



Masters Module

PLANNING AND MANAGING THE USE OF SPACE FOR AQUACULTURE

## **Topic 5: Geographic Information Systems**

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Horizon 2020

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# 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)

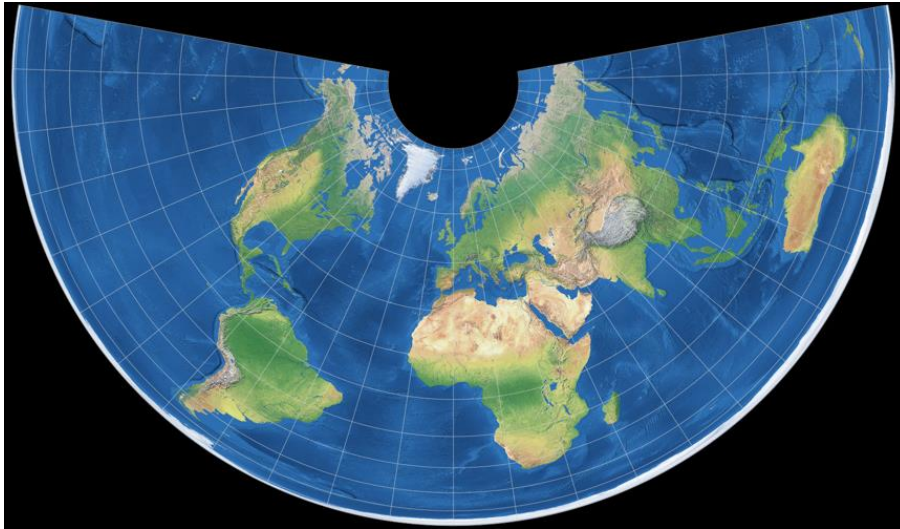
# Purposes

Examples applications in relation to aquaculture ...

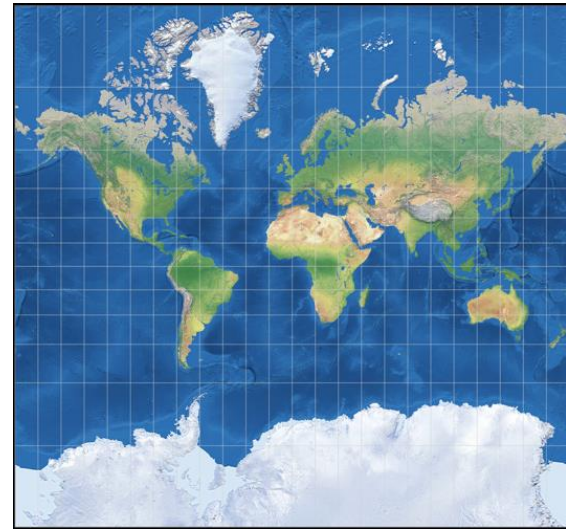
- **Geographic Information Systems –**
  - Bringing together data on natural resources, protected areas, transport routes, model output datasets
- **Spatial analysis -**
  - Deriving visibility of fish cages from tourist viewpoints
  - Measuring distance between features (e.g. coast and aquaculture site)
  - 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/>

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# 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 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

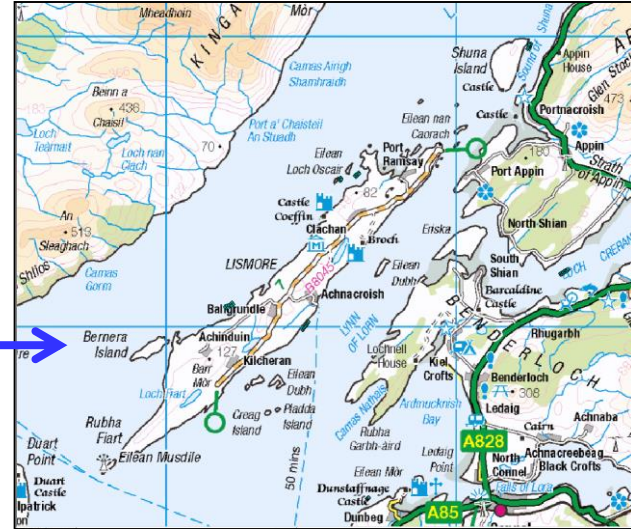
- Data are held in one of many different formats
- Many are proprietary; conversions are possible between most, but not always
  - Example formats
    - Image                      JPG, PNG,
    - Raster                      ESRI GRID, IMAGE (Erdas Imagine)
    - Polygon, lines              Shapefile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

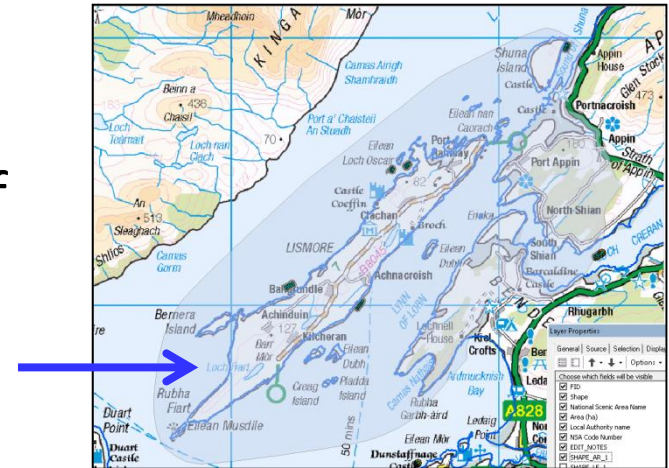


# Data Structures

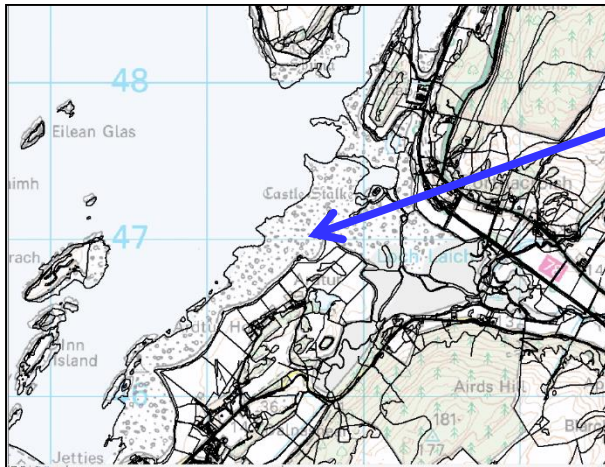
- Most common data structures (polygons, lines)

**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)

Shape *	AQ_Site	No Cages	Aquacult	AquaSpace	Local Authorit	National Sceni	NSA C	SHAPE_Lengt	SHAPE Area (	EDIT_NOTES
Point	Geasgill	12	FS0839	33	Argyll and Bute	Loch na Keal, Is	19	89989.892877	442497083.493	No changes
Point	Geasgill	12	FS0839	33	Argyll and Bute	Loch na Keal, Is	19	89989.892877	442497083.493	No changes
Point	Geasgill	12	FS0839	33	Argyll and Bute	Loch na Keal, Is	19	89989.892877	442497083.493	No changes
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Point	Geasgill	12	FS0839	33	Argyll and Bute	Loch na Keal, Is	19	89989.892877	442497083.493	No changes
Point	Geasgill	12	FS0839	33	Argyll and Bute	Loch na Keal, Is	19	89989.892877	442497083.493	No changes
Point	Walters (East Lismore)	9	FS0875	35	Argyll and Bute	Lynn of Lorn	18	54461.474978	157263524.016	No changes
Point	Walters (East Lismore)	9	FS0875	35	Argyll and Bute	Lynn of Lorn	18	54461.474978	157263524.016	No changes
Point	Walters (East Lismore)	9	FS0875	35	Argyll and Bute	Lynn of Lorn	18	54461.474978	157263524.016	No changes
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Point	Walters (East Lismore)	9	FS0875	35	Argyll and Bute	Lynn of Lorn	18	54461.474978	157263524.016	No changes
Point	Lismore West	9	FS0914	34	Argyll and Bute	Lynn of Lorn	18	54461.474978	157263524.016	No changes
Point	Lismore West	9	FS0914	34	Argyll and Bute	Lynn of Lorn	18	54461.474978	157263524.016	No changes

436 (0 out of 499 Selected)

Aquaspace Sites 2017 NSAs

General	Source	Selection	Display	Symbology	Fields	Definition Query	Labels	Joins & Relates	Time	HTML Popup
Options										
Choose which fields will be visible										
<input type="checkbox"/>	FID									
<input checked="" type="checkbox"/>	Shape									
<input type="checkbox"/>	FID_AandBA									
<input type="checkbox"/>	Id									
<input checked="" type="checkbox"/>	AQ_Site									
<input checked="" type="checkbox"/>	No Cages									
<input checked="" type="checkbox"/>	Aquaculture Site ID									
<input checked="" type="checkbox"/>	AquaSpace Proj Id									
<input type="checkbox"/>	Radius2									
<input type="checkbox"/>	OffsetA									
<input type="checkbox"/>	OffsetB									
<input type="checkbox"/>	FID_SG_Nat									
<input checked="" type="checkbox"/>	Local Authority									
<input checked="" type="checkbox"/>	National Scenic Area (NSA)									
<input type="checkbox"/>	HECTARES									
<input checked="" type="checkbox"/>	NSA Code									
<input type="checkbox"/>	SHAPE AR 1									

