of the findings of the ER and the outcome of the consultations in **deciding** whether to adopt or modify the draft P/P
- Make **known** the decision on adoption of the P/P and how SEA influenced the outcome.

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SEA Directive [3]

- Environmental Report
  - Contains the likely significant effects on the environment of implementing the PP
  - Reasonable alternatives
- Significant effects on the environment
  - Issues and their interrelationships
- Environmental objectives
  - How does the PP take conservation objectives in the area into account

Nature Conservation: Birds and Habitats Directives and Biodiversity Policy

Birds Directive (2009/147/EC)

- Seeks to protect, manage and regulate all bird species naturally living in the wild within the European territory of the Member States, including the eggs of these birds, their nests and their habitats
- 193 endangered species and sub-species
- Requirement to designate Special Protection Areas (SPAs) on land or at sea (Wetlands of particular importance)
- Requires the avoidance of pollution or deterioration of habitats generally, outside SPAs
- May require the prevention or control of activities on, near or in an area which is the habitat of a protected bird

Levels of Protection in Birds Directive

- **Annex 1**: 194 species and sub-species are particularly threatened. Member States must designate SPAs for their survival and all migratory bird species.
- **Annex 2**: 82 bird species can be hunted. Hunting periods are limited and forbidden when birds are at their most vulnerable
- **Annex 3**: generally, activities that directly threaten birds, are banned. With certain restrictions, Member States can allow some of these activities for the 26 species listed in this Annex.
- **Annex 4**: the Directive provides for the sustainable management of hunting but Member States must outlaw all forms of non-selective and large scale killing of birds, using the methods listed in this Annex.
- **Annex 5**: the Directive promotes research to underpin the protection, management and use of all species of birds covered by the Directive, which are listed in this annex.

Habitats Directive (92/43/EEC)

- Preamble – to ensure "the restoration and maintenance of natural habitats and species of Community interest at **favourable conservation status**."
- Objective: 'To contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora in the **European territory** of the Member States to which the EC Treaty applies' (Art. 2(1))
- Seeks to ensures the conservation of a wide range of rare, threatened or endemic animal and plant species
  - 1000 animal and plant species
  - 200 habitat types
- Requirement to designate Special Areas of Conservation (SACs) on land or at sea

Levels of Protection in Habitats Directive

- **Annex II species** (about 900): core areas of their habitat are designated as sites of Community importance (SCIs) and included in the Natura 2000 network. These sites must be managed in accordance with the ecological needs of the species.
- **Annex IV species** (over 400, including many Annex II species): a strict protection regime must be applied across their entire natural range within the EU, both within and outside Natura 2000 sites.
- **Annex V species** (over 90): Member States must ensure that their exploitation and taking in the wild is compatible with maintaining them in a Favourable Conservation Status.

Natura 2000 Network

- Largest **coordinated** network of protected areas in the world
- Aim is to ensure the **long-term survival** of Europe's most valuable and threatened species and habitats
- **Not** a system of strict nature reserves
- **Management Plans** may be drawn up for designated sites
- Duty on Member States to **avoid** deterioration of habitats and **significant** disturbance of species
- Also have to establish the **standards** to be applied to consideration of development proposals potentially threatening any sites

Impact of Designation

- Designation does not exclude all human activities
- Developments likely to have an adverse effect on a Natura 2000 site must be subject to an Appropriate Assessment in light of the site's conservation objectives
- Developments must have no significant effects on the integrity of a designated site considering the
  - Site structure,
  - Function and
  - Conservation objectives.

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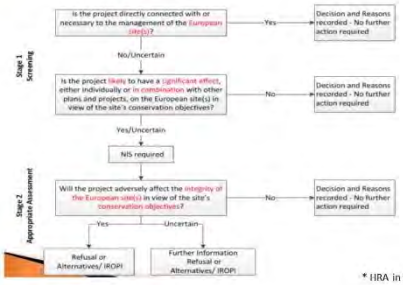
Appropriate Assessment* Process



* HRA in the UK

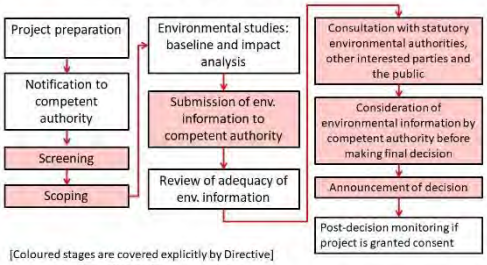
Environmental Impact Assessment Directive [1]

- Introduced in 1985
  - Amended in 1997, 2003 and 2009
  - Codified in 2011
  - Amended in 2014
- Requires an assessment of the environmental impact of any project likely to have significant effects on the environment before consent can be granted
  - Annex I
  - Annex II
- Other Member States must be consulted about proposals that are likely to have a transboundary effects.

EIA Directive [2]

- Developer **may request** the competent authority to say what should be covered by the EIA (scoping stage);
- Developer **must provide** information on the environmental impact (EIA report – Annex IV);
- The environmental authorities and the public must be **informed and consulted**;
- The competent authority decides, **taking into consideration** the results of consultations;
- The public is informed of the decision **afterwards** and can challenge the decision before the courts.

EIA Directive [3]



[Coloured stages are covered explicitly by Directive]

Source: ERM, 2001

EIA Directive [4]

- What should an EIA do?
- What type of information should be included?
- Note changes in legislation (Directive and transposing instruments)
- What type of effects should be covered?
- How are cumulative impacts dealt with?
- How is monitoring dealt with?

Summary

SEA	EIA
Takes place at earlier stages of decision-making cycle: aims to prevent impacts	Takes place near the end of decision-making cycle: aims to minimise impacts
Pro-active approach to development proposal	Reactive approach to development proposal
Considers broad range of potential alternatives	Considers limited number of feasible alternatives
Emphasis on meeting environmental objectives, maintaining natural systems	Emphasis on mitigating and minimising impacts
Broad perspective, lower level of detail to provide a vision and overall framework	Narrow perspective, high level of detail

Differences between Assessments

	EIA	AA
Development type?	All projects in Annex I, discretionary for Annex II projects.	Any development likely to have an adverse effect on a Natura 2000 site.
Impacts to be assessed?	Direct and indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative significant effects.	Assessment should be made in view of the site's conservation objectives (which are a function of the species/ habitat types for which the site was designated).
Done by?	The developer.	The Competent Authority (with developer input).
Outcomes?	Results must be **taken into consideration** in the development consent procedure.	**Binding**. Competent authorities can agree to the development only after having ascertained that it will not adversely affect the integrity of the site.

Suggested Exercise

- Facilitated discussion on current planning and management frameworks covering topics such as:
- Strategic aquaculture policy (presence/absence?
- SWOT Analysis of existing legal framework
  - What impacts positively on the sector?
  - What impedes development?
  - Attention should be paid to whether these derive from international/EU/national law or administrative processes
- Theory v. practice
- How is monitoring dealt with?
- Enforcement and compliance aspects

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AquaSpace For more information about the AquaSpace CPD Course and spatial planning toolbox, visit our website: www.aquaspace-h2020.eu Horizon 2020 The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, https://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.	

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Topic 3: Maritime Spatial Planning in Europe: Opportunities for Aquaculture

AquaSpace

CPD Course
PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 3: Marine Spatial Planning in Europe: Opportunities for Aquaculture

Lucy Greenhill (SAMS)
Anne Marie O'Hagan (UCC)

February 2018

Horizon 2020

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Overview

- What is MSP?
- Why is it different?
- What is the status of MSP?
- Opportunities for aquaculture
- Key challenges

What is MSP?

"Marine spatial planning (MSP) is a **public process** of analyzing and allocating the **spatial and temporal** distribution of human activities in marine areas to **achieve ecological, economic, and social objectives** that are usually specified through a political process."

(Ehler, 2014)

What is MSP?

https://vimeo.com/album/3680099/video/219515087

Drivers of MSP

- Increasing demand for marine resources
- Increasing competition for space and resources
- Increasing concern regarding social and ecological thresholds
- Overcomplicated and inefficient planning processes

Why is MSP different to current management?

- **Multi-objective and integrated**
- Focus on social, ecological and economic objectives
- Sectors currently managed through fragmented processes
- Difficulties in understanding the cumulative impacts and in balancing priorities

Why is MSP different to current management?

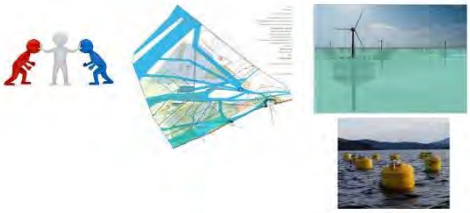
- **Strategic and future-orientated**
- Visioning a key part of MSP, enabling foresight to potential conflicts through considering alternative scenarios
- Current development on a project-by-project basis
- Considering conflicts and trade-offs comes too late to address effectively

BaltSeaPlan
Vision 2030

Why is MSP different to current management?

- **Designed to address conflict and promote synergies** to optimise use of marine space and resources

Conflict | Co-existence | Co-location



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Why is MSP different to current management?

- **Emphasis on participation** - meaning two-way interaction between authorities and deliberation between participants
- Not 'consultation' on plans which have already been designed
- Enable ownership and empowerment of society in planning of marine activities

Why is MSP different to current management?

- **Dynamic and adaptive**
- Emphasis on performance monitoring and evaluation and learning by doing

Benefits of MSP

Identification and early resolution of conflicts	Economic
Greater certainty for developers	
May reduce costs	
Facilitates sectoral growth	
Streamlined and more transparent licensing procedures	
Sustainable use of resources	Environmental
Identification of ecologically and biologically significant areas	
Enables planning of conservation areas e.g. MPAs	
Identification/reduction of cumulative effects of human activities	
Increases involvement and cooperation among stakeholders	Social
Identification of effects of decisions on the allocation of ocean space on communities	
Identification and preservation of social, cultural, and spiritual values related to use of ocean space	
Administrative	

MSP in Europe

EC Maritime Spatial Planning Directive (2014)

Member States must:

Transpose MSP Directive into their national laws by 2016

Draw up national MSPs by 2021

European Atlas of the Seas (European Commission)

EU MSP Directive [1]

Recitals:

- Increasing demand for maritime space for different purposes… require an integrated planning and management approach
- Coordinated, integrated and transboundary approach
- A framework for consistent, transparent, sustainable and evidence-based decision-making
- Recognises role of LOSC and says MSP is a logical progression of rights granted under it
- Member States remain responsible and competent for designing and determining the format and content of the maritime spatial plans applicable to their marine waters
- The Directive ***should not impose any other new obligations***

EU MSP Directive [1]

Subject matter: **Article 1**

- Framework for MSP

Aimed at:

1. Promoting the sustainable growth of maritime economies,
2. Sustainable development of marine areas and
3. Sustainable use of marine resources

Provides for the creation and implementation of MSP that

- Takes into account land – sea interactions
- Enhances cross-border cooperation

EU MSP Directive [2]

Scope and definitions: **Articles 2 and 3**

- **Shall apply** to marine and coastal waters of Member States
  - Marine waters has the same definition as the Marine Strategy Framework Directive (MSFD)
  - Coastal waters has same definition as the Water Framework Directive (WFD) plus their seabed and subsoil
- 'Marine region' also has same meaning as MSFD
- **Shall not apply** to coastal waters falling under a Member State's town and country planning legislation
- **Shall not influence** the delineation and delimitation of maritime boundaries by the Member States

EU MSP Directive [3]

Objectives of maritime spatial planning: **Article 5**

- Shall consider economic, social and environmental aspects to support sustainable development and growth in the maritime sector,
- Apply an ecosystem-based approach
- Promote the coexistence of relevant activities and uses
- Member States decide how the different objectives are reflected in their MSP

Sectors included:

- Energy, maritime transport, fisheries and aquaculture,
- 'Preservation, protection and improvement of the environment'
- 'Promotion of sustainable tourism'
- 'Sustainable extraction of raw materials'

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EU MSP Directive [4]

Minimum requirements: **Article 6**

- 'Take account of' land-sea interactions
- 'Take account of' environmental, economic, social and safety aspects
- 'Promote' coherence between MSP and, e.g., ICM
- 'Ensure' the involvement of stakeholders
- 'Organise' the use of best available data
- 'Ensure' transboundary cooperation
- 'Promote' cooperation with third countries

Plans to be reviewed at least **every 10 years**

Dutch MSP

Belgian MSP

MSP for Germany

Examples of MSP in Europe

(UNESCO, 2014)

MSP in Europe

European MSP Platform

http://www.msp-platform.eu/

Online tool with extensive information on progress on MSP in Europe.

MSP Process

Opportunities for Aquaculture through MSP

- Improving public perception and facilitating social licence through:
  - Dialogue between industry and civil society
  - Communicating early in the planning process
  - Understand real and perceived conflicts
  - Developing shared solutions

Opportunities for Aquaculture through MSP

- Allocating space for aquaculture and mitigating conflict
  - Assign space alongside other uses
  - Provide framework for negotiation with other sea users e.g. through visioning and scenarios
  - Promote co-location (e.g. of aquaculture and renewable energy)

Opportunities for Aquaculture through MSP

- Reduce uncertainty in planning processes
  - Enable reflection on overcomplicated processes and differences between sectors
  - Promote simplified procedures and rationalisation of administrative effort across sectors and interests

Opportunities for Aquaculture through MSP

- Adaptive management and review of processes and practice
  - On-going monitoring and evaluation enabling collective learning
  - Reflection based on quantitative and qualitative criteria
  - Refer to UNESCO guide:

http://unesdoc.unesco.org/images/0022/002277/227779e.pdf

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Opportunities for Aquaculture through MSP

- Dealing with cumulative impacts
  - Requires dealing with trade-off's, comparisons and priority setting up front
  - Multi-sector and interest scenarios provide basis for more fairly assessing potential impacts

Key Challenges in MSP

MSP is not a panacea and is limited by a range of factors such as:

- Capacity and resources - human, technical and financial
- Relationship to existing sectoral management for aquaculture
- How to evaluate MSP – what is 'success', what are the qualitative and quantitative factors?

Summary

- MSP is progressing rapidly in Europe in response to the MSP Directive
- MSP represents a new way of approaching planning and management of marine activities
- *Could* help address some key planning constraints facing aquaculture
- Faces a number of challenges, including investment in the process, financial and political

Additional Reading (1)

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Additional Reading (2)

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- Rochette, J., Bille, R. (2013). Bridging the gap between legal and institutional developments within regional seas frameworks. International Journal of Marine and Coastal Law, 28(3):433-463.

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Topic 4: Ecosystem Approach to Aquaculture (EAA)

AquaSpace

CPD Module
PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 4: The Ecosystem Approach to Aquaculture (EAA) and Spatial Planning

Paul Tett (SAMS), Anne Marie O'Hagan (UCC), José Aguilar-Manjarrez (FAO)

Horizon 2020

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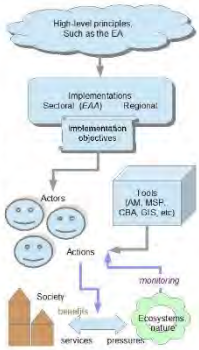
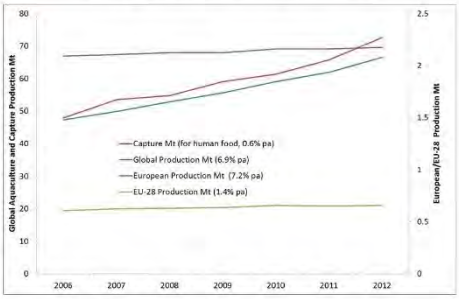
From the principles of the Ecosystem Approach to their operational application

Conceptual model for the implementation of principles such as those of the Ecosystem Approach of the Convention on Biological Diversity, showing the flow of a 'steering medium' from Constitutional to Operational levels. The interactions between society and nature are shown in terms of *services* (from ecosystem to society) and *pressures* (on ecosystems due to human activities).

AM is Adaptive Management;
MSP is Maritime Spatial Planning;
CBA is Cost-Benefit Analysis;
GIS is Geographic Information System



Why focus on spatial planning?



The need for Spatial Planning

- Access to land, water and associated infrastructure
- Higher productivity and returns for investors
- More effective mitigation of environmental, economic and social risks
- Less disease outbreaks and more effective biosecurity (prevention and control of diseases and the introduction of invasive species)
- Better resilience to external factors (disasters, climatic variability)
- May contribute to a better understanding of aquaculture and improve public perception of the industry

Fundamental Principles

An Ecosystem Approach to Aquaculture (**EAA**) is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems
(FAO, 2010)

MSP is strategic planning process for analysing, allocating and managing the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives and address multiple, cumulative, and potentially conflicting uses of the sea
(adapted from Ehler and Douvere, 2009)

Framework for Ecosystem Approach to Aquaculture

FAO Code of Conduct on Responsible Fisheries (CCRF)

Purpose:

- To promote long-term conservation and sustainable use of fisheries resources, and
- To strengthen the international legal framework for more effective conservation, management and sustainable exploitation and production of living aquatic resources

Sets out **principles** and **standards** of behaviour for responsible practices

CCRF is **voluntary** and is interpreted and applied in conformity with international law

FAO Code of Conduct on Responsible Fisheries (CCRF)

Article 9 = Aquaculture Development

- Encourages States to develop and maintain appropriate **legal and administrative frameworks** in order to facilitate the development of responsible aquaculture (Art. 9.1.1)
- Urges States to produce and regularly update aquaculture development **strategies and plans** (Art. 9.1.3)
- Requests States to ensure that the **livelihoods** of local communities, and their **access** to fishing grounds, are not negatively affected by aquaculture developments (Art. 9.1.4)
- Calls upon States to establish environmental assessment and monitoring procedures **specific to** aquaculture (Art. 9.1.5)

Instruments under CCRF

- Four International Plans of Action
- Two Strategies
  - Strategy and Outline Plan for Improving Information on Status and Trends of Aquaculture
- 29 Technical Guidelines
  - 7 relating to different aspects of Aquaculture
    - **Ecosystem Approach to Aquaculture (2010)**
    - Not what is done but **how** it is done
    - Requires a "tighter coupling of science, policy and management"

See http://www.fao.org/docrep/013/i1750e/i1750e00.htm

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Steps in the FAO EAA

- **Scoping:** definition of ecosystem boundaries and relevant stakeholders
- **Zoning:** can be all or part of any hydrological system that is at least partly suitable for aquaculture
- **Site Selection:** Most appropriate sites for individual farm development
- **Aquaculture Management Areas (AMAs):** shared waterbodies where all the aquaculture operators agree to certain management practices that act to minimise the overall impacts from their collective activities

© FAO and World Bank, 2017

Material and Illustrations based on Report ACS18071 part 1

Aquaculture Zoning, site selection and area management under the ecosystem approach to aquaculture: a handbook

- José Aguilar-Manjarrez & Doris Soto (FAO)
- Randall Brummett (World Bank) 2017
- http://documents.worldbank.org/curated/en/421101490644362778/full-document

Figure 1: potential steps in the spatial planning and management process

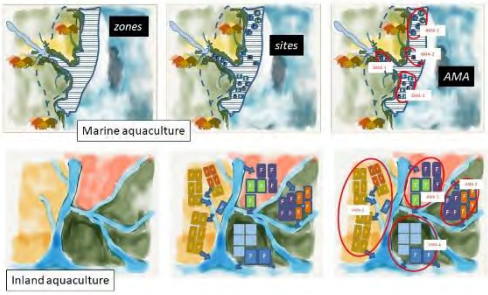

Figure 2: suitability for *Tilapia*

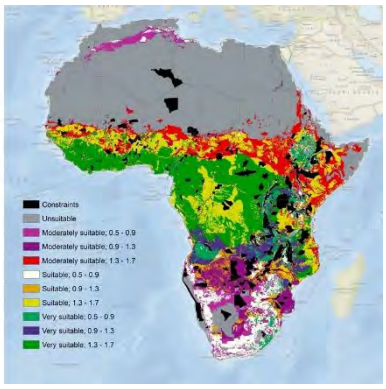

Figure 3: Output from a fish farm particulate waste deposition model

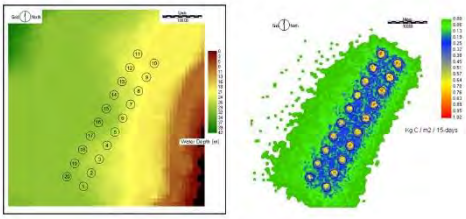

Figure 4: Fish production in overcrowded (pre-2009) and optimal densities

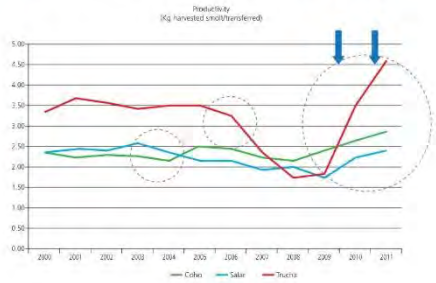

Figure 5a: aqua-cultural sites within AMA within zones

Figure 5b: aquaculture sites within AMA

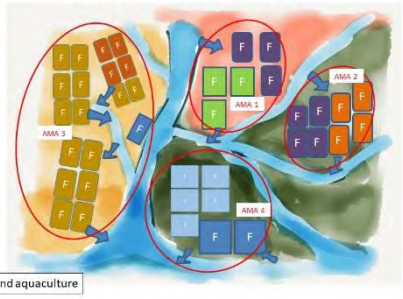

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Figure 6: MODIS remote sensing of southern Chile (first part)

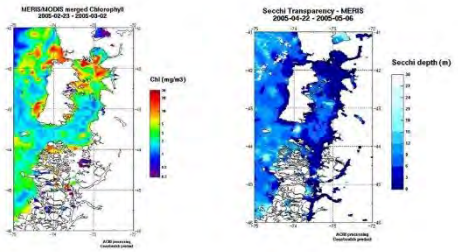
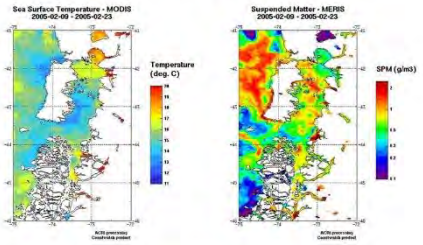


Figure 6, part 2



Source: Stockwell et al., 2006

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Topic 5: Introduction to the AquaSpace Tool for use in spatial planning

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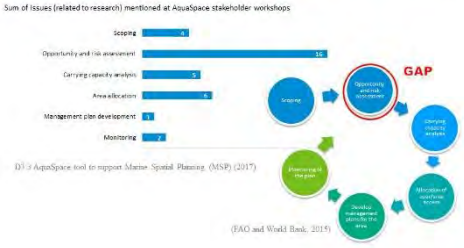
Appendix – Presentation Content

Stakeholder opinions on what is needed to support an EAA

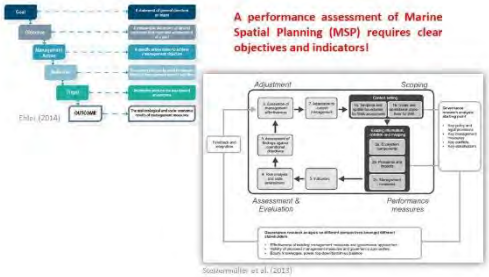
Stakeholder consultation on issues constraining the growth of aquaculture resulted in the following gaps (structured around the steps of the EAA):



D3.3 AquaSpace tool to support Marine Spatial Planning (MSP) (2017)

Performance assessment of MSP

A performance assessment of Marine Spatial Planning (MSP) requires clear objectives and indicators!



Evaluating the risks and opportunities of EAA with aquaculture

A performance assessment of the EAA requires GIS-based tools for an integrated assessment of spatially explicit indicators

- Industry-specific and multiple-use planners rely heavily on spatially-referenced data and Geographic Information System (GIS) -based analytical tools
- Accounting for stakeholder needs in the EU project AquaSpace we developed a GIS based MSP tool to explore the risks and opportunities of planning options for aquaculture

D3.3 AquaSpace tool to support Marine Spatial Planning (MSP) (2017)

What does integrated mean?

Aquaculture intensification has to be sustainable!

- EAA has been developed by the FAO as a means to enhance aquaculture production in an environmentally and socially acceptable way that takes account of multiple uses of space, and is compatible with the legal basis defined in the MSFD and the Common Fisheries Policy (CFP)
- The EAA should form the basis for development of spatial planning under the Ecosystem Approach within the EU (O'Hagan et al., 2017)
- The objective is to fulfil the socio-economic targets for the area as well as the protection and conservation goals
- An integrated assessment means to take into account different environmental, social and economic components of the ecosystem
- Such an assessment should typically promote the coexistence of marine activities (e.g. windfarms and aquaculture) - and should be consistent with other sectors' objectives (Galparsoro et al., 2017)

Categories describing risks and opportunities

- Inter-sectorial: for a cohesive approach, in which aquaculture is an equal partner in development decisions - in the best interest of aquaculture as a sector
- Environmental: in order to consider any conditions aquaculture candidates and systems have to experience in nature, based on a mix of physical and environmental factors
- Economic: the price paid for aquatic products by the consumer requires understanding of the price structure in the supply chain, and how value is apportioned along the different stages
- Socio-cultural: the local social acceptance affects aquaculture development in Europe and competition with other prospective uses of the marine space, impacts consumption, marketing and profitability. Therefore, addressing public acceptance of aquaculture will improve its long term environmental, social and economic sustainability

Definition of indicators (representing categories)

Inter-sectorial

- Spatial conflict potential (highest conflict score with other human uses)*
- Spatial synergy potential (highest synergy score with other human uses)*
- Integrated Multi-Tropic Aquaculture potential (IMTA; Yes or No, recommended IMTA species)
- Risk of disease spread (based on minimum distance between aquaculture sites)

*In combination with Fisheries, Ocean energy, Platforms, Cables, Pipelines, Sediment extraction, Marine traffic, Waste disposal, Marine Protected Areas (MPA).

Economic

- Economic performance (revenue, added value)
- Economic effectiveness (benefits, return on fixed tangible assets, opportunity cost)
- Economic efficiency (net present value)
- Economic impact (induced impact, indirect impact)
- Tourism

Environmental

- Aquaculture suitability (low to high)
- Wave height specific exposure of the site (m)
- Current velocity (m/s)
- Sediment type
- Chlorophyll a (mg/m³, surface)
- Temperature (°C)
- Salinity (PSU)
- Nitrogen (mol/l, NO3; surface)
- Phosphorus (mol/l, PO4; surface)
- Cumulative pressure (1 - 8; 8 = high magnitude)
- Habitat vulnerability (1- 3; 3 = highly vulnerable)
- Water depth (m)
- Water quality (level of background pollution)

Socio-cultural

- Visual impact (landscape, seascape, distance to populated areas)
- Cultural heritage (shipwrecks, archaeological sites; distance calculation)

Definition of indicators (representing categories)

Site specific information

- Ecosystem (country; marine or freshwater)

Management information

- UNCLOS area
- Conservation area

Aquaculture specific information

- Aquaculture (finfish, shellfish or algae)
- Species to be cultivated (species name)
- Culture system (cage, longline, bottom, trestles; culture system size in m³/ha)
- Stocking density (per m³/ha)
- Production cycle (years)
- Production (tons)

Challenge of spatial representation of indicators

Development of the AquaSpace tool

A GIS-based tool for an integrated assessment of spatial planning trade-offs with aquaculture

Built on indicators required and data freely available to do an integrated assessment

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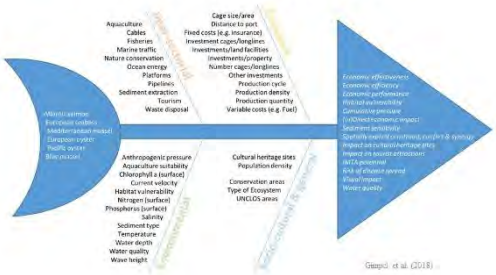
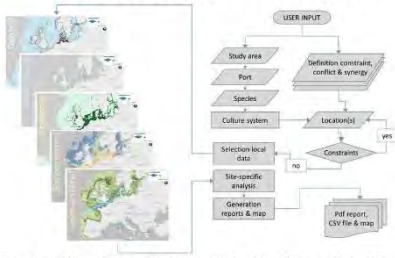
AquaSpace tool – Data view



Gimpel et al. (2018)

AquaSpace tool – Process view

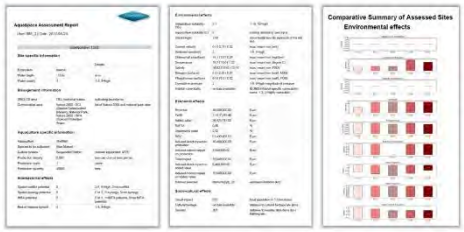


Depending on the specified aquaculture system for each planning scenario an integrated assessment of ecological, economic and social indicators is computed (Gimpel et al., 2018)

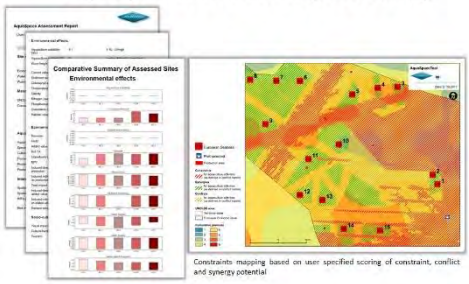
AquaSpace tool – GIS AddIn mxd view

Gimpel et al. (2018)

AquaSpace tool – PDF Output

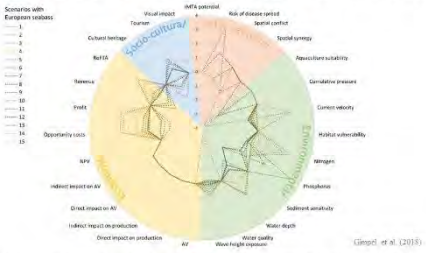


AquaSpace tool – PDF Output incl. map



Constraints mapping based on user specified scoring of constraint, conflict and synergy potential

AquaSpace tool – Scenario & trade-off assessment



Gimpel et al. (2018)

Graphical comparison of indicators for each planning site and export of assessment results (template provided online)

AquaSpace tool - Step by step application

The AquaSpace tool: a brief insight

The AquaSpace tool enables the user to assess individual marine site locations planned for aquaculture in terms of essential biological, ecological, economic, physical and social aspects. It is implemented as an AddIn for ArcGIS Desktop (from 10.3.1 and ArcGIS Basic with Spatial Analyst). The initial installation of the AquaSpace tool is a manual process of copying/pasting of file packages provided. All steps are precisely described in Gimpel et al. (2017) => Install the AquaSpace tool files.

Important to mention is that the AquaSpace tool comes initially with an EU-wide data package, provided as file GDB 10.3. Implemented are basic settings for test runs at German case study level, allowing the check if the installation procedure was performed properly. Ensuing from that, the user can customise the tool settings individually and even replace datasets. Those procedures are explained in Gimpel et al. (2017) => Customization options but require a minimum of ArcGIS usage skills. Register via https://gdi.thuenen.de/geoserver/sf/www/aqspce.html) to get access to comprehensive video instructions for installation process and usage of the tool - provided online (https://free-redmine.saas-secure.com/projects/agua).