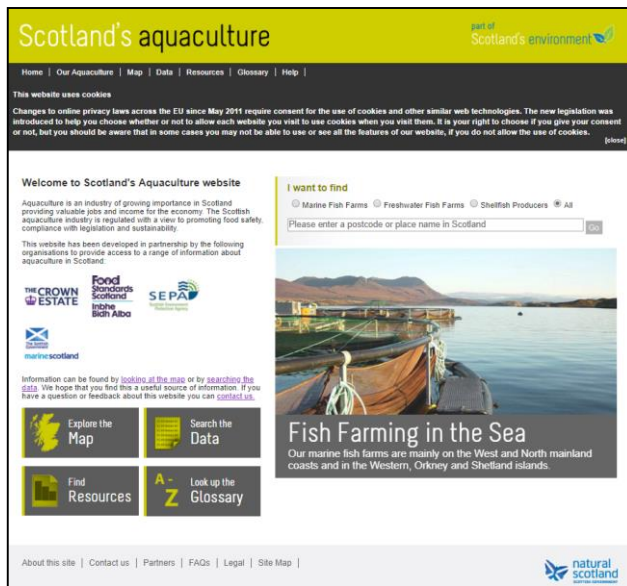
Appearance	
Alias	Aquaculture Site ID
Highlight	No
Read-Only	No
Field Details	
Data Type	Text
Length	50
Name	SiteID
Allow NULL Values	No

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

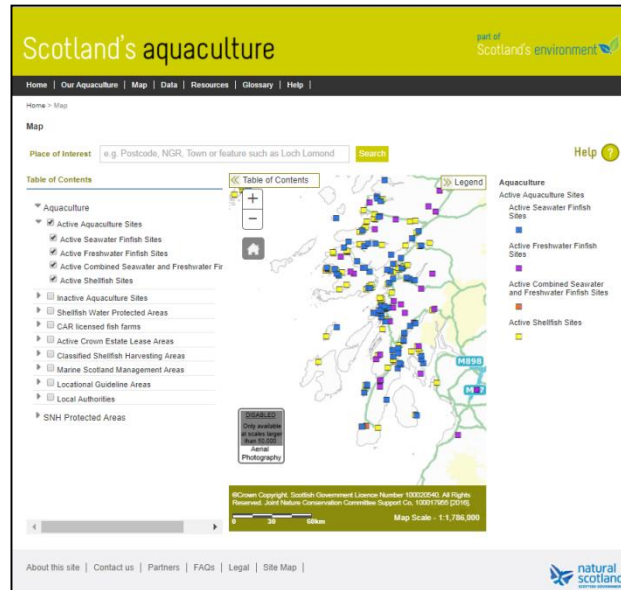
**Fields** – Headings for which data are held (e.g. area, length, title, reference number)

# Data and Information

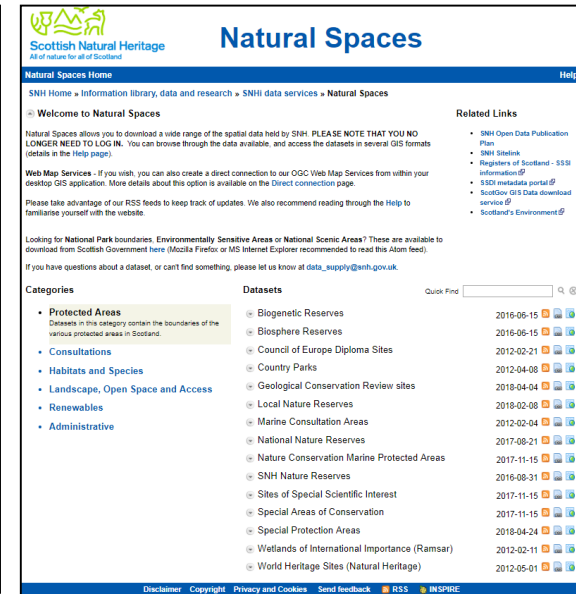
- Example sources of spatial data and information, for Scotland, relevant to:
  - environmental impact assessments
  - spatial planning



**Scotland's  
Environment Web:  
Aquaculture site**



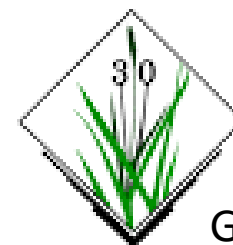
**Scotland's  
Aquaculture map  
(online)**



**Scottish Natural  
Heritage (e.g.  
Designated areas)**

# GIS Software

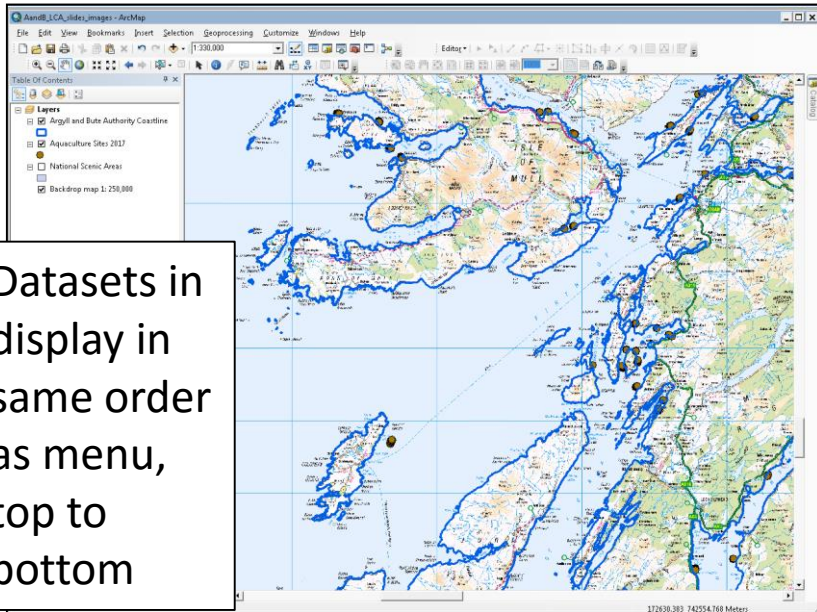
- Choose software to fit the purpose
- Numerous packages with differences including:
  - Functionality (e.g. strengths in handling certain types of data – raster processing, polygons, etc.)
  - Target applications (e.g. utility management, environmental management, cartography)
  - Costs and licencing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



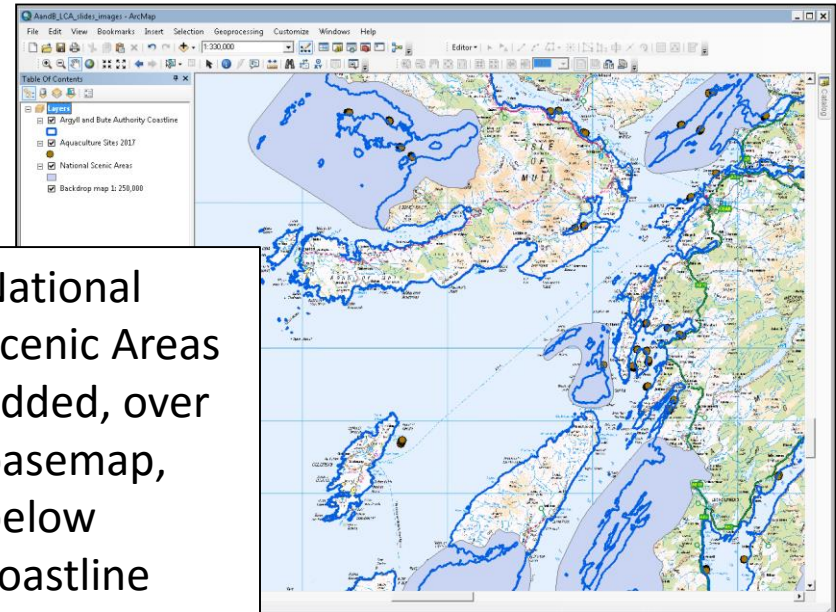
(Logos courtesy of ERSI, MapInfo, QGIS, GRASS)

# Functions

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



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



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

## Location:

Case Study Area, Argyll and Bute, UK



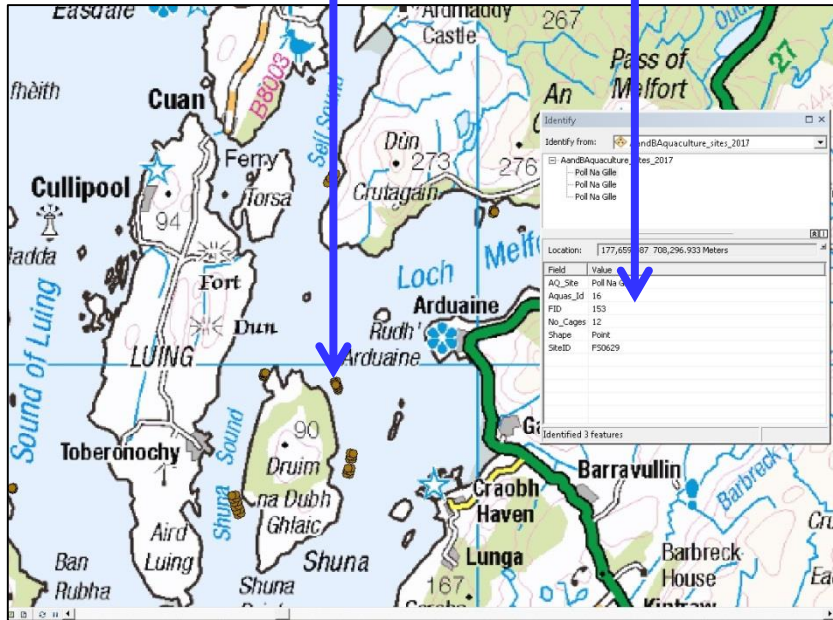
# Functions

- 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

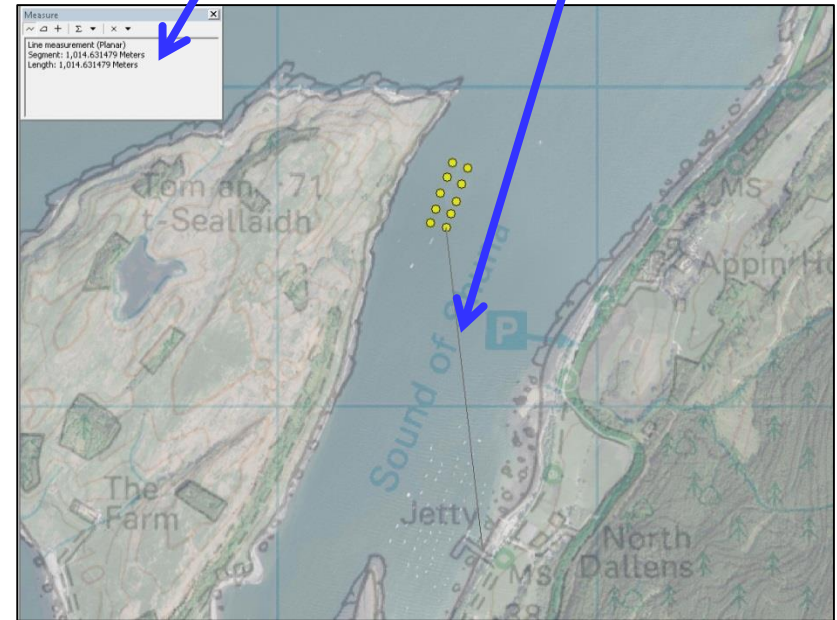
Entry in the fish cage database



## Measurement

Result  
c.179 m

Measure distance from  
nearest fish cage to jetty

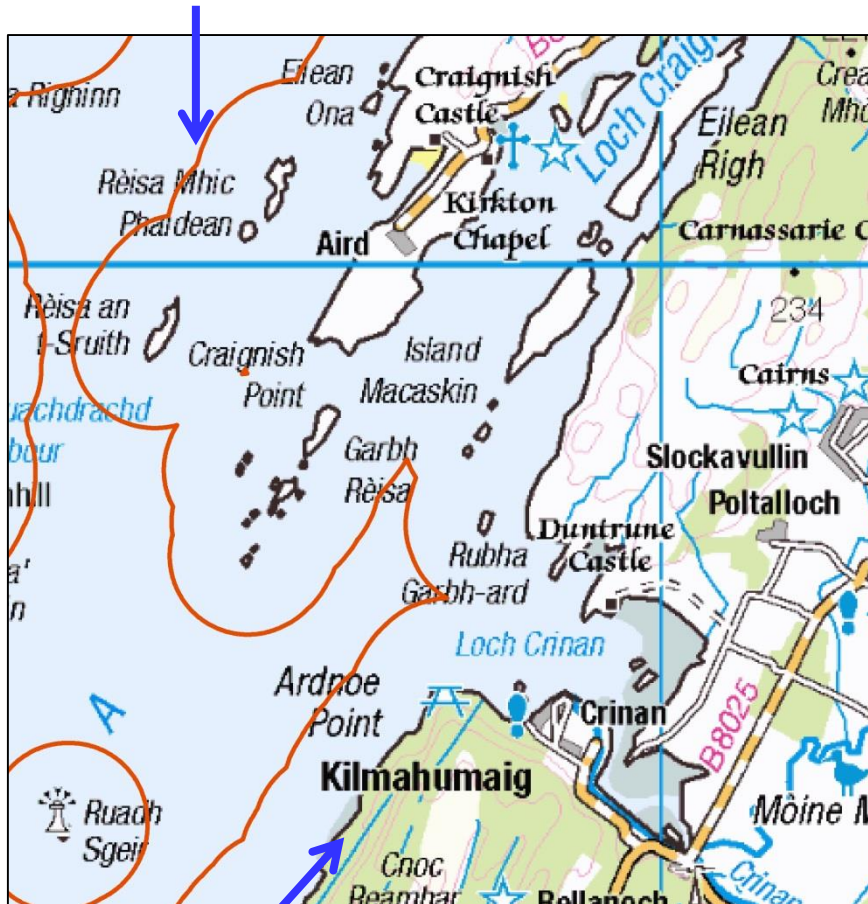




# Functions

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

## Buffer 1 km from coastline



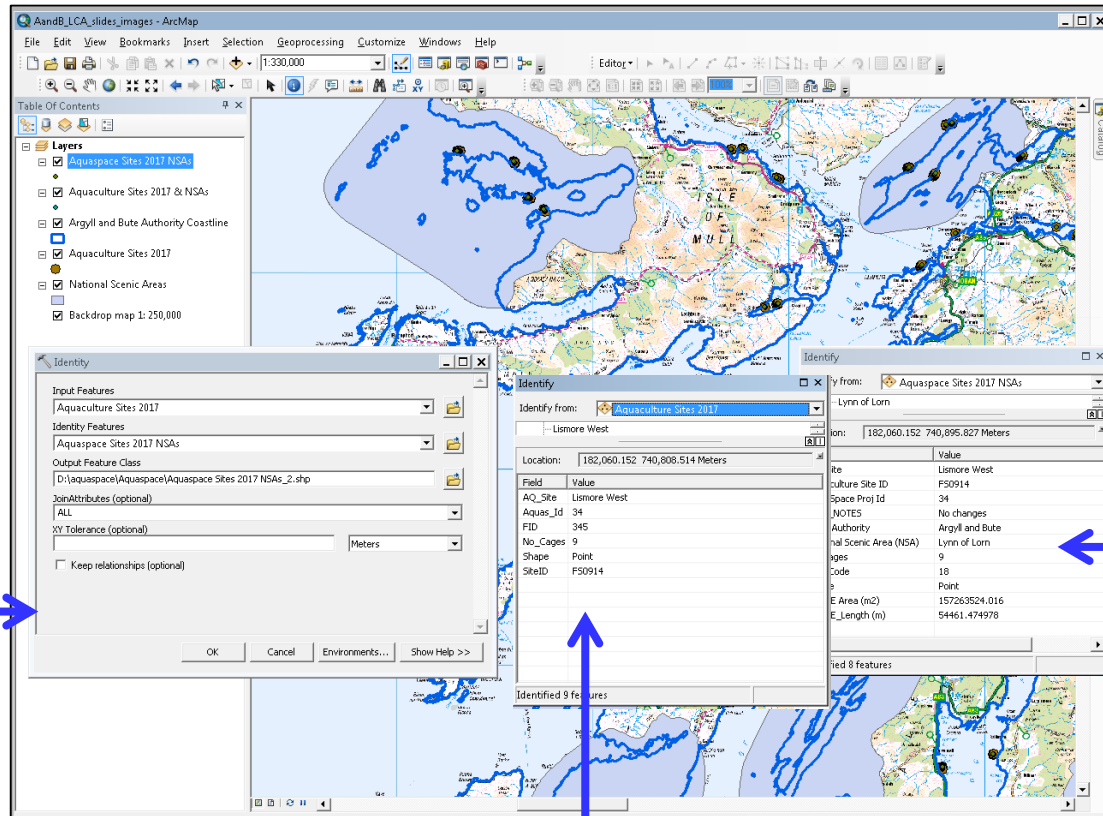
- Key user controlled settings –
  - the type of feature (e.g. coastline)
  - distance from the feature (e.g. 1 km)
  - Individual or grouped features (e.g. all islands or individual islands)