AquaSpace tool - Step by step application

AquaSpace tool components

The user receives via -> https://gdi.thuenen.de/geoserver/sf/www/aqspce.html access to the AquaSpace Redmine website, where all AquaSpace tool files, technical documents as well as video instructions are provided, facilitating the installation and testing of the AquaSpace tool. The current status of technical documentation can be found under => Documents. In addition, user requests (in particular regarding tool bugs, data hints or support requests) can be placed under -> New issue.

The tool is composed of:

- The mxd (ArcGIS format) project
- The tool bar
- The Geodatabase (GDB)

The Arc GIS mxd file visualises the spatial extent of the tool in terms of a background map (esri bg map), all data sets required to run the tool and the respective symbology. Therefore, it ensures the correct symbolisation and paths' availability when using the tool.

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AquaSpace tool - Step by step application

The AquaSpace mxd, including the table of contents (left), the AquaSpace toolbar (top) and the Arc GIS catalog window (right), showing the AquaSpace Geodatabase.

AquaSpace tool - Step by step application

Quick start guide*

1. Part of AquaSpace tool installation
- Check the AquaSpace tool system requirements carefully, see [[http://free-redmine.saas-secure.com/documents/83]]
- Watch the video of installation process, see [[http://free-redmine.saas-secure.com/documents/83]]
- Get the latest version under => **News**, consider your ArcGIS version and follow the installation/update instructions carefully; in case you have questions please do not hesitate to place your support request under => **New issue**
- Watch the video for AquaSpace tool usage, see [[https://free-redmine.saas-secure.com/documents/91]]
- Test your local installation by a test run using the default GDB (German case study) simply by starting the **Aquaspace_pro.mxd** file under => C:\arcgis_addin\AquaSpace\Data. If you get an error or warning, please check the track list under issues [[https://free-redmine.saas-secure.com/projects/aquaa/issues]] and place a new issue here in case you could not find the support you need

2. Part of GDB Data Adjustments for your AquaSpace case study area
- **Clip your country data set / case study area:** this step is recommended in case there is no case study area listed under prepared country datasets, see [[https://free-redmine.saas-secure.com/news/46]]. In this context, by offering an EU-wide data package we aim to minimize the user effort of data harmonization and data adding. But for ArcGIS performance issues it is highly recommended to clip your country/ case study data set, see video instructions [[http://free-redmine.saas-secure.com/documents/82]]. This step is completed as soon as your clip result is stored under => C:\arcgis_addin\AquaSpace\Data and is renamed by the standard **ecba_tool_data0.gdb**
- Add your own data to the AquaSpace GDB, see [[https://free-redmine.saas-secure.com/documents/97]]
- Create your individual interaction conflict matrix, see Tool use case: create interaction matrix
- Now you are ready for using the AquaSpace Tool for your case study, please go to Tool application

* The user receives via => https://gdi.thuenen.de/geoserver/st/www/aqspce.html access to the AquaSpace Redmine website

AquaSpace tool - Step by step application

Install the AquaSpace tool files

1. Store the downloaded files on your PC
AquaSpace Tool expects the following storage path => **C:\arcgis_addin\AquaSpace**. Different storage paths would require more adjusting configuration work at the tool installation.
Go to => C:\arcgis_addin\AquaSpace\AquaSpaceTool and double-click the "AquaSpaceTool.Esri.Addin.Rle"

2. Adjust the PC Python Library
Backup the current Python Installation => C:\Python27\ArcGIS10.3 – copy folder (this avoids losing the original scripts that come with ArcGIS) and name it ArcGIS10.3_ESRI
In C:\Python27 overwrite the ArcGIS10.3 folder with the new folder "ArcGIS10.3" (PLEASE NOTE both installation procedures for python library transfer – one for ArcGIS 10.3 and another for ArcGIS 10.4 - depending on your local ArcGIS version

3. Adjust ArcGIS Map Style
Transfer the Legend Item "IMTA" from the source file => ArcGISMapStyleToCopy_IMTA.style ("Style Manager"; „Style" / "Add Style to list") to your personalized ArcMap Style => C:\Users\<USER_NAME>\AppData\Roaming\ESRI\Desktop10.3\ArcMap with copy&paste by using the Architect Style Manager (menu "Customize"=>"Style Manager") (Fig. 14)

4. Add the AquaSpace toolbar to your mxd
Open "Aquaspace_pro_(aster.mxd". The layer data sources will be invalid for Constraints, Conflicts and Synergies (those will re-connected under Gimpel et al. (2017) => Create interaction matrix)
Choose the toolbar via => Customize => Toolbars => "AquaSpace"
Drag and drop the toolbar on the top of your mxd

AquaSpace tool - Step by step application

Perform site assessment

The AquaSpace AquaSpace toolbar simplifies to perform a site assessment: Follow the toolbar inputs from left to right (excl. the purple button 'create interaction matrix') and make your choices (which need to be renewed for each tool run) regarding:

The selection of the extent (Country) => selection is optional, you can also zoom into the map to choose your favoured site

The harbour from which the aquaculture site will be supplied (Port) => selection required

The aquaculture species you want to assess (Species) => selection required

The background layer which shall be highlighted in the result map (Map Layer) => selection optional

The extent defined for the assessment (blue button) => selection required

The provision of sites to be assessed using the siting tool (Site Location)
- Choose a => Model Run ID (e.g. your name)
- Choose a => Production cycle (years)
- Choose a => Production density (bins/m² or tons/ha)
- Choose a => Cage size (m³) or Area (ha)
- Choose a => Production quantity (tons)
- Click on the feature set of the species you want to assess and click a point on the map to define the site to be assessed
- Click "Ok"

Software availability

- Name of software: AquaSpace tool - a GIS Addin
- Developers: Antje Gimpel, Sandra Töpsch, Vanessa Stelzenmüller
- Email: antje.gimpel@thuenen.de
- Year first available: 2017
- Operating System: Microsoft Windows 7, Windows 8/8.1 (32 or 64 bit) or Windows 10
- Processor/CPU: 2.7 GHz Intel Core i5 processor or equivalent (4 cores) (hardware below/above will increase/decrease tool run times)
- System RAM: 4 GB total minimum, 16 GB recommended
- Windows Feature .NET Framework: .NET 4.6 Framework
- ESRI ArcGIS license needed: ArcGIS Desktop Basic, Standard or Advanced with Extension Spatial Analyst, installation 10.3 and higher
- Python Environment: Standard Python library 32bit of ArcGIS installation 10.3 and higher
- Program size: 1.7 MB; GDB 400 MB
- Availability: https://gdi.thuenen.de/geoserver/st/www/aqspce.html
- Cost: nil

Summary AquaSpace tool application

- ✓ Integrates robust indicators to give a first overview
- ✓ Informs about the spatial extent of management effects
- ✓ Allows holistic scenario comparison and trade-off assessments
- ✓ Facilitates the presentation of associated opportunities and risks / management decisions
- ✓ Tool settings can be changed individually and datasets replaced

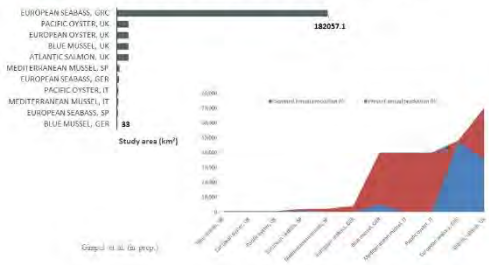
- – Limited data availability at EU level (low resolution)
  AquaSpace tool currently presents a static GDB (response of WFS too slow)
- – Temporal aspects only considered indirectly ('annual mean values')
  Most economic indicators driven by 'distance to port' calculations

Outlook

- Ecosystem-based MSP processes will have to account for existing and emerging activities such as fisheries and aquaculture
- Spatial planning based on EAA would:
  - simplify licensing process
  - promote sustainable development
  - mitigate spatial use conflicts
- Practical planning tools are emerging
- Need to promote the uptake of decision-support tools in the MSP processes

© NOAA

AquaSpace tool – Current implementation



Gimpel et al. (in prep.)

Appendix – Presentation Content

References related to the AquaSpace tool

Published (or under revision):

- Gimpel, A., Stelzenmüller, V., Töpsch, S., Galparsoro, I., Gubbins, M., Miller, D., et al. 2018. A GIS-based tool for an integrated assessment of spatial planning trade-offs with aquaculture. Science of the Total Environment. DOI 10.1016/j.scitotenv.2018.01.133
- Gimpel, A., Stelzenmüller, V., Marbà, N., Aguilar-Manjarrez, J., Arantzamendi, L., Asplin, L., Black, K., et al. 2016. Tools and Methods to support an Environmental Approach to Aquaculture (EAA) – practical needs. Thünen Institute, Hamburg and AquaSpace project (H2020 no. 633476), Oban. Deliverable 5.1. Pdf obtainable from http://www.aquaspace-h2020.eu/wp-content/uploads/2016/10/Tools-and-methods-supporting-EAA.pdf
- Gimpel, A., Stelzenmüller, V., Töpsch, S., Brigolin, D., Galparsoro, I., Gubbins, M., Marba, N., et al. 2017. AquaSpace tool to support MSP. Thünen Institute, Hamburg and AquaSpace project (H2020 no. 633476), Oban. Deliverable 5.3. Pdf obtainable from http://www.aquaspace-h2020.eu/wp-content/uploads/2017/10/D3.3_AquaSpace_tool_to_support_MSP_tool_manual_2nd_version.pdf
- Pinarbaşı, K., Galparsoro, I., Borja, Á., Stelzenmüller, V., Ehler, C., and Gimpel, A. 2017. Decision Support Tools in Marine Spatial Planning: Present Applications, Gaps and Future Perspectives. Marine Policy, 83: 83-91.

In preparation:

- Galparsoro et al. Basque country case study
- Galparsoro et al. AquaSpace synthesis: lessons learnt and recommendation towards MSP and aquaculture
- Gimpel, A., Stelzenmüller, V., Töpsch, S. et al. In prep. The AquaSpace tool. Experiences, key issues, short comings
- Watret, R., Gubbins, M., Gimpel, A., et al. (in prep.). Multi-criteria evaluation GIS applied to aquaculture in a Scottish Marine Region. A comparison of approaches (The AquaSpace tool vs MAIS)

Exercises*

1) Calculation of an environmental, an economic and a social scenario for European seabass in Germany (use of interaction matrix, economic input table and user-specific input as provided)
2) Calculation and interpretation of a trade-off assessment comparing the environmental, economic and social scenario created in task 1 for European seabass in Germany (use of template under https://free-redmine.saas-secure.com/documents/139)
3) Calculation of an environmental, an economic and a social scenario for the Mediterranean mussel in Spain
   - Download of Spanish GDB under http://free-redmine.saas-secure.com/news/64
   - Adaption of interaction matrix → supplementary information A
   - Adaption of economic input table → supplementary information B
   - User-specific input → supplementary information C

*ESRI ArcGIS license required: ArcGIS Desktop Basic, Standard or Advanced with Spatial Analyst Extension

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- FAO, World Bank, 2010. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Policy brief. Rome, Italy.
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- Galparsoro, I., A. Murillas, K. Pinarbasi, Á. Borja, A. M. O'Hagan, E. MacMahon, A. Gangnery, R. Corner, J. Ferreira, R. Ferreira, A. Gimpel, A. Boyd, J. Icely, Ø. Bergh, C. Donolkos, H. Lui, S. Billing, J. M. Giannetsba, L. Luigos and L. Arantzamendi. 2017. Synthesis of the lessons learned from the development and testing of innovative tools to support ecosystem-based spatial planning to aquaculture. Deliverable 5.1; AquaSpace. Ecosystem Approach to making Space for Aquaculture. EU Horizon 2020 project grant nº 633476. 103 pp.
- Gimpel, A., Stelzenmüller, V., Grote, B., Buck, B. H., Floeter, J., Núñez-Ribera, I., Pogoda, B., Temming, A., 2015. A GIS modelling framework to evaluate marine spatial planning scenarios: Co-location of offshore wind farms and aquaculture in the German EEZ. Mar. Policy, 55, 102-115.
- Gimpel, A., Stelzenmüller, V., Marbà, N., Aguilar-Manjarrez, J., Arantzamendi, L., Asplin, L., Black, K., et al. 2016. Tools and Methods to support an Environmental Approach to Aquaculture (EAA) – practical needs. Thünen Institute, Hamburg and AquaSpace project (H2020 no. 633476), Oban. Deliverable 5.1. Pdf obtainable from http://www.aquaspace-h2020.eu/wp-content/uploads/2016/10/Tools-and-methods-supporting-EAA.pdf
- Gimpel, A., Stelzenmüller, V., Töpsch, S., Brigolin, D., Galparsoro, I., Gubbins, M., Marbà, N., et al. 2017. AquaSpace tool to support MSP. Thünen Institute, Hamburg and AquaSpace project (H2020 no. 633476), Oban. Deliverable 5.3. Pdf obtainable from http://www.aquaspace-h2020.eu/wp-content/uploads/2017/10/D3.3_AquaSpace_tool_to_support_MSP_tool_manual_2nd_version.pdf
- Gimpel, A., Stelzenmüller, V., Töpsch, S., Galparsoro, I., Gubbins, M., Miller, D., et al. 2018. A GIS-based tool for an integrated assessment of spatial planning trade-offs with aquaculture. Science of the Total Environment. DOI 10.1016/j.scitotenv.2018.01.133
- Gimpel, A., Stelzenmüller, V., Töpsch, S. et al. In prep. The AquaSpace tool. Experiences, key issues, short comings
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- Stelzenmüller, Vanessa, et al. 2016. Monitoring and evaluation of spatially managed areas: a generic framework for implementation of ecosystem based marine management its application. Marine Policy. 27. pp. 145-154.
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- WOR 2013. World Ocean Review. http://worldoceanreview.com/en/wor-2/aquaculture/portals-provider-for-the-world/

Good luck!

URL AquaSpace tool:
https://gdi.thuenen.de/geoserver/sf/www/aqspce.html

„Easy to understand"- MSP brochure ; Baltic Sea Plan (WWF)

Supplementary Information - A

	OID	USE_A	USE_B	CONFLICT_S	SAFETY_BUF	COMBINATIO	GEOMETRY
	0	Aquaculture	Aquaculture finfish	1	0	01	PG
	1	Aquaculture	Aquaculture shellfish	1	0	02	PG
	2	Aquaculture	Platform	6	0	03	PT
	3	Aquaculture	Cable	6	0	04	PL
	4	Aquaculture	Pipeline	0	0	05	PL
	5	Aquaculture	Sediment extraction	6	0	06	PG
	6	Aquaculture	Shipping	5	0	07	PG
	7	Aquaculture	Waste disposal	6	0	08	PT
	8	Aquaculture	Policy Management	6	0	09	PG
	9	Aquaculture	Ocean energy	6	0	10	PG
	10	Aquaculture	Fisheries q3	0	0	11	PG
	11	Aquaculture	Fisheries	0	0	12	PG
	12	Aquaculture	Tourism	3	0	13	PG

Supplementary Information - B

	OID	NAME	PARAMETER	UNIT	VALUE
	0	ui1	Investment equipment (per cage/trestle/longline)	Euro	18875,72
	1	ui2	Other investments (excl. Equipment, land facilities and properties)	Euro	253650
	2	ui3	Investment land facilities	Euro	0
	3	ui4	Investment property	Euro	0
	4	ui5	Market value culture species per ton	Euro/tons	650
	5	ui6	Annual expenditure on wages/salaries	Euro	174000
	6	ui7	Annual intermediate costs (variable, e.g. juveniles/seeds/food)	Euro	35,17
	7	ui8	Annual rate on capital resources (e.g. 1%=0,01)	%	0
	8	ui9	Annual intermediate costs (fixed, e.g. insurance/maintenance and repair ship)	Euro	145265
	9	AER	Interest rates (e.g. 1%=0,01)	%	0
	10	ui10	Other costs (variable)	Euro	3500
	11	ui11	Other costs (fixed)	Euro	29500
	12	ui12	Average no. of days at sea/culture site	days	240
	13	ID	Induced direct impact multiplier (e.g. 1%=0,01)	%	0,49
	14	II	Induced indirect impact multiplier (e.g. 1%=0,01)	%	0,9
	15	OM	Output multiplier (e.g. 1%=0,01)	%	1,94
	16	IM	Income multiplier (e.g. 1%=0,01)	%	0,28
	17	IE	Income effects (e.g. 1%=0,01)	%	0,51
	18	ui13	Average fuel costs	Euro/km	4,58

Supplementary Information - C

Description	Unit	Quantity
Production cycle	years	1
Production density	tons/m³/ha	42
Cage size/area	m³/ha	0,34
Production quantity	tons	420

For more information about
the AquaSpace CPD Course
and spatial planning toolbox,
visit our website:

www.aquaspace-h2020.eu

Horizon 2020

The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.