## Coastline

# Functions

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

Example of  
menu  
interface –  
Identity  
function



Database  
entry for fish  
cage after  
datasets  
combined

Details of  
National  
Scenic Areas  
added to fish  
cage database

Database entry for fish cage  
before datasets combined

**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

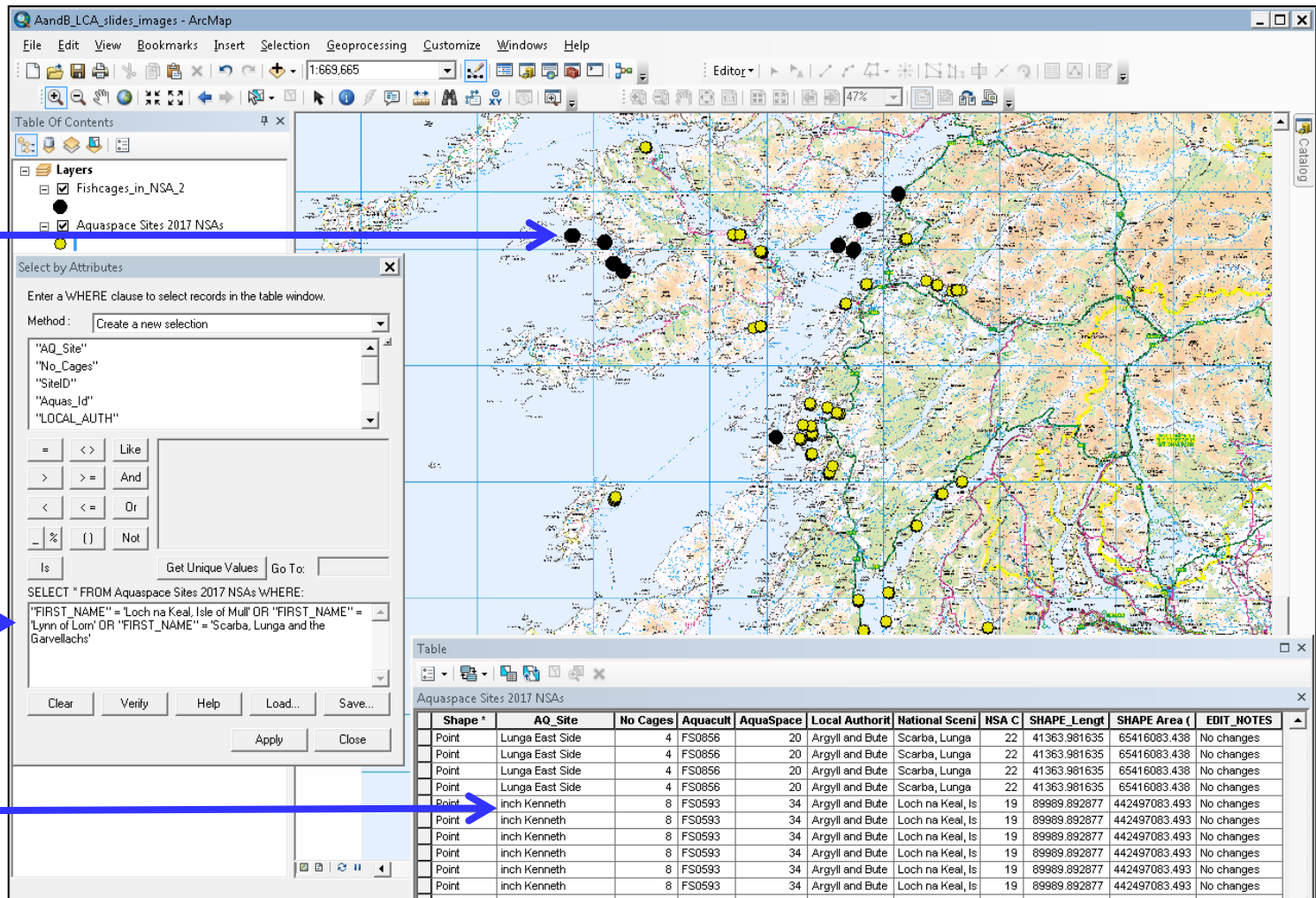
# Feature Selection

- **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

## Fish cages in National Scenic Area

## Rule for selecting fish cages in National Scenic Area

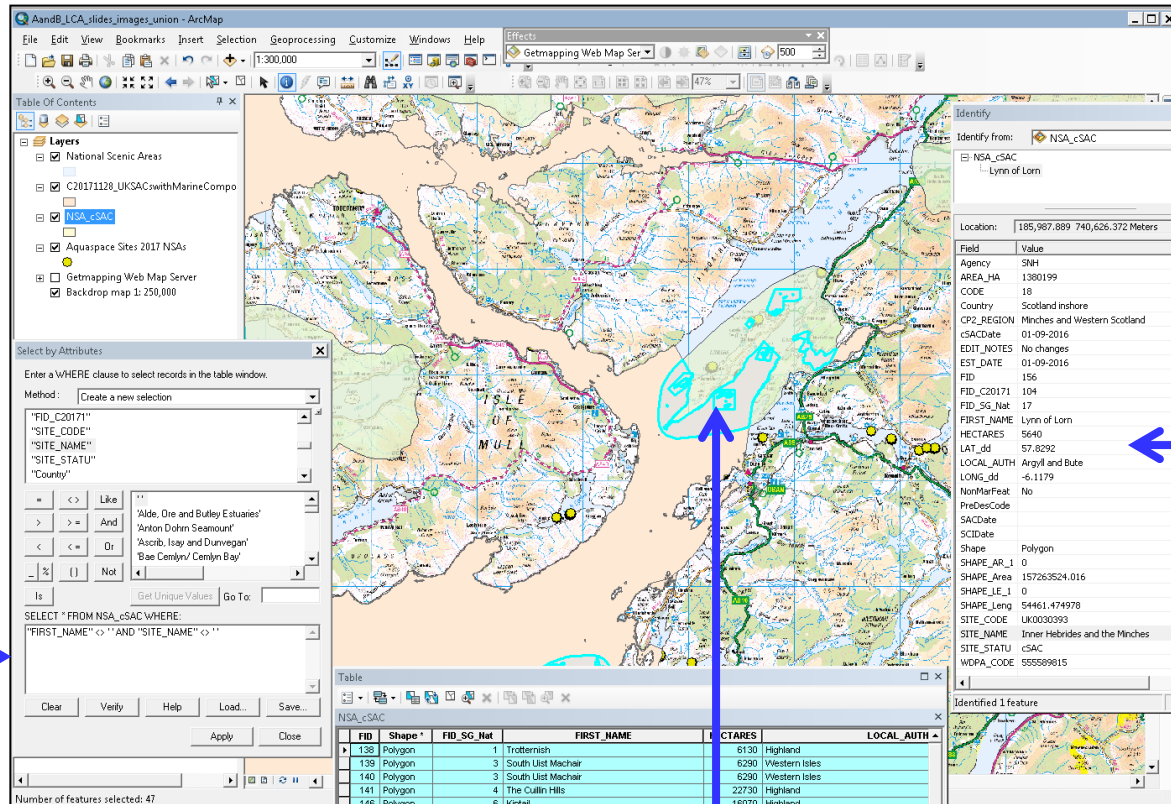
## Dataset attributes

[illegible]