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Appendix – Presentation Content

Topic 6: Tools – Geographical Information Systems

AquaSpace

CPD Course

PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 6: Geographic Information Systems

David Miller, Chen Wang, Gillian Donaldson-Selby,
Dave Miller, Margaret McKeen
James Hutton Institute
Antje Gimpel, Thünen-Institut

Horizon 2020

- The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 923476.

Definitions

- The term Geographic Information Systems (GIS) is often interpreted as different things.
- Distinctions are made between the following three …
- Geographic Information System (GIS)
  - a **framework** for gathering, managing, and analyzing data. (Source, ESRI)
- Spatial Analysis
  - extracts or creates new information from **spatial** data (Source, ESRI)
- Cartography
  - the discipline dealing with the conception, production, dissemination and study of **maps** (Source, International Cartographic Association)

Purposes

Examples applications in relation to aquaculture …

- Geographic Information Systems –
  - Bringing together data on natural resources, protected areas, transport routes, model output datasets
- Spatial analysis -
  - Deriving visibility of fish cages from tourist viewpoints
  - Measuring distance between features (e.g. coast and aquaculture site)
  - Quantifying number of fish cages within a defined area
- Cartography -
  - Producing maps of areas suitable for aquaculture development

Map Projections

- Fundamental to handling GIS data is use of correct map projection
  - Differences between two projections can be seen below

Albers Map Projection

Mercator Map Projection

- Note: If data are in the wrong projections the analysis will produce false results (e.g. features that should overlap will not)

Further reading on map projections:
http://geoawesomeness.com/5-tools-will-let-master-map-projections/

Scale and Resolution

- Fundamental concepts are scale and resolution
- Map scale refers to the relationship (or ratio) between distance on a map and the corresponding distance on the ground (Source, Geoscience Australia)

[Note, in cartography …
Large scale = greater detail; Small scale = lower detail.
In other disciplines, the terms are used the opposite way around]

- Resolution refers to the detail with which a map depicts the location and shape of geographic features (source, ESRI)

Data

- What data do you need for the task?
  - What should it represent? (e.g. topography, vegetation, etc.)
  - What is the relevant scale?
  - What is the relevant spatial resolution?
  - Should it represent a moment in time or change?
- Are the data available for the entire area of interest?
- Are the data accessible? (i.e. public, confidential)
- What are the limitations? (e.g. dissemination, licencing)
- Does the format of the data suit the tool? (e.g. raster, vector, TIN)
- What is the cost?

Data Structures

Data Structures

- Geographic features or elements are represented in one or more of different data structures:
  - Raster, Vector, Triangulated Irregular Network, Object-based (see next slide for examples)

Data Formats

- Data are held in one of many different formats
- Many are proprietary; conversions are possible between most, but not always
  - Example formats
    - Image — JPG, PNG,
    - Raster — ESRI GRID, IMAGE (Erdas Imagine)
    - Polygon, lines — Shapefile (.shp, .shx etc.), DXF

Data Structures

- Most common data structures (raster, points)

Raster – Imagery (e.g. satellite, aerial), scanned maps, elevation

Scanned map used as backdrop (original, 1:250,000)

Individual fish cages

Points – Features too small for their areas to be relevant to purpose of the application (e.g. building, tree, fish cage, mooring buoy)

Fields in the database of points features (e.g. fish cages in an aquaculture development)

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Data Structures

- Most common data structures (polygons, lines)

Polygons – Features with areal extent meaningful in context of the application (e.g. designated area, lake, forest, extent of fish farm consent, fish cage)

National Scenic Area (shaded blue)

Fields in database of feature

Lines – Physical features that are linear (e.g. roads, fences, communication cables), or representations of concepts (e.g. ferry route, navigation channel)

Data

- What data do you need for the task?
  - What should it represent? (e.g. topography, vegetation, etc.)
  - What is the relevant scale?
  - What is the relevant spatial resolution?
  - Should it represent a moment in time or change?
- Are the data available for the entire area of interest?
- Are the data accessible? (i.e. public, confidential)
- What are the limitations? (e.g. dissemination, licencing)
- Does the format of the data suit the tool? (e.g. raster, vector, TIN)
- What is the cost?

Databases

- Underpinning a GIS is an attribute database (e.g. Relational, Object Oriented)
- Database holds data on individual features (e.g. on each fish cage, designated area)

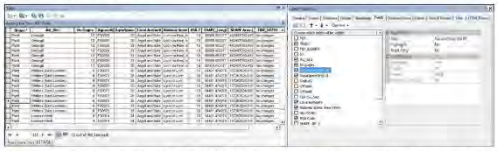


Table – Data for each field in database of attributes (e.g. of fish cages, with links data on landscape designations)

Fields – Headings for which data are held (e.g. area, length, title, reference number)

Data and Information

- Example sources of spatial data and information, for Scotland, relevant to:
  - environmental impact assessments
  - spatial planning

Scotland's Environment Web: Aquaculture site

Scotland's Aquaculture map (online)

Scottish Natural Heritage (e.g. Designated areas)

GIS Software

- Choose software to fit the purpose
- Numerous packages with differences including:
  - Functionality (e.g. strengths in handling certain types of data – raster processing, polygons, etc.)
  - Target applications (e.g. utility management, environmental management, cartography)
  - Costs and licencing varies
  - Some are Open Source (e.g. QGIS; GRASS)

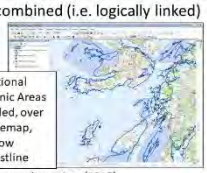
(Logos courtesy of ERSI, MapInfo, QGIS, GRASS)

Functions

- Displaying multiple datasets
  - Graphical overlay
  - Datasets overlaid in sequence for the desired visual message
  - Datasets themselves are not combined (i.e. logically linked)

Datasets in display in same order as menu, top to bottom

- Aquaculture sites (2017)
- Overlaid on coastline
- Overlaid on basemap



National Scenic Areas added, over basemap, below coastline

- Aquaculture sites (2017)
- Overlaid on National Scenic Areas Designation
- Overlaid on coastline
- Overlaid on basemap

Location:
Case Study Area, Argyll and Bute, UK

Functions

- The key strength of GIS-based tools is their use in answering questions of 'what is where?' and 'what is where compared to …?'
- Two of the basic capabilities in GIS packages are:

Query
On-screen query of individual features
Entry in the fish cage database

Measurement
Result c.179 m
Measure distance from nearest fish cage to jetty

Functions

- Buffer – Area around feature or type of features of interest

Buffer 1 km from coastline

Coastline

- Key user controlled settings –
  - the type of feature (e.g. coastline)
  - distance from the feature (e.g. 1 km)
  - Individual or grouped features (e.g. all islands or individual islands)

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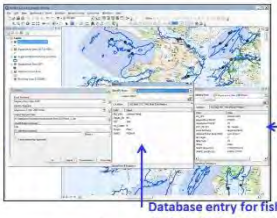
Appendix – Presentation Content

Functions

- Combining datasets
  - Topological overlay (e.g. ArcGIS function: Identity)
  - Multiple datasets combined into a new dataset

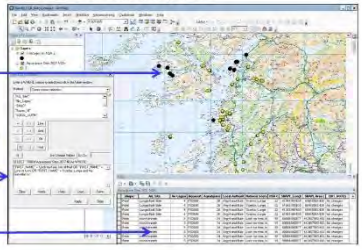


Location:
Case Study Area, Argyll and Bute, UK

Map images: Ordnance Survey, (c) Crown Copyright and database right (2017). All rights reserved. The James Hutton Institute. Ordnance Survey Licence Number: 100019294

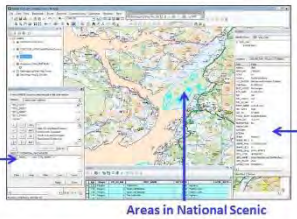
Feature Selection

- Select features based upon a user specified criteria
  - e.g. to identify the number of fish cages within any National Scenic Areas in the case study area



Functions

- Combining datasets
  - Topological overlay (e.g. ArcGIS function: Union)
  - Multiple datasets combined into a new dataset, of polygons



Location:
Case Study Area, Argyll and Bute, UK

Map images: Ordnance Survey, (c) Crown Copyright and database right (2017). All rights reserved. The James Hutton Institute. Ordnance Survey Licence Number: 100019294
cSAC, Joint Nature Conservation Committee and Scottish Natural Heritage

Example Analysis: Mapping and Integrating Aquaculture Indicators

Purpose

- Identify potential areas of suitability for aquaculture development
- Geographic Information System-based spatial planning tools

- Spatially explicit and integrated assessment of indicators : Economic, environmental, inter-sectorial and socio-cultural risk

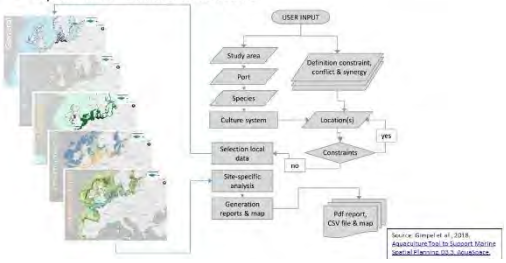
Source: Gimpel et al., 2018; AquaSpace D3.3, for more details, and masters Course Module 5

Mapping and Integrating Aquaculture Indicators

- Tool provided as an Add-in to ArcGIS
- Example application in south-east North Sea

Analysis: AquaSpace Tool

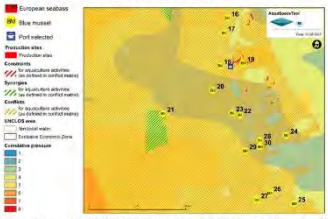
- Inputs (e.g. study area, culture species and system, constraints, conflicts)
- Aquaculture locations to be tested



Source: Gimpel et al., 2018. Aquaculture Tool to Support Marine Spatial Planning D3.3. AquaSpace.

Analysis: AquaSpace Tool

- Example output map for blue mussel
- Site offshore of Hörnum/Sylt, Germany

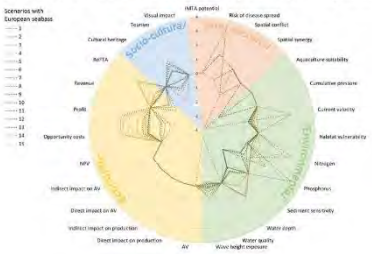


- Areas of constraint, synergy and conflict, management boundaries, areas of aquaculture production
- Cumulative pressure map as background map for map output

Analysis: AquaSpace Tool

Output data for creating graphic or tabular representation

e.g. European seabass - spatially explicit performance of inter-sectorial, environmental, economic and socio-cultural indicators for 15 different aquaculture planning scenarios



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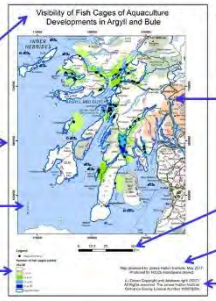
Cartography

- Aim: Production of a high quality map output
- Key components labelled below



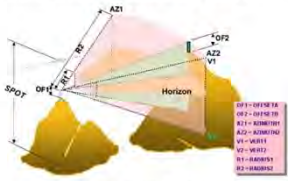
Visibility Analysis

Function What can be seen from where?

Application How many fish cages can be seen from where?

Data inputs:

- Digital Elevation Model
- Coordinates of view point(s), height of observer above the ground
- Height above the ground (sea) of target features (e.g. height of fish cage or feeder system)



Schematic representation of visibility calculation as implemented in ArcGIS (Source: ESRI)

Images: Courtesy of ESRI

Example Application: Seascapes

Context

- Strategic Guidelines for the sustainable development of EU aquaculture (European Commission 2013)
- Environmental Impact Assessment Directive (85/337/EEC)

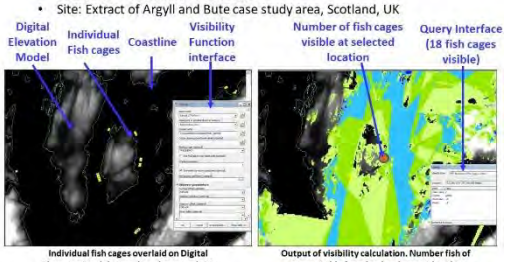
One aim …

"The identification of the most suitable areas for freshwater aquaculture will help expanding production while enhancing landscapes, habitats and biodiversity protection."