# Functions

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



**Database entry  
for National  
Scenic Area  
once datasets  
combined**

**Details of one  
area in  
National  
Scenic Area  
and candidate  
Special Area of  
Conservation**

**Areas in National Scenic  
Area and cSAC**

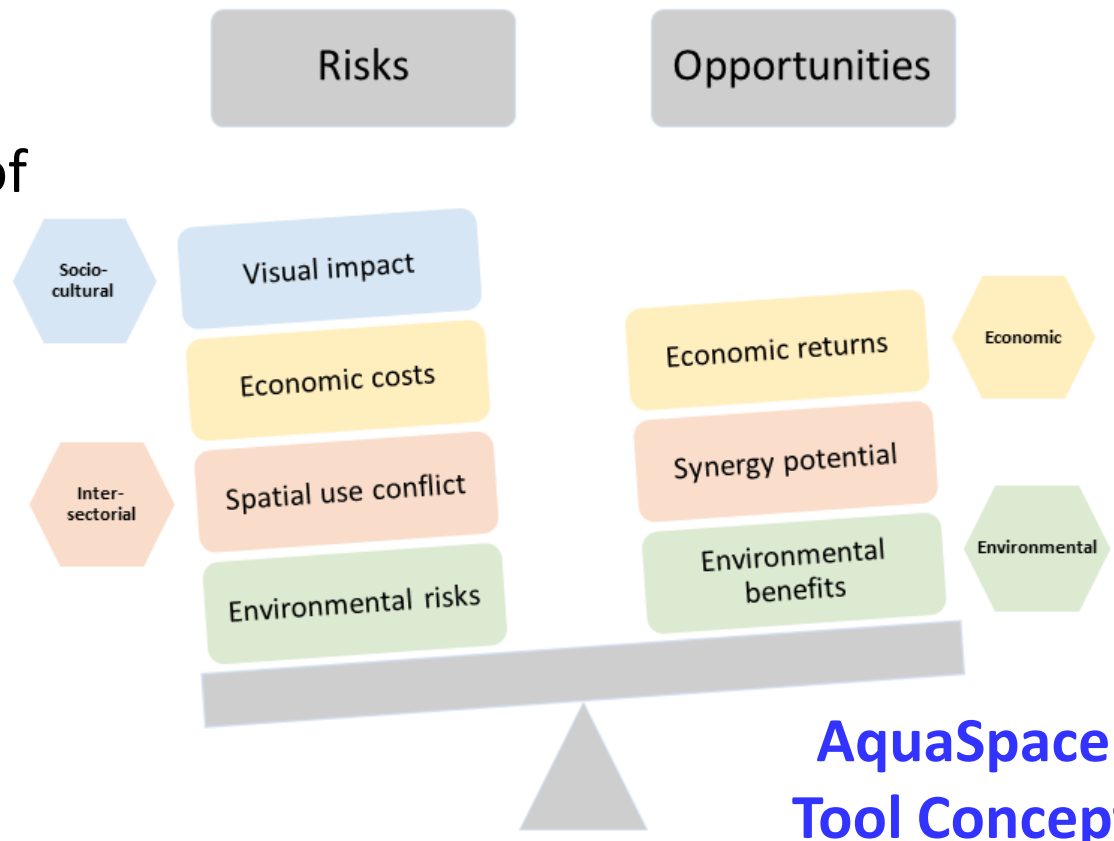
**Location:**  
Case Study Area, Argyll and Bute, UK

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

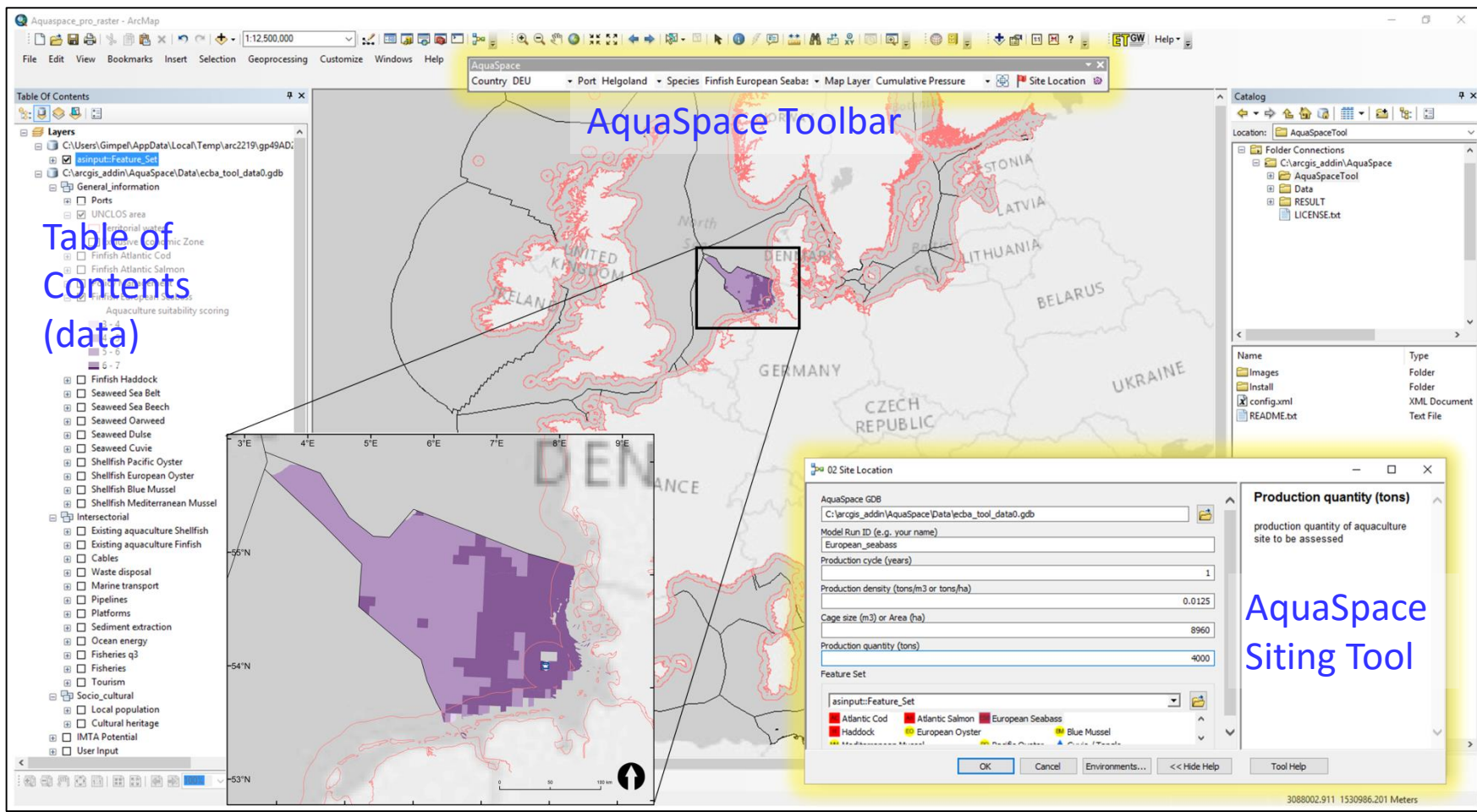


Source: Gimpel et al., 2018;  
[AquaSpace D3.3](#), for more details,  
and masters Course Module 5

**AquaSpace  
Tool Concept**

# Mapping and Integrating Aquaculture Indicators

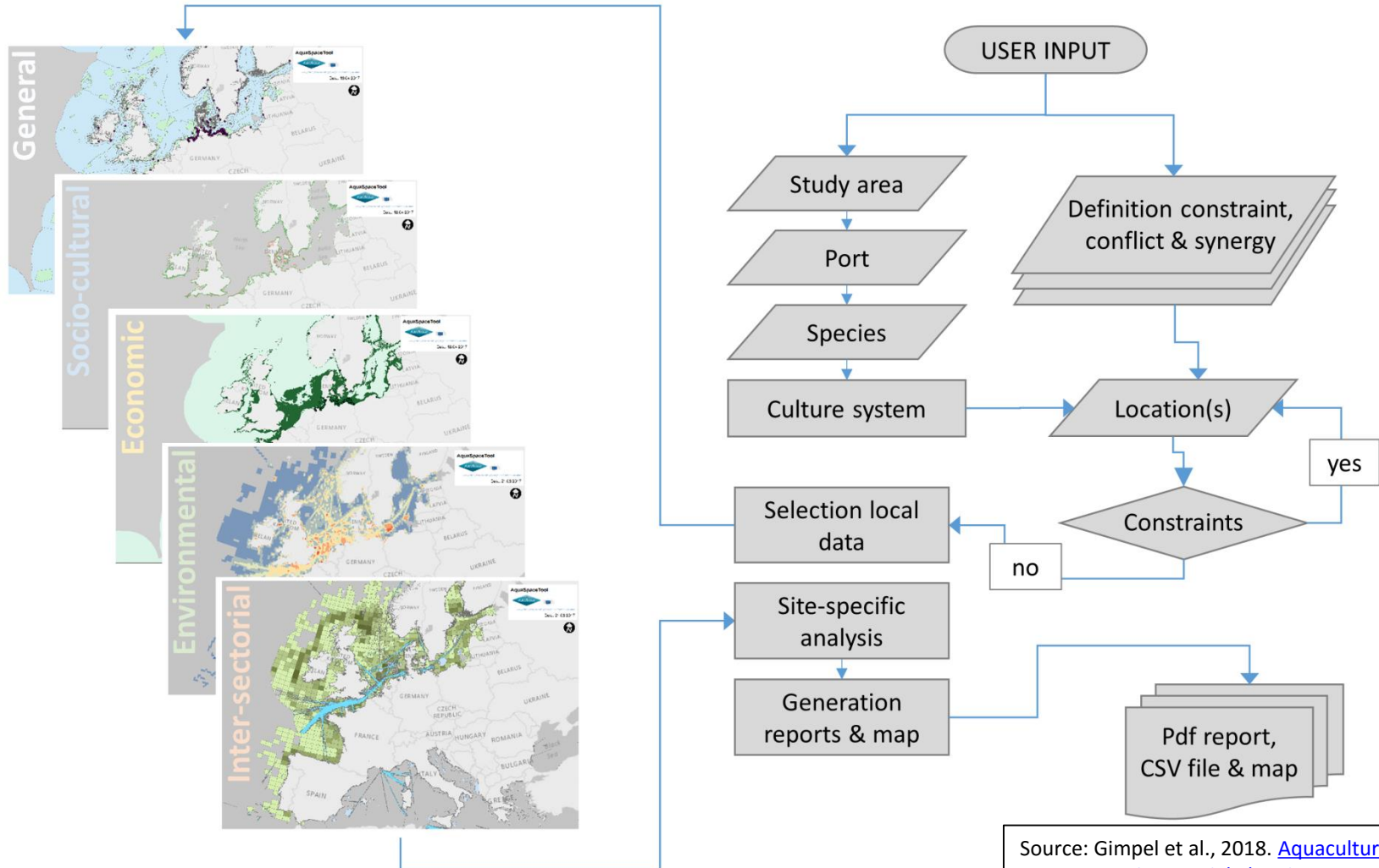
- Tool provided as an Add-in to ArcGIS
- Example application in south-east North Sea