- Landscape and seascape is one key factor when considering aquaculture developments
- Guidance on landscape issues is provided on aquaculture development (e.g. Scotland)

Methods: Visibility of Fish Cages

- Calculation of visibility of fish cages
- Site: Extract of Argyll and Bute case study area, Scotland, UK

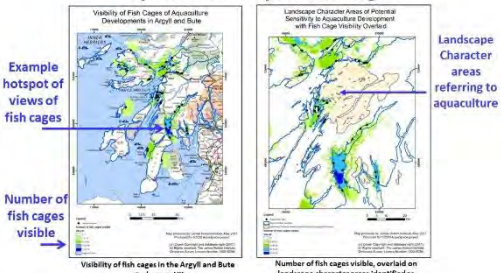


Individual fish cages overlaid on Digital Elevation Model. Coastline shown and GIS visibility function interface

Output of visibility calculation. Number fish of cages visible from land and sea within the extract of the case study area

Map images: Ordnance Survey, (c) Crown Copyright and database right (2017). All Rights reserved The James Hutton Institute. Ordnance Survey License Number 100018294

Outputs: Visibility of Fish Cages



Visibility of fish cages in the Argyll and Bute study area, UK

Number of fish cages visible, overlaid on landscape character areas identified as sensitive to aquaculture related development

For background information see: Gimpel et al. (2018) A GIS-based tool for an integrated assessment of spatial planning trade-offs. The AquaSpace tool. Science of the Total Environment

Landscape Context for Aquaculture

- Existing uses of land and sea (e.g. woodland)
- Context of landscape characteristics (e.g. topographic scale, openness, sense of place)
- Aquaculture associated with **Disturbance** and **reduced Naturalness (i.e. negative)**
- In places, association with **Visual Complexity** and **Stewardship (i.e. positive)**
- Aquaculture is only one element of change in uses of land and sea

Aquaculture and Seascapes: Conclusions

- Landscape concepts of **Good stewardship, naturalness, coherence** and **visual complexity** are associated with positive preferences of aquaculture in seascapes
- **Poor stewardship, incoherence** and **reduced naturalness** are associated with negative preferences
- In engagement activities, areas avoided were close to leisure use (e.g. marinas), historic features (e.g. castles), housing, and areas perceived as **'remote', 'wild' or 'natural'**
- In such areas, development was considered intrusive
- Aquaculture associated with some types of seascapes by residents in areas without such developments [limited data]

Emerging Uses for GIS

- Public collection and publishing of environmental data (citizen science), often via Apps on mobile devices
- Public participation in planning, e.g. submission of information identifying the Main Issues in the development of public plans (e.g. local development plans in Scotland)
- Web-mapping services, providing spatial data through online and mobile mechanisms

Scotland's Aquaculture Map: Oban and Firth of Lorne
http://aquaculture.scotland.gov.uk/map/map.aspx

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Appendix – Presentation Content

Further Reading

- General introduction
  - Heywood, I., Cornelius, S. and Carver, S. (2011) An Introduction to Geographical Information Systems, Prentice Hall 4th Edition, pp. 480.
- Senior managers and technology specialists
  - Tomlinson, R. (2013) Thinking About GIS: Geographic Information System Planning for Managers. 5th Edition. ESRI.
- ArcGIS desktop software
  - www.esri.com/software/arcgis/arcgis-for-desktop
- ArcGIS Online Support Site
  - http://support.esri.com

Video Tutorials

- The following is a short list of snippets uploaded to www.youtube.com which contain demonstrations of how to use some of the functionality of ArcGIS

University of Toronto, Youtube channel of Don Boyes. Example videos of GIS:

- Working in ArcMap (15mins) www.youtube.com/watch?v=zlYHu60Z_ZQ
- Digitising in ArcMap (14mins) www.youtube.com/watch?v=YYwhX-jhthk
- Vector Buffers in ArcMap (5mins) www.youtube.com/watch?v=PdRvCYMKQBk
- Selecting features in ArcMap (6mins) www.youtube.com/watch?v=9rTN710KLfw

AquaSpace GIS Tools

- Examples of use of Geographic information Systems in aquaculture in the AquaSpace Toolbox:
  - Aquaculture Planning Decisions Support Systems
  - AquaSpace Tool (Arc GIS add-in)
  - Bluefarm 2 (QGIS add-in)
  - SISAQUA (GIS Web tool derived from AkavaVIS)
  - Visibility Analysis (in ArcGIS)

Acknowledgements

- **Materials**
  - James Hutton Institute: David Miller, Margaret McKeen, Dave Miller, Chen Wang, Gillian Donaldson-Selby
  - Thünen-Institut: Antje Gimpel, Vanessa Stelzenmueller
- **Data**
  - Ordnance Survey, (c) Crown Copyright and database right (2017). All Rights reserved. The James Hutton Institute. Ordnance Survey Licence Number 100019294 for raster map images on slides 7, 8, 13, 14, 15, 16, 17, 18, 24, 27, 28.
- **Graphics**
  - ESRI, www.esri.com, Slide 25
- **Video links**
  - Don Boyes, University of Toronto

For more information about the AquaSpace CPD Course and spatial planning toolbox, visit our website:
www.aquaspace-h2020.eu

Horizon 2020

The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.

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Appendix – Presentation Content

Topic 7: Tools - Remote Sensing for Marine Spatial Planning

AquaSpace

CPD Course

PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 7: Remote Sensing for Marine Spatial Planning: useful for aquaculture site selection

Sónia Cristina, Bruno Fragoso, John Icely
Sagremarisco Lda.

Horizon 2020

- The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 923476.

Content

- What is Remote Sensing
- Example of a satellite and sensors
- Remote sensing applications
- Advantages of Remote Sensing for MSP - to assess the potential aquaculture sites
- Satellite missions – sensors, products and contributions for the selection of aquaculture sites
- Case studies:
  - Algarve coast;
  - North Adriatic Sea;
  - The Mont Saint-Michel bay;
  - Eastern Passage, NS (Halifax Harbour)
- SNAP software - to improve the application of Earth observations for marine aquaculture
  - Exercise 1. Install the SNAP software
  - Exercise 2. Extract satellite images from one of the following sites
  - Exercise 3. Open and extraction of data (product) from the OLCI satellite images useful for selection of aquaculture sites.

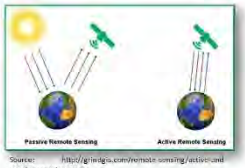
References

What is Remote Sensing?

Remote sensing is the science of obtaining information about objects or areas remotely, typically from aircraft or satellites. Remote sensors collect data by detecting the energy that is reflected from Earth either passively or actively.

Passive sensors respond to external stimuli. They record natural energy that is reflected or emitted from the Earth's surface. The most common source of radiation detected by passive sensors is reflected sunlight.

Active sensors use internal stimuli to collect data about Earth. For example, a laser remote sensing system projects a laser beam onto the Earth's surface and measures the time that it takes for the beam to reflect back to its sensor.



Source: http://gringis.com/remote-sensing/active-and-passive-remote-sensing

Example of satellite and sensors

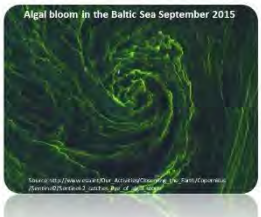
The **Sentinel-3 A** was launched on 16 February 2016 and carries sensors that can provide data useful for aquaculture applications.

Source: https://sentinel.esa.int/web/sentinel/missions/sentinel-3/instrument-payload

Remote Sensing applications

Remote sensing has a wide range of applications:

- ✓ primary production;
- ✓ occurrence of algal blooms;
- ✓ physical oceanography;
- ✓ fisheries biology ;
- ✓ sediment transport;
- ✓ ocean modelling;
- ✓ coastal management.



Advantages of the use of Remote Sensing for MSP

to assess the potential aquaculture sites

- Low-cost way for cost-effective planning, management and rational exploitation of marine resources;
- Synoptic scale;
- Retrieve products that can be interpreted in terms of the:
  - total chlorophyll *a* concentrations (TChl*a*);
  - suspended particulate matter (SPM);
  - coloured dissolved organic matter (CDOM);
  - sea surface temperature (SST).

Satellite missions – sensors, products and contributions to the selection of aquaculture sites

Satellite	Sensor	Product	Contribution
Envisat	Medium Resolution Imaging Spectrometer (MERIS)	•Total Chlorophylla concentration (TChla); •Total suspended matter concentration (TSM); •Colour dissolved organic matter (CDOM)	These parameters for seawater affect the conditions of fish growth, determine the success or failure of an aquaculture activity, contribute to feasibility studies for implementing aquaculture facilities. •identifying suitable sites ; •issuing warnings on potential water quality threats (e.g. pollution and harmful algal blooms) • monitoring the environmental impact of aquacultures
Sentinel - 3 A	Ocean and Land Colour Instrument (OLCI)		
Aqua	Moderate Resolution Imaging Spectroradiometer (MODIS)		
Envisat	Advanced Along-Track Scanning Radiometer (AATSR)	Sea surface temperature (SST)	Influences the variation of many other physical and biochemical seawater properties as well as the entire life cycle in terms of fish size, metabolism, sex determination, growth and, in the natural environment, the population structure
Sentinel - 3 A	Sea and Land Surface Temperature Radiometer (SLSTR)		
Sentinel-1	High resolution Synthetic Aperture Radar (SAR)	•Ocean Wind field (OWI) ; •Ocean Swell spectra (OSW) ;	Detects and maps aquaculture in coastal area at a very large scale.
Sentinel - 2	MultiSpectral Instrument (MSI)	•Total Chlorophylla concentration (TChla); •Total suspended matter concentration (TSM).	Providing high spatial resolution optical images of water properties

Case Studies-Algarve Coast

The use of **Sentinel 2** images providing high-spatial resolution optical images

1-8. Current offshore aquaculture concessions along the Algarve coast of Portugal

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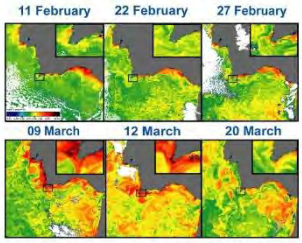
Appendix – Presentation Content

Case Studies-Algarve Coast

Detection of Algal Blooms

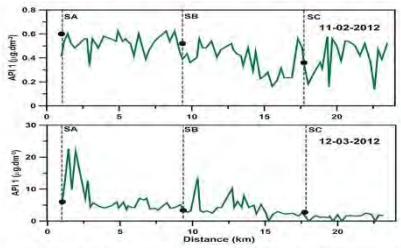


Food for shellfish but potential for HABs as well

Source: Cristina, S., Icely, J., Goela, P.C., Delilelis, T.A., Newton, A., 2015. Using remote sensing as a support to the implementation of the European Marine Strategy Framework Directive in SW Portugal, Continental Shelf Research, 108, 169-177.

Case Studies-Algarve Coast

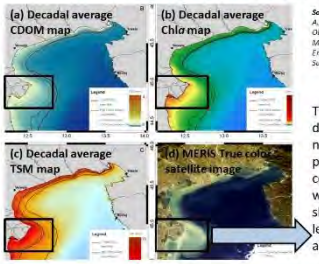
Transects, extending perpendicular from the coast up to 24 km offshore



Days with different TChla concentrations. Where the MERIS Algal Pigment Index 1 (API1) is equivalent to the TChla green line and the dots are the *in situ* optical weighted TChla.

Case Studies-North Adriatic Sea

Water properties limits, which defined the area to be considered not viable for aquaculture

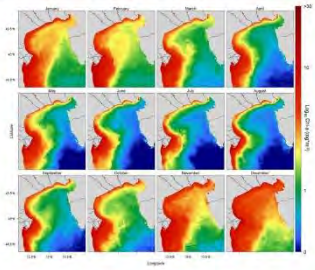


Source: Valentini, E., Filipponi, F., Nguyen Xuan, A., Passarelli, F. M., Taramelli, A. (2016). Earth Observation for Maritime Spatial Planning: Measuring, Observing and Modeling Marine Environment to Assess Potential Aquaculture. Sustainability 8(6):519

This area show the Po river discharge; where the nutrients enrich the phytoplankton (high concentration of Chla **(d)**) which are food for shellfish, but render water less suitable for finfish aquaculture.

Case Studies-North Adriatic Sea

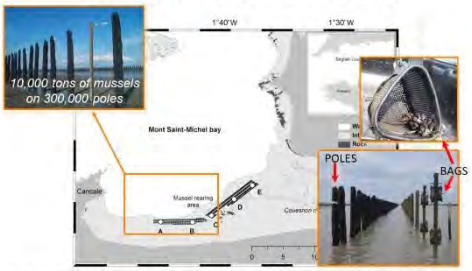
Variability of the Chlorophyll *a* concentration between 2002–2012 (monthly averages)



Northern Adriatic Sea: **eutrophic nearshore** and **oligotrophic offshore**

Source: Valentini, E., Filipponi, F., Nguyen Xuan, A., Passarelli, F. M., Taramelli, A. (2016). Earth Observation for Maritime Spatial Planning: Measuring, Observing and Modeling Marine Environment to Assess Potential Aquaculture. Sustainability 8(6):519

Case Study-Mont Saint-Michel bay

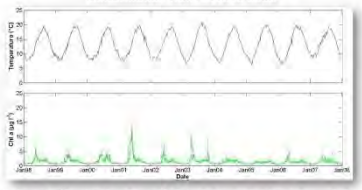


Source: Thomas, Y., Mazurié J., Alunno-Bruscia, M., Bacher C., Bougel, J-F., Gohin, F., Pouvreau,S., Struski, C. (2011). Modelling spatio-temporal variability of Mytilus edulis (L.) growth by forcing a dynamic energy budget model with satellite-derived environmental data. Journal of Sea Research. 66 (4), 308–317.

Case Study-Mont Saint-Michel bay

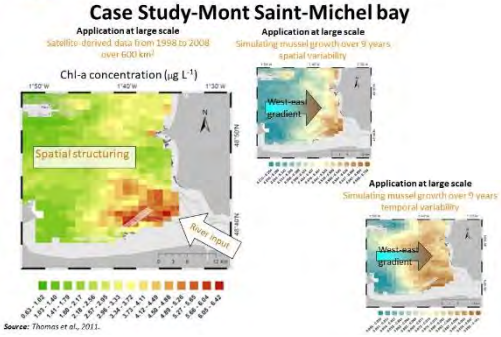
To calibrate/validate the DEB model for blue mussel *Mytilus edulis* by using satellite Chla and temperature as forcing variables

Satellite derived mean Temperature and Chl-a concentration from 1998 to 2008



Source: Thomas,Y., Mazurié J., Alunno-Bruscia, M., Bacher C., Bougel, J-F., Gohin, F., Pouvreau,S., Struski, C. (2011). Modelling spatio-temporal variability of Mytilus edulis (L.) growth by forcing a dynamic energy budget model with satellite-derived environmental data. Journal of Sea Research. 66 (4), 308–317.

Case Study-Mont Saint-Michel bay



Source: Thomas et al., 2011.

Case Study-Eastern Passage, NS (Halifax Harbour)

Low-altitude aerial photography

Source: Jon Grant. The Importance of Spatial Perspective in Aquaculture Management. NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, Dept. of Oceanography, Dalhousie University

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Case Study-Eastern Passage, NS (Halifax Harbour)

Source: Jon Grant. The Importance of Spatial Perspective in Aquaculture Management. NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, Dept. of Oceanography, Dalhousie University

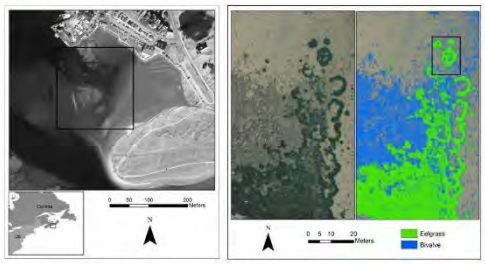
Case Study-Eastern Passage, NS (Halifax Harbour)

Aerial images with different colour schemes

- RGB
- NGB

Source: Jon Grant. The Importance of Spatial Perspective in Aquaculture Management. NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, Dept. of Oceanography, Dalhousie University

Case Study-Eastern Passage, NS (Halifax Harbour)



Source: Jon Grant. The Importance of Spatial Perspective in Aquaculture Management. NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, Dept. of Oceanography, Dalhousie University

SNAP software - to explore the earth observation for marine aquaculture

The Sentinel Application Platform (SNAP) reunites all Sentinel Toolboxes in order to offer the most complex platform for this mission.

The basic function includes:

- **opening a product (or data)** - within the Sentinel Toolbox, a product can contain meta-data, geo-coding information, tie-point grids and bands. All band raster datasets within a product have the same pixel resolution and share the same geo-coding;
- **exploring the product components such as bands** – the bands contain a spectral or geophysical raster dataset of a product. The band's sample values are usually the measurements of a sensor;
- **masks** – marks a regions of raster dataset. Masks can be derived from an expressions, a value range or a geometry;
- and **tie point grids** - geo-coding of data products in satellite co-ordinates is stored in so called tie-point grid datasets.

Navigation tools and pixel information functionality also represents some of the basic capabilities. The satellite images can be opened and the data can be extracted with this software.

SNAP software - to explore the earth observation for marine aquaculture

Exercise 1. Install the SNAP software from the: http://step.esa.int/main/toolboxes/snap/

To install SNAP, click/double-click the installer and follow the on-screen instructions to install SNAP.

SNAP software - to explore the earth observation for marine aquaculture

Exercise 2. Extract satellite images from one of the following sites:

MODIS: https://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am

MERIS: http://www.odesa-info.eu/info/ ***(Need registration)***

Sentinel 1 and 2: https://scihub.copernicus.eu/dhus/#/home ***(Need registration)***

Sentinel 3: https://coda.eumetsat.int/#/home ***(Need registration)***

SNAP software - to explore the earth observation for marine aquaculture

Exercise 3. Open and extract data (product) from the OLCI satellite images useful for selection of aquaculture sites.

Exercise 3.1 Open data (product) from the Sentinel-3/OLCI satellite image.

Sentinel-3 products are provided not as single files but as a collection of files contained within a folder. The folder name is the actual product name, ending on **.SEN3**. Each folder contains a metadata file named **xfdumanifest.xml** and at least one netcdf-file. Each netcdf-file contains a subset of a Sentinel-3 product's content.

You can also open single netcdf-files. Just keep in mind that these will only show a part of the Sentinel-3 product and, in most cases, lack a geocoding.

Product type	Description	Level
OL_1_ERR___	Full Resolution top of atmosphere radiance	Level 1
OL_1_EFR___	Reduced resolution top of atmosphere radiance	Level 1
OL_1_RAC___	Dark offset and gain coefficients from calibration calibration	Level 1
OL_1_SPC___	Wavelength characterisation time spectral calibration	Level 1
OL_2_WFR___	Full Resolution Water & Atmosphere geophysical products	Level 2
OL_2_LFR___	Full Resolution Land & Atmosphere geophysical products	Level 2
OL_2_WRR___	Reduced resolution Water & Atmospheric geophysical products	Level 2
OL_2_LRR___	Reduced resolution Land & Atmosphere geophysical products	Level 2

Main Product	Sub-product Parameters
OL_1_ERR___	ERR radiance
OL_1_EFR___	EFR radiance
OL_2_WFR___	• Total Backscattering coefficient • Total Absorption coefficient • Phytoplankton Absorption coefficient • Adult Chlorophyll Fluorescence • Total Suspended Matter Concentration
OL_2_WRR___	• Total Backscattering coefficient • Total Absorption coefficient • Phytoplankton Absorption coefficient • Adult Chlorophyll Fluorescence • Total Suspended Matter Concentration • Total Chlorophyll Pigment Concentration
OL_2_LFR___	• Global Vegetation Index • Total Leaf Chlorophyll Content
OL_2_LRR___	• Global Vegetation Index • Total Leaf Chlorophyll Content

SNAP software - to explore the earth observation for marine aquaculture

Exercise 3. Open and extract data (product) from the OLCI satellite images useful for selection of aquaculture sites.

Exercise 3.1 Open data (product) from the Sentinel-3/OLCI satellite image.

To open a Sentinel-3 product you can:

- Choose "File->Open Product", navigate to the xfdumanifest.xml file and click "Open Product";
- Drag and drop the whole folder into the "Products View";
- Drag and drop the xfdumanifest.xml-file into the "Products View";
- Choose "File->Import->Optical Sensors ->SENTINEL-3", navigate to the xfdumanifest.xml file and click "Open Product".

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SNAP software - to explore the earth observation for marine aquaculture

Exercise 3. Open and extraction of data (product) from the OLCI satellite images useful for selection of aquaculture sites.

Exercise 3.2 Extraction of data (product) from the Sentinel -3/OLCI satellite image.

1. Choose the coordinates that you would like to extract the data from the satellite image for that go to pin manager.

2. You can extract the data using:
•the **pin manager** where you can just select a specific product or all the products but here just extract a single pixel;
•or you can choose "**Raster Menu->Open Product", click "Export" and then click on "Extract Pixel Values**" where you can choose what is the window size of the matrix that you would like to extract depending of the system that you are studying.

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  - from Dr Aline Gangery (Ifremer) for Mont-Saint Michel Bay;
  - Professor Jon Grant (Dalhousie University) for Halifax Harbour.

For more information about the AquaSpace CPD Course and spatial planning toolbox, visit our website:
www.aquaspace-h2020.eu

Horizon 2020

The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 633476.

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Appendix – Presentation Content

Topic 8: Tools - Visualisation issues and tools

AquaSpace

Masters Module
PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 8: Visualisation Issues and Tools

David Miller, Gillian Donaldson-Selby,
Chen Wang
James Hutton Institute

Horizon 2020

- The materials used here have been assembled as part of the AquaSpace project (Ecosystem Approach to making Space for Aquaculture, http://aquaspace-h2020.eu) and has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement n° 923476.

Content

- Strategic Guidelines for the sustainable development of EU aquaculture (European Commission, 2013)
- **One aim …**
  Identifying areas which are suitable for aquaculture to expand production whilst enhancing landscapes, habitats and biodiversity protection
- Landscape and seascape is a key factor in considering aquaculture development, for which countries provide guidance (e.g. Scotland)

Context: Participation

- Aarhus Convention (United Nations Economic Commission for Europe, 1998)
- The EU and Member States are signatories
  - The right to participate
  - The right to information
  - The right to justice

Right to participate in decision-making on decisions to permit to participate in decision-making on decision to permit activities that may have a significant effect on the environment and during the preparation of plans, programmes, policies and legislation relating to the environment.

Context: Participation

- European Landscape Convention (Council of Europe, 2000)
- Most EU Member States are signatories

EUROPEAN LANDSCAPE CONVENTION
CONVENTION EUROPÉENNE DU PAYSAGE

The landscape …

… has an important public interest role in cultural, ecological, environmental and social fields

… constitutes a resource favourable to economic activity

… whose protection, management and planning can contribute to job creation;

… contributes to the formation of local cultures is a basic component of the European natural and cultural heritage

Landscape Concepts

- Theory of landscape visual concepts (Tveit et al., 2006; Ode and Miller, 2011)
- Framework for interpreting and testing public preferences with respect to characteristics of landscapes and seascapes

Examples of landscape visual concepts

- **Visual scale**
  - openness
- **Imageability**
  - Strong image, genius loci
- **Complexity**
  - Diversity and pattern
- **Naturalness**
  - Perceived naturalness
- **Ephemera**
  - Changes with time of day, season, weather

Concept: Stewardship

- **Stewardship** is a significant landscape characteristic of human preferences for landscapes
- **Stewardship** has characteristics in relation to seascapes

Stewardship - landscape

Concept: Stewardship (seascape)

Signs of use or Non-use (e.g. craft, cages, energy structures)	Shore facilities presence and status (e.g. jetty, marina, boathouse)	Management detail (e.g. infrastructure – buoys, navigation markers)	Waste, rubbish, materials	Activity (e.g. movement, light, sound)	Smell

- Principal indicators – Number of features visible from types of viewpoint (e.g. number of fish cages, feeder unit)

References: Tveit et al., 2006

Definitions

- **3D Model**
  - The representation of an object which has width, depth and height. Such a model need not relate to a specific geographic location (Source: Miller *et al.*, 2016)
- **Scientific Visualisation**
  - Primarily the visualization of three-dimensional phenomena (architectural, meteorological, medical, biological), where emphasis is on realistic rendering of volumes, surfaces, illumination sources, and sometimes a time component (Source: based on Friendly, 2009)
- **Geovisualisation tools**
  - Tools for visual exploration, analysis, synthesis, and presentation of geospatial data (Source: MacEachren and Kraak 2001)

Purposes

- **Design and development**
  - Design components and layout of a development (e.g. aquaculture layout), generally requiring interactive functionality
  - Present the concept and specific development plans to inform the audience
- **Participatory tools**
  - Facilitate community inputs and participation in protection, management and planning of seascapes, generally requiring interactive functionality
- **Tools for awareness raising and training**
  - Enable planning and training by public agencies (e.g. emergency responders)
  - Inform and train those involved in the decision-making process (e.g. elected representatives, advisors)

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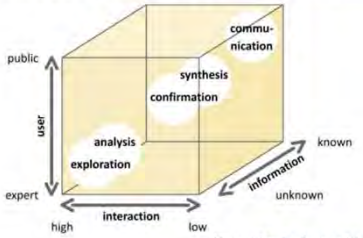
Purposes of Geovisualisation

- The purposes of geovisualisation, from exploration to communication, are illustrated in a "geovisualisation cube"



(Source: MacEarchren and Kraak, 2001)

Model Requirements and Outputs

- What data do you need for the task?
  - What should it represent? (e.g. topography, vegetation, fish tanks, fish, water surface)
  - What is the appropriate level of details?
  - Should it be a still image, movement of the observer, or movement of features?
- Are the data available for the entire area of interest?
- Are the data accessible? (i.e. public, confidential)
- What are the limitations? (e.g. real-time, pre-recorded)
- Does the format of the output suit the purpose? (e.g. video, still image, real-time navigation)
- What is the cost?

Level of Detail

- Level of detail will differ to fit the purpose of the model and representation of the area
- Identification of features at different distances is influenced by weather, lighting, contrast and colour of the feature, feature or the viewer moving, knowledge of what is being observed.
- An example is shown relating to trees and ground vegetation

Verisimilar

Biologically realistic (plants)

Indexed (general taxonomic description)

Generic shape of trees

Symbolic or Schematic

Icon of trees

(Derived from Schroth et al., 2011; Sherman and Craig, 2003)

Visualisation Software

- Choose software to fit the purpose
- Differences between the numerous packages available include:
  - Functionality (e.g. strengths in interactivity, photo-realism)
  - Target applications (e.g. interactive design, visual impact assessment)
  - Costs and licencing varies
  - Some are Open Source (e.g. Google Earth Models, KML formats)

vegaprime octaga VISUAL SOLUTIONS MAYA VISUAL NATURE STUDIO 3

(Logos courtesy of: Presagis Vega Prime, Octaga, Autodesk Maya, Visual Nature Studio, Google Earth)

Hardware

- Match hardware to purpose or use of the visualisations
- Group discussion and experience, and voting on issues:
  - Theatre, large format screen (e.g. 5.5 m wide x 2.25 m tall)
  - Virtual reality model projected onto screen
  - Audience size of c. 16 people
- Individual experience, exploration of seascapes, aquaculture sites, and one-to-one engagement
  - Head Mounted Displays and navigation handset

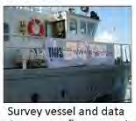
(Photographs: James Hutton Institute)

Creation and Use of VR Model

- Creation of the AquaSpace Virtual Reality Coastal Model

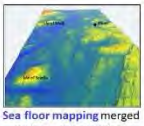
Compilation of spatial databases
- surface and sea floor topography
- uses of land and sea
- natural heritage designations
- aquaculture sites

Representations created at regional, local and site levels in visualisation tools

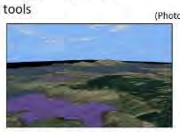


Survey vessel and data capture on seafloor mapping (Source: John Howe, SAMS)

(Photographs below: James Hutton Institute)



Sea floor mapping merged with model of surface terrain

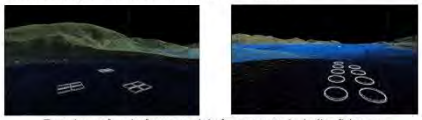


Draping textures from aerial imagery over terrain model and colour shading of the seafloor

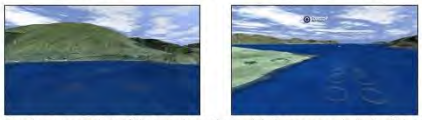
Engagement events and surveys with public audiences

Combine Terrain and Features

- The 3D models of land and sea were transformed into formats useable in virtual reality tools, and individual features added



Two views of a wireframe model of a seascape, including fish cages

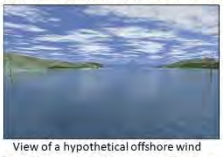


Textured representations of the two views of a model of a seascape, including fish cages

Seascape Characteristics

Ephemeral characteristics are important for the credibility of the visual coherence and interpretation when representing seascapes
- Examples of ephemeral characteristics
  - Movement in natural environment (e.g. waves, clouds moving)
  - Reflections of features off water (e.g. clouds, wind turbines)
  - Shadows (e.g. of wind turbines, changing direction by time of day)
  - Weather (e.g. fog, mist)

Waves and reflections capabilities in the AquaSpace VR Coastal Model



View of a hypothetical offshore wind farm: imagery includes waves, reflections of clouds and wind turbines

View of a set of fish cages in, Loch Linnhe, UK: imagery includes waves and clouds

(Imagery: James Hutton Institute)

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Appendix – Presentation Content

AquaSpace Virtual Reality Coastal Model

- Model represents an area of Loch Linnhe in coastal west Scotland
- Content comprises a single 3D model of the seafloor and surrounding terrain, with textures of land cover, buildings and transport routes
- Represents actual features (e.g. fish cages), and hypothetical siting (aquaculture, tidal and offshore wind renewable energy, leisure craft)

(Photographs: James Hutton Institute)

Virtual Reality Environment

Opportunities

- Provide 'safe space' for a virtual exploration of environments not otherwise accessible

Discuss dimensions of marine renewable energy (wind turbines) with public audience in **AquaSpace VR Coastal Model** in Virtual Landscape Theatre

Audience approaching access platform on offshore wind turbine in **AquaSpace VR Coastal Model** (February 2018)

(Photographs: James Hutton Institute)

AquaSpace Visualisation Tool

Visualisation tool interface

- Easy navigation around model in Virtual Reality environments
- Move observer between preset viewpoints
- Switch between scenarios of sea uses (aquaculture, energy, leisure)
- Addition of new features and move by mouse

AquaSpace Visualisation Tool Interface

Viewing position at from preset viewpoints

Features for audience to select and add to the model

Scenarios of preset features to 'switch on': aquaculture, renewable energy

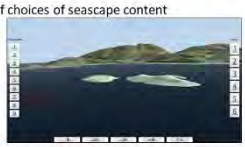
(Imagery: James Hutton Institute)

Seascape Creation

AquaSpace Visualisation Tool functionality enables

- Creation of seascapes by groups or individuals
- Addition, dragging and dropping features in a seascape model
- Recording options for uses of land and sea and reasons for preferences with respect to seascapes
- Discussion of issues and explanations of choices of seascape content

Participant locating features in the AquaSpace VR Coastal Model using Visualisation Tool



Example of locating potential fish farms in shelter of islands (green) and not in open water (red)

(Imagery: James Hutton Institute)

Public Engagement on Shared Issues On & Off-shore

Aims

- Identify shared issues of uses of land and sea, on- and offshore

Method

- Alternative future scenarios for Scotland's coastal environments were presented to audiences from land and marine planning, conservation, land management, the public and schools

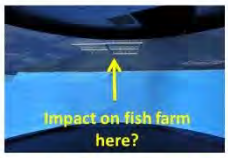
Introduction to geography of the Scottish west coast to young audience

Explore the seafloor of the loch with a public audience

Public Engagement on Shared Issues On & Off-shore

Example issues from public engagement

- Farming and aquaculture are compatible in the character of many coastal landscapes;
- Could there be impacts of woodland expansion on nutrients in sea water and problems for fish farms?