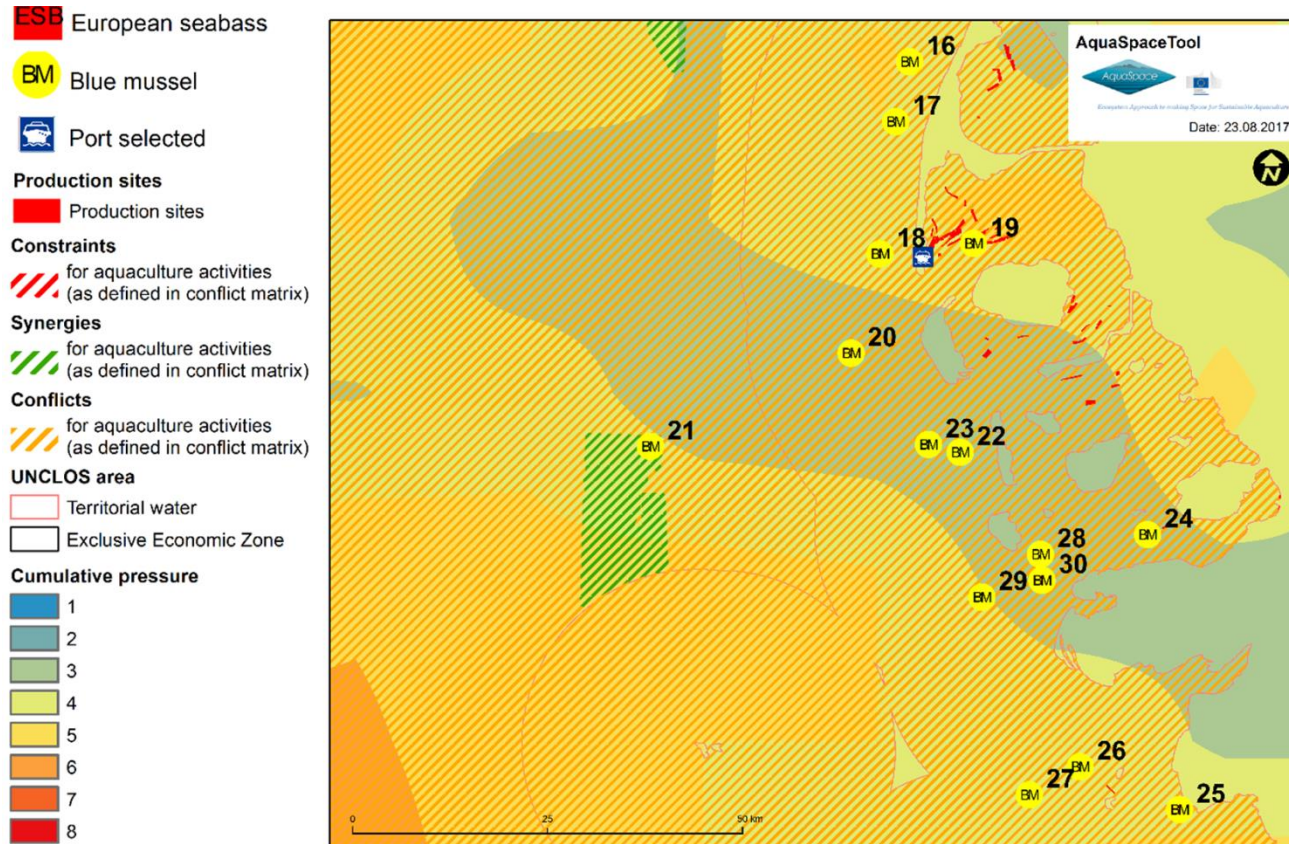
# Analysis: AquaSpace Tool

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



# Analysis: AquaSpace Tool

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

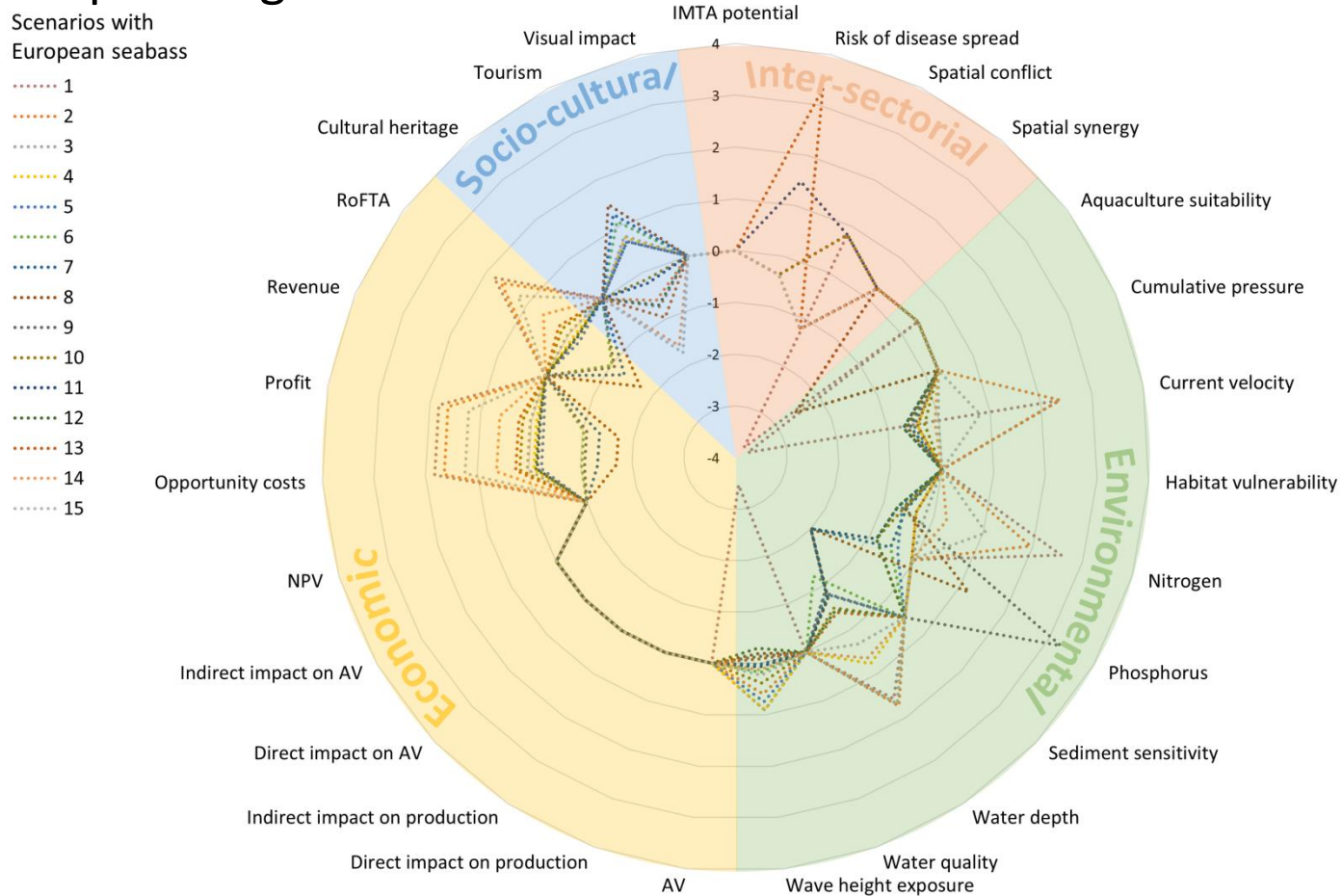


- Areas of constraint, synergy and conflict, management boundaries, areas of aquaculture production
- Cumulative pressure map as background map for map output

# 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

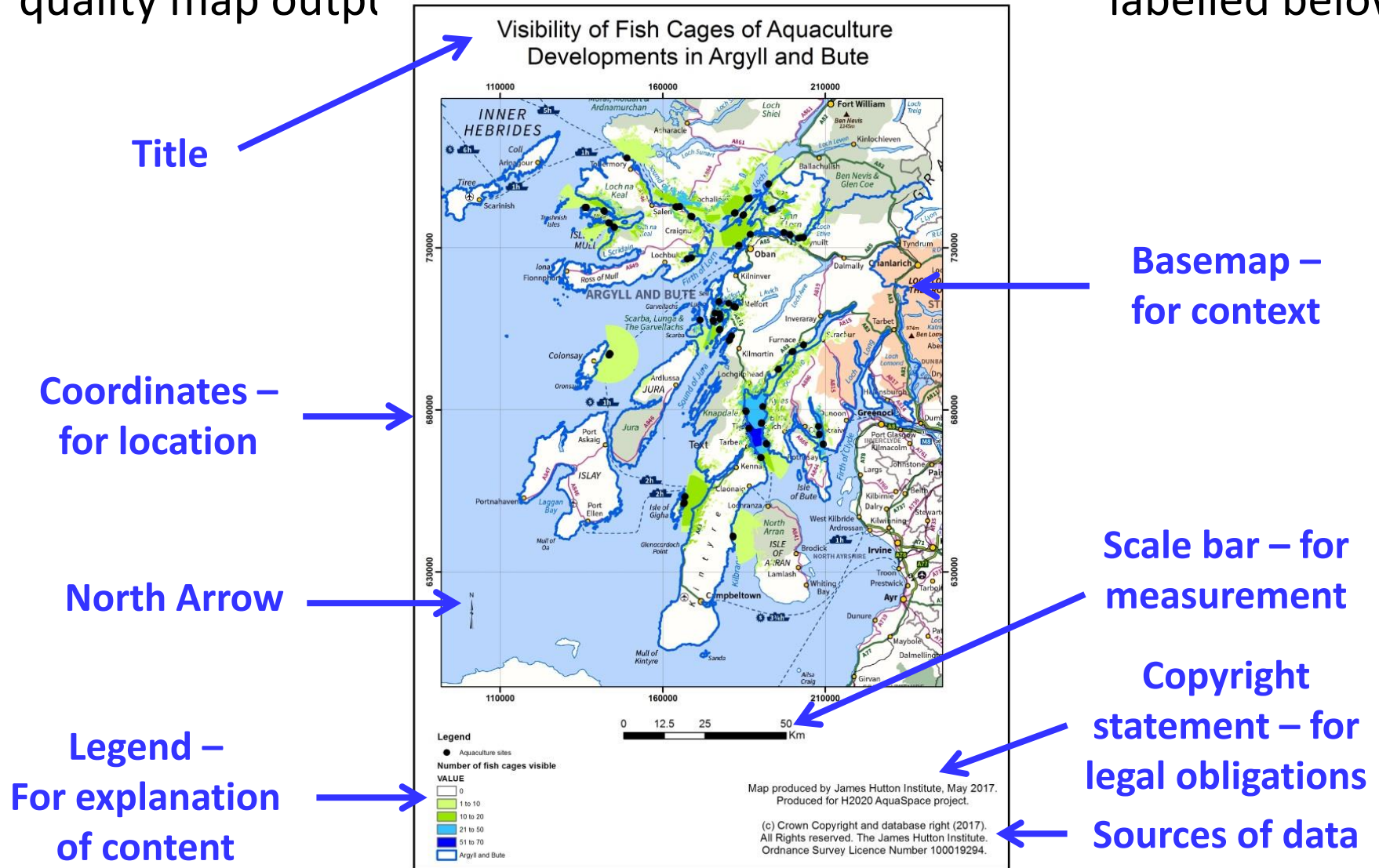




# Cartography

- Aim: Production of a high quality map output

- Key components labelled below



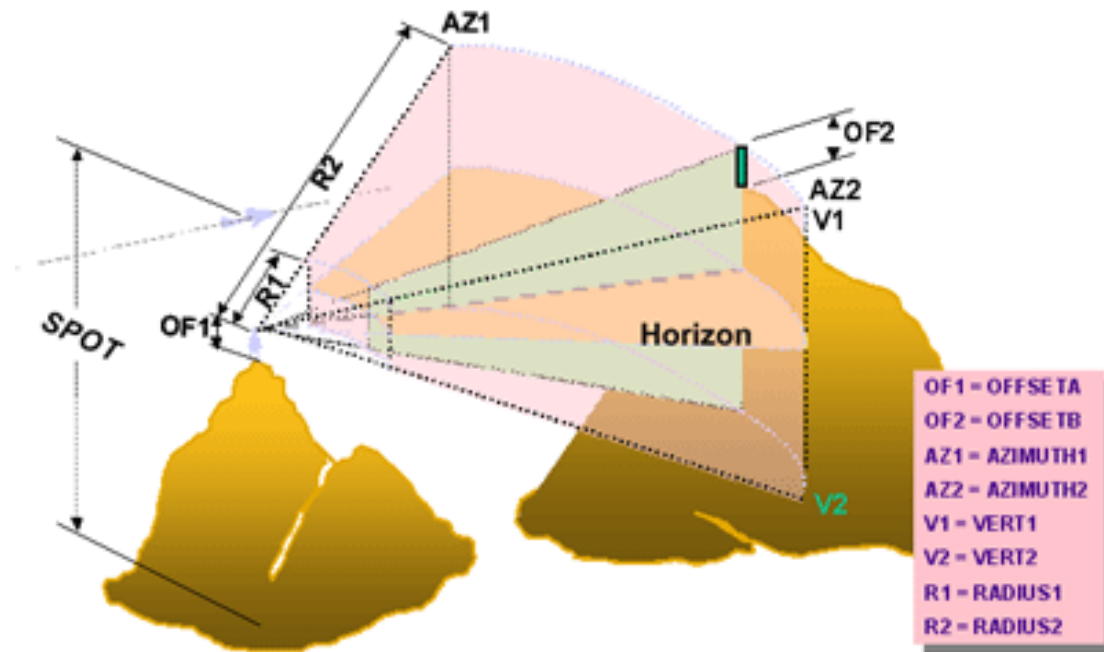
# Visibility Analysis

**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)

# Example Application: Seascapes

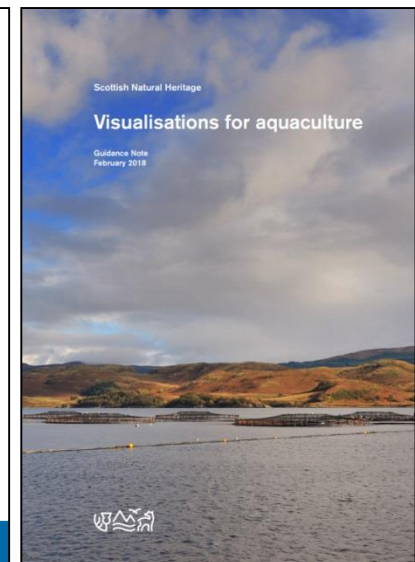
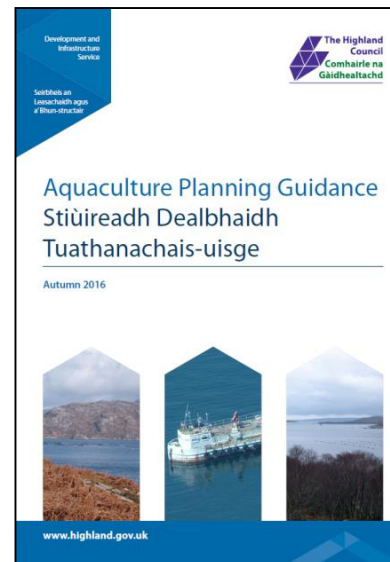
## Context

- 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.”