(Imagery: James Hutton Institute, Virtual Landscape Theatre)

Visualisation: Site Level

Aims:

- To raise awareness and understanding of aquaculture
- To elicit issues of concern or interest amongst public audiences

Method:

- 3D model of hypothetical aquaculture development with fish cages, feeder station, feeder pipes and dinghy
- Exploration of 3D model in a virtual reality environment
- Electronic voting and interview of issues arising about aquaculture

View of model content: Hypothetical aquaculture site showing fish cage and dinghy

Handset control and view of model content: Fish in fish cage

(Prototype model courtesy Anders Bae, Norwegian University of Science and Technology ; Imagery: James Hutton Institute)

Visualisation: Site Level

- **Aquaculture topics identified**
  - Significance of feeding stations
  - Feeder pipe infrastructure
  - Requirements for maintenance
- **Seascape issues identified**
  - Movement around site, consistent with good stewardship (i.e. maintenance)
  - Colour/contrast can be incoherent due to reflections and lighting (i.e. also visual complexity concept)
- **Visualisation tool feedback**
  - Easy to use (navigate, interpretation)
  - Easy to understand aquaculture components
  - Easy recognition of feature contents

Audiences exploring aquaculture simulator using Head Mounted Displays

(Photographs: James Hutton Institute)

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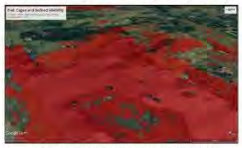
Appendix – Presentation Content

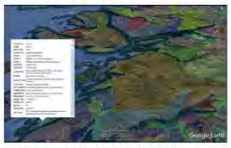
Visualisation: Regional Level

Aims

- To represent landscape characteristics for interpretation an area and comparisons between sites
- To provide information about aquaculture developments (locations of fish cages, feeder units) and derived analysis (e.g. visibility of fish cages)



Google Earth interface: Locations of fish cages (points), and derived data on their visibility (red) (Argyll and Bute, UK)



Google Earth: Querying data on Landscape Character Assessment and designated areas (Argyll and Bute, UK)

(Images: Google Earth)

Visualisation: Regional Level

Aims

- Representation of locations of fish cages and feeder stations
- Hypothetical scenarios of change in number and layout of aquaculture developments for testing public preferences

Alternative layouts of fish cages, presented in Google Earth model

- **Participant responses to changes in layout**
  - Limited recognition of site expansion when: viewed as though standing at the coast, low contrast between cages and background sea or terrain, layout maintains geometry of layout
  - Adverse reaction to expansion when: increase in the field of view occupied by fish cages, and cages recognised

360° Videos

- Presentation of seascapes in video form (i.e. as photographed, not translated through a model)

Strengths

- Seamless capture of views around a point, in 360° horizontal plane
- Portable, low cost, camera and simple image capture

Capturing 360° video: Taynuilt, Loch Etive, UK
Camera: Nikon Keymission 360 on tripod (January 2018)

Limitations

- Imagery sensitive to illumination conditions (e.g. views into sunlight, mist and fog reducing visibility)
- Short camera focal length means limited detail in imagery in middle and far distance

(Photograph: James Hutton Institute)

360° Videos

Display

- Video and audio recorded for 360° panorama, retaining correct geographic orientation of features (i.e. direction of view to north)
- 360° video played on mobile device (e.g. iPad)

Use

- Capture of site (video and sound)
- Use in discussion off-site
- Backdrop for augmented reality models

360° video viewed on mobile device

(Photograph: James Hutton Institute)

Dissemination

- Visualisation tools provide powerful means of communication:
  - Raising public awareness of aquaculture
  - Dissemination of findings
  - Enable access to materials for post-project exploitation

Describing issues of uses of land (e.g. forestry) and sea (e.g. aquaculture) to a public audience, in the Virtual Landscape Theatre (February 2018)

Demonstration and dissemination of findings at Science and the Parliament, Edinburgh, UK (November 2017)

(Photographs: James Hutton Institute)

Principal Findings

Principal findings from research using visualisation tools

- **Positive associations** of aquaculture are where it is in the vicinity of other forms of primary production (e.g. forestry)
- Landscape concepts of **good stewardship, naturalness, coherence** and **visual complexity** are associated with positive preferences of aquaculture in seascapes
- **Poor stewardship, incoherence** and **reduced naturalness** are associated with negative preferences
- In engagement activities, areas avoided were close to leisure use (e.g. marinas), historic features (e.g. castles), housing, and areas perceived as **'remote', 'wild' or 'natural'.**

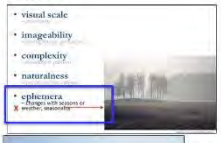
  In such areas, development was considered intrusive

Future Opportunities and Uses

- Virtual Reality hardware, software and uses are evolving rapidly
- **Education**
  - Head Mounted Displays are increasingly available in schools
  - Models relevant to the school curriculum are limited
  - Opportunity to create outputs to link food security, environmental sciences and planning
- **Virtual Reality hardware and software**
  - Retail and public uptake of Augmented and Mixed Reality tools (e.g. Microsoft HoloLens)
- **On-site planning**
  - Augmented and Mixed Reality tools to visualise aquaculture and infrastructure overlaid on video backdrop

Significance of Light?

- Likely significant factors – caveat on findings
- Ephemeral factors: seasonal, weather, shadow, lighting, reflections, viewing directions (e.g. sunrise, sunset)



Illumination of buildings at Oban harbour, UK, May 2012

View to west of sun setting over mountains west of Oban, May 2012

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Visualisation

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- United Nations Economic Commission for Europe, 1998. Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters. United Nations Economic Commission for Europe.

Further Reading

- **General introduction to visualisation**
  - Dykes, J., MacEachren, A.M. and Kraak, M.-J. 2005. *Exploring Geovisualization*. Pergamon, pp. 730.
- **Visualisation for communication of options, change and evaluation**
  - Steinitz, C. 2012. *A Framework for Geodesign: Changing Geography by Design*. ESRI Press, Redlands. CA. pp. 224.
- **Virtual Landscape Theatre**
  - www.hutton.ac.uk/learning/exhibits/vlt
- **Marine Spatial Planning**
  - European Union marine spatial planning Directive and associated documentation https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en

Video Materials

- The following is a short list of videos in which visualisation principles are explained, or applications are demonstrated
- University of Illinois at Urbana-Champaign, Visualisation design rules: www.coursera.org/learn/datavisualization/lecture/4yiGl/2-3-1-tuftes-design-rules
- Aquaculture simulator, Norway www.youtube.com/watch?v=ho6A65PuUDM
- 360° video - Oyster Aquaculture, Chesapeake Bay, USA www.youtube.com/watch?v=N7UXoYGic_M&t=63s

AquaSpace Visualisation Tools

- Examples of use of Visualisation Tools in aquaculture in the AquaSpace Toolbox:
  - Visualisation (Virtual Seascapes)
- Related analysis on the visibility of aquaculture and seascapes is Factsheet:
  - Visibility Analysis (in ArcGIS)

Acknowledgements

- **Materials**
  - James Hutton Institute: David Miller, Chen Wang, Gillian Donaldson-Selby
- **Data**
  - Ordnance Survey, (c) Crown Copyright and database right (2017). All Rights reserved. The James Hutton Institute. Ordnance Survey Licence Number 100019294 for raster map images on slides 14, 15, 16, 17, 18, 19, 20, 21, 22, 25, 26 and 29
  - Google Earth and data suppliers
- **Aquaculture site model**
  - Anders Bøe, Norwegian University of Science and Technology
- **Participants**
  - Thanks to all the participants at the stakeholder, public engagement and dissemination events at which the visualisation tools were tested and used

AquaSpace

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Horizon 2020

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Appendix – Presentation Content

Topic 9: Tools - Social investigation and engagement tools

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PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Unit 9: Social Investigation and Public Engagement Tools

Suzannah-Lynn Billing

SAMS

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Contents

1. Introduction: Social issues related to space
2. Public and Stakeholder Engagement – Why do it?
3. Salmon farming in Scotland
4. Qualitative enquiry; why do people object to or support fish farms?
5. Methods and results
6. How does social licence to operate help us interpret the results?
7. Engagement and social licence to operate
8. Practical applications
9. Benefits and limitations of the qualitative approach and SLO

Introduction: Social issues related to space

- Which should get priority, the fish farm, the forestry operation, or the person who lives in the house overlooking both?
- What extent of disturbance to the environment/ view is 'acceptable' within society?
- Is there a way that different industries, homeowners, and leisure seekers can operate in the same area? If so, what measures need to be taken to make it happen?

Introduction: Social issues related to space

[redacted]

Visual impact is another area of spatial social issues which can influence the growth, or lack thereof, of the aquaculture industry.

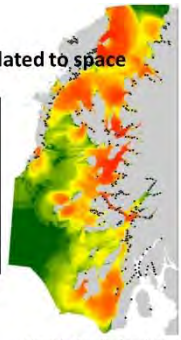


Figure 1. Viewshed analysis. Source: O'Higgins (2017)

Public and Stakeholder Engagement – why do it?

Source: Mitchell and Haas (2011)

Salmon Farming in Scotland

- Approximately 170,000 tonnes produced annually
- Government growth strategy aimed at doubling this figure by 2030
- Provides approximately 2,500 jobs to remote and rural areas
- Biological issues mainly to do with sea lice caused an 11% reduction in production from 2016 to 2017 – but the value of the product increased

Source: The Scottish Government
http://www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/TrendAquaculture

Qualitative enquiry; Why do people object or support fish farms?

"It provides steady jobs for young folk."

"I trust that the SEPA [Scottish Environment Protection Agency] has done their job and therefore have no cause for concern."

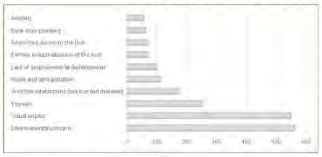
"It's not something I want to see out of my living room window."

"The practice doesn't match the science – when that happens, I will stop objecting"

Number of public comments that were analysed

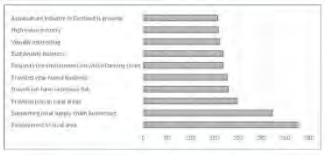
Planning case	Date	Type of comment		Total number of comments
		Objection	Support	
Loch Striven	2012	12	35	48
Loch Etive	2013	589	218	812
Loch Etive	2016	225	183	408
Isle of Shuna	2014	29	17	46
Loch Slapin (pilot)	2014	69	2	71
Total		924	455	1388

Method and Results



Reasons why people *object* to fish farms – environmental and visual impacts are the most cited reason.

Reasons why people *support* fish farms – direct employment and support of other businesses are the most cited.



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How does social licence to operate help us interpret the results?

"The company [SSC] has a sponsorship programme and is willing to take part in and engage with communities."

Good corporate social practice wins support

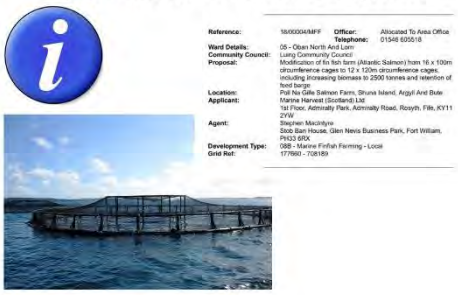
Trust, communication, and involvement are essential for SLO.

"At no stage…has the developer tried to discuss or address the severe impacts with which its plan threaten [Estate]…Dawnfresh admits that [Estate] will suffer the worst impact in terms of the visual intrusion of the farm but the developer has not even bothered to talk to me about this."

Poor corporate social practice creates conflict and objections

Engagement and social licence to operate

Engagement and social licence to operate



Reference:	18/00004/MFF	Officer:	Allocated To Area Office
		Telephone:	01546 605518
Ward Details:	05 - Oban North And Lorn		
Community Council:	Luing Community Council		
Proposal:	Modification of fin fish farm (Atlantic Salmon) from 16 x 100m circumference cages to 12 x 120m circumference cages, including increasing biomass to 2500 tonnes and retention of feed barge		
Location:	Poll Na Gille Salmon Farm, Shuna Island, Argyll And Bute		
Applicant:	Marine Harvest (Scotland) Ltd 1st Floor, Admiralty Park, Admiralty Road, Rosyth, Fife, KY11 2YW		
Agent:	Stephen Macintyre Blob Ban House, Glen Nevis Business Park, Fort William, PH33 6RX		
Development Type:	088 - Marine Finfish Farming - Local		
Grid Ref:	177960 - 708189		

Practical applications

Effective communication strategy

Ensure that simple measures are taken to reduce visual impacts such as keeping sites clean and tidy.

Benefits and limitations of this approach

- Benefits
  - The benefit of this type of qualitative research is that it provides evidence for why there are social issues around expanding aquaculture.
  - Low-cost
  - Provides useable results in a format that is well-understood by the industry (SLO)
  - Can identify areas where there are 'quick wins' for industry – such as tidying up sites
  - Can identify long-term issues which will need to be addressed
- Limitations
  - Requires a lot of time
  - Requires specialist training
  - Requires more research to understand the role of information in SLO as this is currently not understood

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Topic 10: Tools - Sea lice and salmon aquaculture

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PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 10: Sea lice and Salmon Aquaculture

Dr. Thomas P. Adams

SAMS

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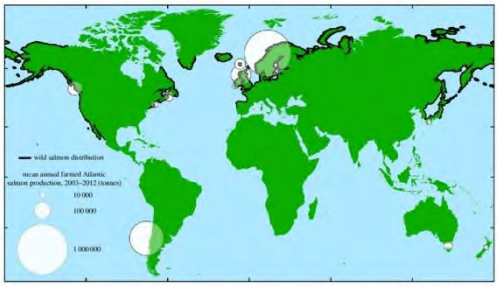
Contents

- Context
- Life Cycle
- Larval dispersal
- Lice on wild fish
- Lice on farmed fish
- Farmed lice on wild fish
- Modelling sea lice populations

Context



Gromer et al. 2016, 10.1098/rstb.2015.0203

Sea lice

- A persistent problem for aquaculture
- Reduce fish welfare
- Annual economic cost >£24m (UK), >£221m (global)
- Ecological impacts: wild fish links, chemical treatment impacts

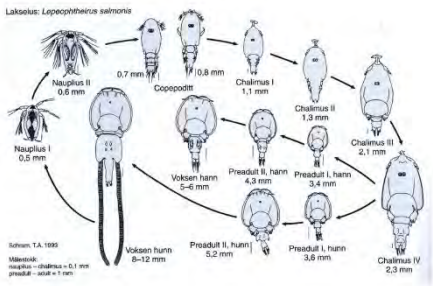
Sea lice

Adult *Lepeophtheirus salmonis*. (Alan Pike)

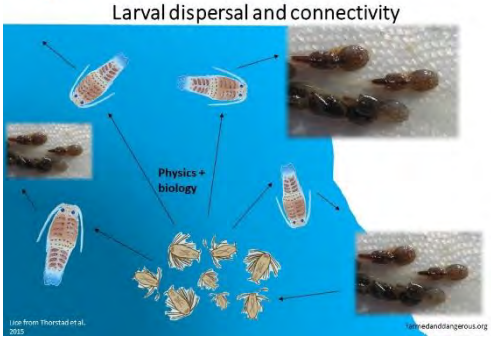
Caligus elongatus (Paul Tatner)

Adult *Caligus* females. (Gordon Rae)

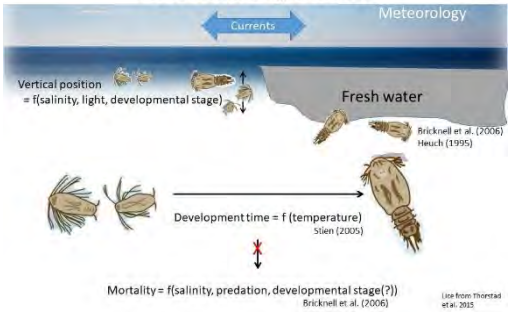
Life cycle



Larval dispersal and connectivity



Factors affecting larval lice



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Lice on wild fish

http://www.nasco.int/atlanticsalmon.html

Groner et al. 2016, 10.1098/rstb.2015.0203

Lice on wild fish

- Sea lice occur naturally on wild salmon and sea trout
- Migrating fish are infected with lice both close to shore and in the open ocean
- When they occur in high numbers, they have a negative impact on the fish

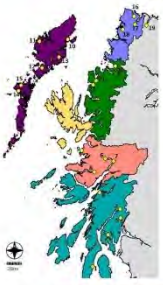
Lice on wild fish

- Numbers over around 10 lice per fish can cause mortality for juvenile salmon

Lice on wild fish

- Lice also pose problems for adult fish
  - Bleeding
  - Changes in mucus biochemistry
  - Tissue damage
  - Loss of microbial and physical protective function (increased risk from other pathogens)
  - Loss of appetite and metabolic rate
  - Osmoregulatory imbalance

Lice on wild fish



Site ID 2012	Site Name	Fishery Trust	No of Site Visits 2012	Total Number of Sea Trout Caught in 2012
1	Carradale	Argyll	2	90
2	Loch Fyne	Argyll	2	91
3	West Ribbon	Argyll	2	59
4	Dunstaffnage	Argyll	2	89
5	Goil	Argyll	2	40
6	Kinlochel	Lochaber	4	60
7	Camas na Gaul	Lochaber	4	134
8	Sunart	Lochaber	4	1
9	Borrisdale	Lochaber	4	13
10	Tang	Outer Hebrides	4	51
11	Ardbell	Outer Hebrides	3	1
12	Borve	Outer Hebrides	3	73
13	Eishken	Outer Hebrides	2	57
14	Kyles	Outer Hebrides	1	13
15	Malacleit	Outer Hebrides	2	31
16	Kyle of Durness	West Sutherland	2	84
17	Polla	West Sutherland	2	126
18	Laxford	West Sutherland	2	57
19	Inchrich	West Sutherland	2	44
20	Kanmard	Wester Ross	2	183
21	Boor Bay	Wester Ross	3	6
22	Flowerdale	Wester Ross	2	42

RAFTS (2013) 2012 Sea Trout Post Smolt Monitoring

http://www.rafts.org.uk/wp-content/uploads/2013/01/RAFTS-Regional-Monitoring-Report-2012.pdf

Lice on wild fish

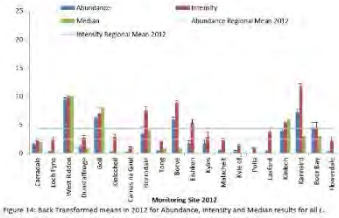


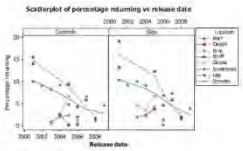
Figure 14: Back Transformed means in 2012 for Abundance, Intensity and Median results for all L. salmonis stages at each monitoring site (including 95% confidence intervals).

Abundance: The mean number of sea lice per fish in the whole sample.
Intensity: The mean number of sea lice per infected fish
Abundance Median: When ranked numerically, the middle value of sea lice abundance within the population of fish.

"Farmed lice" on wild fish

Mortality of medicated and control smolts (Jackson et al. 2013)

1. Marine survival decreased over time
2. Treating the smolts only offered ~1% advantage



Debate on the true meaning of these results (Krkosek et al. 2014): is it 1%, or 25% difference?!

Lice on farmed fish

Media controversy

https://www.pressandjournal.co.uk/fp/news/highlands/606929/calls-for-tough-action-on-lice-infested-fish-farms/

HOME | NEWS | HIGHLANDS

Calls for tough action on lice infested fish farms

by Rita Campbell | June 12, 2015, 4:00 pm

http://www.bbc.co.uk/news/uk-scotland-highlands-islands-20236291

Sea lice killing 'large numbers' of salmon

7 November 2012 | Highlands & Islands

http://www.bbc.co.uk/news/uk-scotland-scotland-business-39578173

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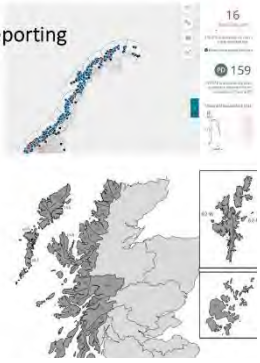
Lice on farmed fish

General points

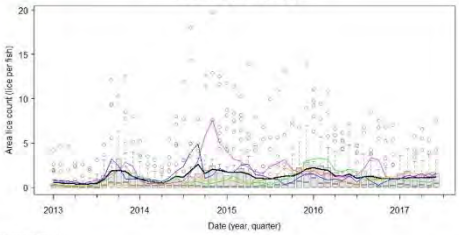
- Farmers generally try to keep lice numbers low
  - In Scotland, treatments to remove lice must be carried out when there is more than 1 lice per fish (on average) over all fish sampled in one week
  - Lice numbers must be reported to the government when more than 3 lice per fish are found

Lice reporting

- Norway: weekly lice reports
- Scotland: monthly counts, aggregated by area (published every three months)



Lice reporting



Mainland south (green)
Mainland north (blue)
Western isles (magenta)
Northern isles (orange)
Overall mean (black)

Data: Scottish Salmon Producers' Organisation (http://scottishsalmon.co.uk/publications/)

Managing sea lice

Lice control: site management

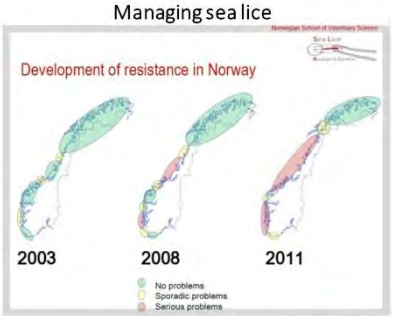
- Regular monitoring of lice numbers
- Single generation sites and management areas with synchronous treatments
- Fallowing of management areas to break lice cycles
- Treatment of lice in the spring when lice numbers are low
- Area Management Agreements, bringing Fisheries Trusts and Farmers together have proven very effective in many areas

Managing sea lice

Lice control: cage treatments

- Bath treatments (e.g. Gautam et al. 2017)
  - Chemicals: azamethiphos ("Salmosan"), hydrogen peroxide ("Paramove"), deltamethrin ("AlphaMax" - discontinued)
  - Attached lice fall off fish and die
  - Warm fresh water
  - Effects immediately
- In-feed treatments
  - Chemicals: emmamectin benzoate ("SLICE")
  - Reduce attachment
  - Attached lice fall off fish and die
  - Effects gradual over c 30-40 days
- ISSUES:
  - Stress on fish
  - Discharge into environment
  - Development of resistance (Aaen et al. 2015)

Managing sea lice



Managing sea lice

Cleaner fish

- Cleaner fish (wrasse species and Lumpfish)
- Graze lice from the skin of salmon
- Optimum ratio
- Possible implications for other diseases

Wikipedia commons

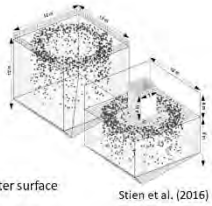
Wikipedia commons

Leclerq et al (2013), MCS (2013), Murray (2014)

Managing sea lice

Barrier technologies

- "Snorkel" cages (Stien et al., 2016, Oppedal et al., 2017)
- Skirts



Stien et al. (2016)

- Issues:
  - Oxygen levels in water
  - Fish need to be able to access water surface (swim bladder)
  - Potential damage to more complex cages

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Appendix – Presentation Content

Modelling sea lice

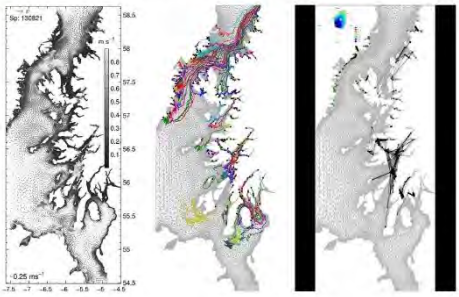
MODELS

Hydrodynamics → Particle tracking → Network analysis / Population model

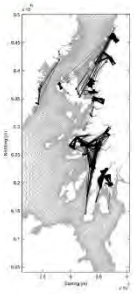
DATA

- Meteorological
- River flow
- Tidal
- Site current/salinity
- Plankton trawls
- Site lice counts

Modelling sea lice



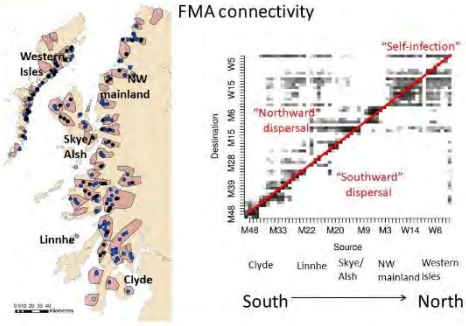
Modelling sea lice



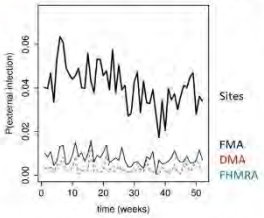
Average connections

- All non-zero connections marked
- Arrow head size ~ connection strength
- Distinct groupings of sites
- **Optimal arrangement of management areas?**

FMA connectivity



Benefits of spatial management



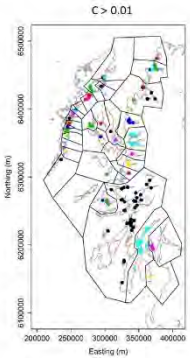
"External infection" = sum of connectivity matrix – main diagonal values

- Management units reduce external connectivity
- In particular, even small units reduce external connectivity by c 75%
- Larger units => greater reduction

Adams et al. 2016

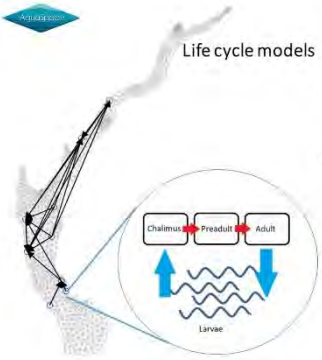
"Optimal" units

- Eliminate connections below a threshold, identify site clusters
- Higher threshold => smaller unit size
- Thresholds can be defined by persistence in population dynamic models
  - likely in range 0.01-0.05



Adams et al. 2016

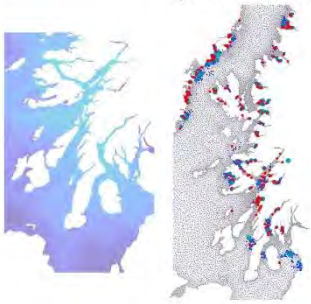
Life cycle models



- Dynamic model of daily lice counts at sites
- Inform:
  - Treatment strategy (sites to focus on, treatment applied)
  - Sites presenting particular issues
- Predict outbreaks prior to detection

Adams, T., Black, K., MacIntyre, C., MacIntyre, I. and Dean, R. 2012.
Adams, T.P., Proud, R. and Black, K.D. 2015.

Space for new sites



- Metrics
  - Oceanographic conditions
  - Fluxes from existing sites to new sites
  - Fluxes from potential new sites to existing sites
  - Management area connections
- Broader picture
- Individual developments

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Appendix – Presentation Content

Other modelling efforts

- Similar efforts in all salmon producing countries
  - Norway (most advanced work)
  - Canada
  - Chile

Final comments

- Lice levels are maintained at a level where there unlikely to be significant harm to the farmed fish
- There is still significant debate about the effect that sea lice from farms have on wild salmon (less debate about sea trout)
- There is room for improvement in sea lice management techniques
- Sea lice are the number one priority in Salmonid aquaculture

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Appendix – Presentation Content

Topic 11: Forthcoming Issues for Aquaculture and Spatial Planning

AquaSpace

CPD Course

PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

Topic 11: Forthcoming Issues for Aquaculture and Spatial Planning

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(UCC)

Horizon 2020

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Aquaculture and future EU policy?

- Aquaculture is one of the identified 'Blue Growth' sectors
- Most recent reform of CFP gives aquaculture more prominence – likely to continue in future Reform packages?
- All EU Member States now have Multi-annual National Aquaculture Plans
  - These include Member States' objectives until 2020 and
  - Measures to be used to achieve those objectives
- Changing environmental legislation
  - Impact Assessment
  - Conservation
- New management approaches (MSP, adaptive management?)

Challenges identified by the EC (2016)

Marine Finfish:

- Lack of available space in inshore sheltered areas
- Competitiveness of products against produce from outside the EU
- Administrative procedures and environmental legislation (monitoring)

Shellfish:

- Lack of space in inshore areas
- Need to extend shelf-life (linked to marketing)
- Changing environmental conditions / Disease control / Hazards

Challenges identified by the EC (2016)

Freshwater aquaculture:

- Small scale operators have limited access to finance to expand operations
- High input costs (e.g. labour, land) put the sector at a disadvantage
- Fragmented structure of the sector (supply v. demand issues)
- Lack of space due to competition with other users

Other Marine Aquaculture:

- Competition with other users

Other considerations

New governance approaches:

- Economic-based management
  - Society more concerned about sustainable and safe food production
  - Rise in Corporate Social Responsibility (CSR)
  - Certification schemes
- Community-based management
  - Role of "Social Licence to Operate"
- Leading to "Hybrid governance"
  - Involves governmental actors, non-state actors such as civil society organizations and NGOs, fishermen's cooperatives, and private businesses in the decision-making process.

The future of Aquaculture:

"What is needed for the future is an approach which makes use of the experience available, adds to the existing know-how through continued research efforts, elaborates and refines guidelines, and creates appropriate frameworks for further development. . .

Aquaculture production is in great demand, but it must not be achieved without due regard to safeguarding our basis of survival."

(Bilio (1993) p.v. quoted in Brugère et al., 2018)

Ecosystem Approach to Aquaculture to support MSP

How to support (selected) countries in managing aquaculture intensification by using the 6 steps of the EAA to support MSP?

EAA has been defined by FAO (2010) as *"a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity and resilience of interlinked social-ecological systems"*.

FAO and World Bank, 2015

Review of Implementation of EAA to date

- Different levels of uptake in different locations
  - General lack of reference to the EAA in aquaculture policy and governance (e.g. Hishamunda et al. 2014; O'Hagan et al., 2017) illustrates the difficulty in linking the EAA to governance matters
  - Only one of the Multi-annual National Aquaculture Plans in AquaSpace partner countries refer to the EAA (O'Hagan et al., 2017)
- Has highlighted the usefulness of more participatory approaches in delivering sustainability
- Efforts to mainstream the EAA into policy have been sectoral
  - Could be compared and contrasted with Integrated Coastal Management
  - Are there lessons here for MSP?
- Differences in how EAA is implemented: is it a conceptual guide or an actual process?

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Good practice examples of EAA implementation

Chile - Fisheries and Aquaculture Law is being reviewed to include the EAA and an associated new policy will guide aquaculture development for the next 20 years

Nicaragua – participatory engagement process with stakeholders from multiple institutions at various administrative levels prepared EAA management plans for aquaculture development in sensitive zones

Scotland – implementation of Farm Management Areas, developed by industry, and Disease Management Areas, created by government and industry

Turkey – aquaculture zoning for fish cages, moving production further offshore to avoid conflicts with other coastal uses

See case study examples in Aguilar-Manjarrez, et al., 2017 and also on the AquaSpace project website

Future needs? [1]

- Need for aquaculture policy, strategies and development plans at national level
  - Multi-annual National Aquaculture Plans are one step but need to be supported by Action Plans and resources for implementation
- Must be embedded within strategic marine policies such as MSP
- Knowledge of existing aquaculture activity and its value chains
- Spatial planning tools that can take account of changes which will occur at local and global levels and their impacts on ecosystems and resource use
- How to deal with trade-offs?
- Availability of credit and appropriate financing instruments
- Transparent and facilitative consenting systems
- Good coordination and stakeholder engagement mechanisms, particularly cross-sectoral
- Social licence to operate

Future needs? [2]

- Risk-based framework
  - Ability to adapt to changing circumstances (e.g. climate, new policies etc.)
  - Increases resilience to external factors
  - Integrated assessment process that promotes co-existence with other uses and sectoral objectives
- Management system that prevents and controls diseases and the introduction of invasive species
- Technical capacity
  - Risk assessment
  - Carrying capacity studies
  - Disease modelling
  - New tools such as GIS-based tools, visualisation and remote sensing?

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