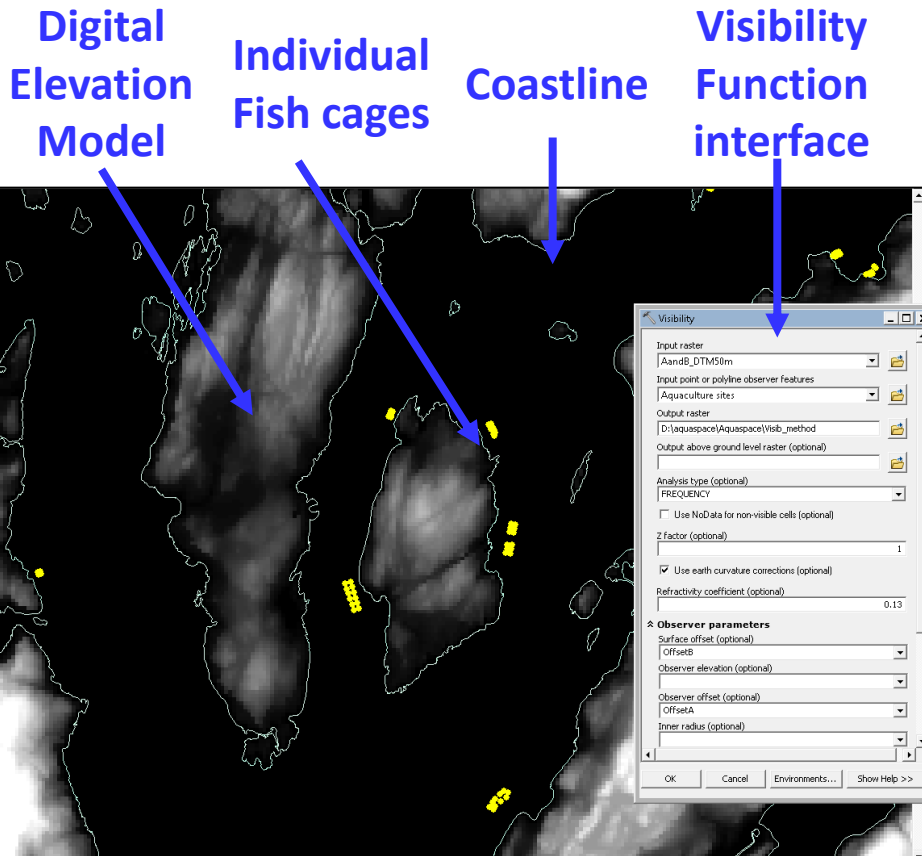
- Landscape and seascape is one key factor when considering aquaculture developments
- Guidance on landscape issues is provided on aquaculture development (e.g. Scotland)



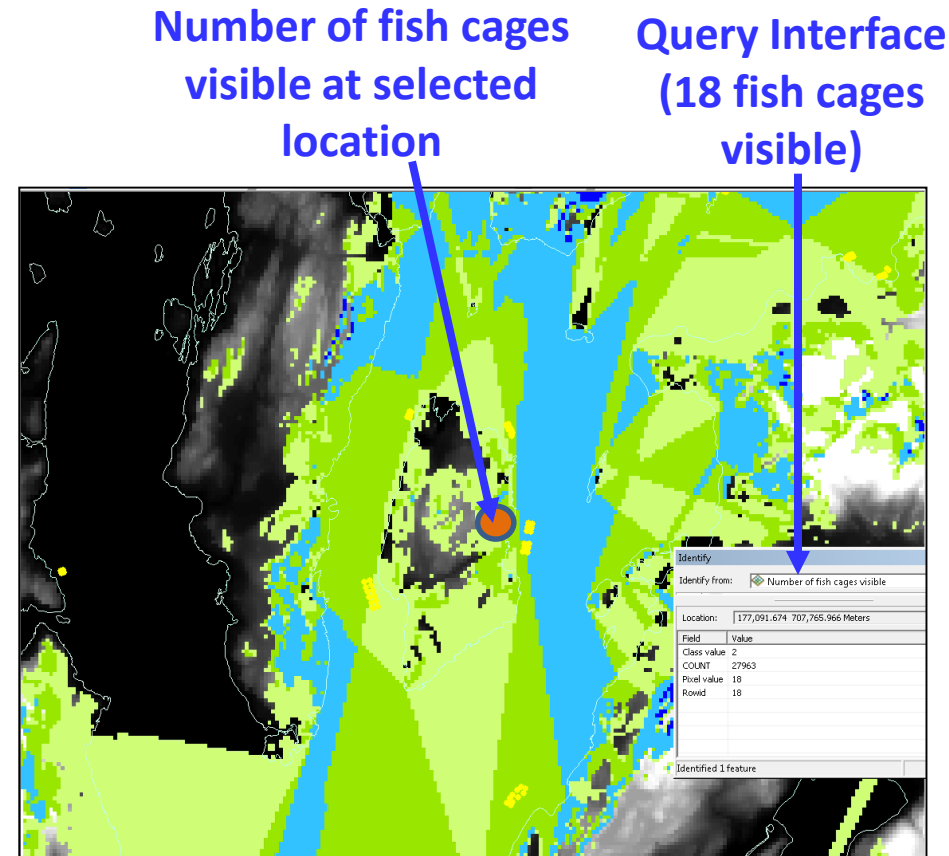


# Methods: Visibility of Fish Cages

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

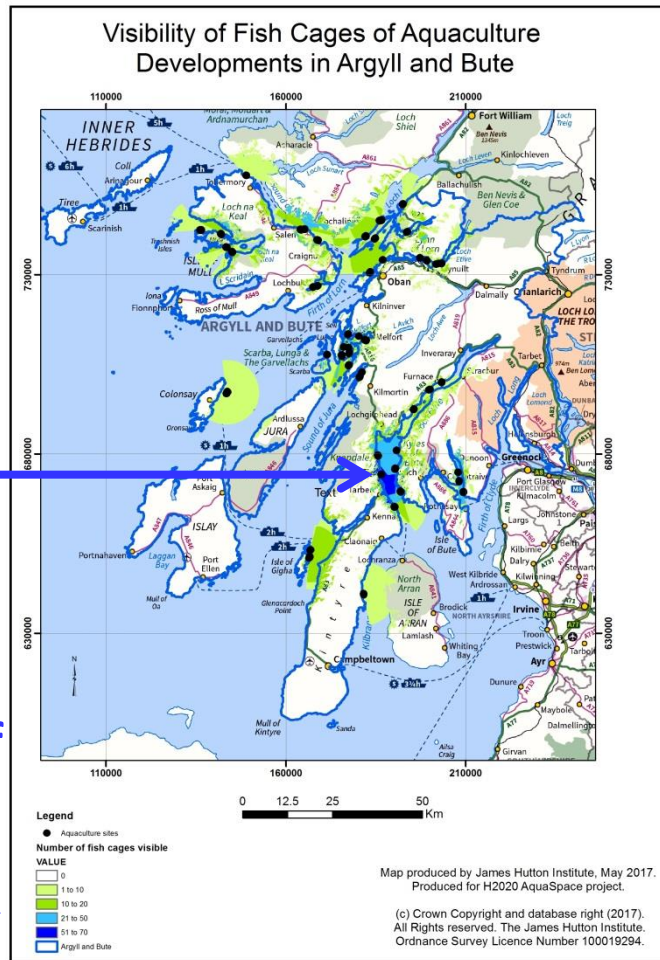


**Individual fish cages overlaid on Digital Elevation Model. Coastline shown and GIS visibility function interface**

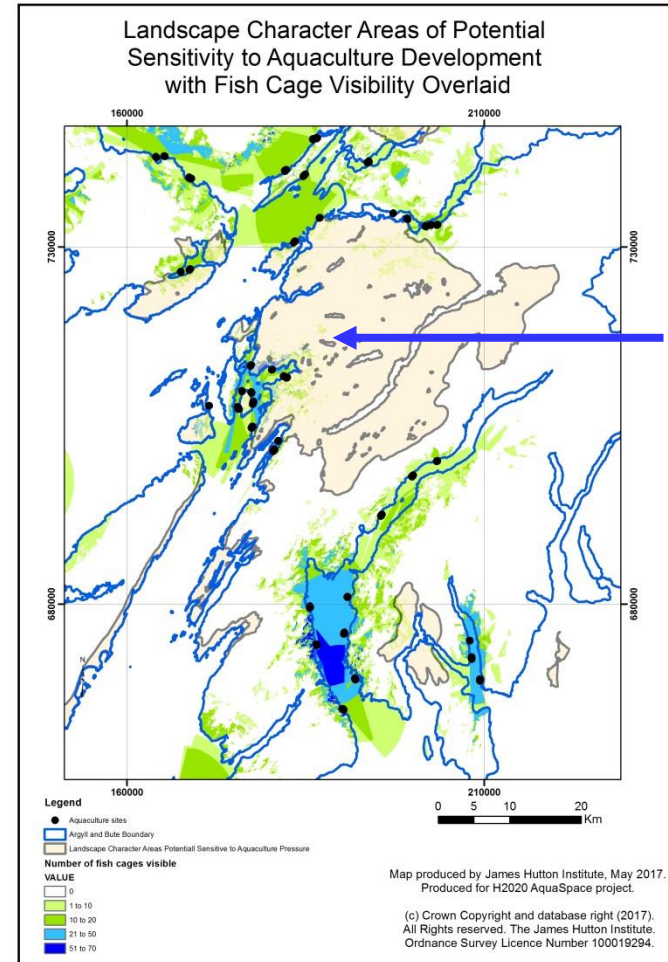


**Output of visibility calculation. Number fish of cages visible from land and sea within the extract of the case study area**

# Outputs: Visibility of Fish Cages



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

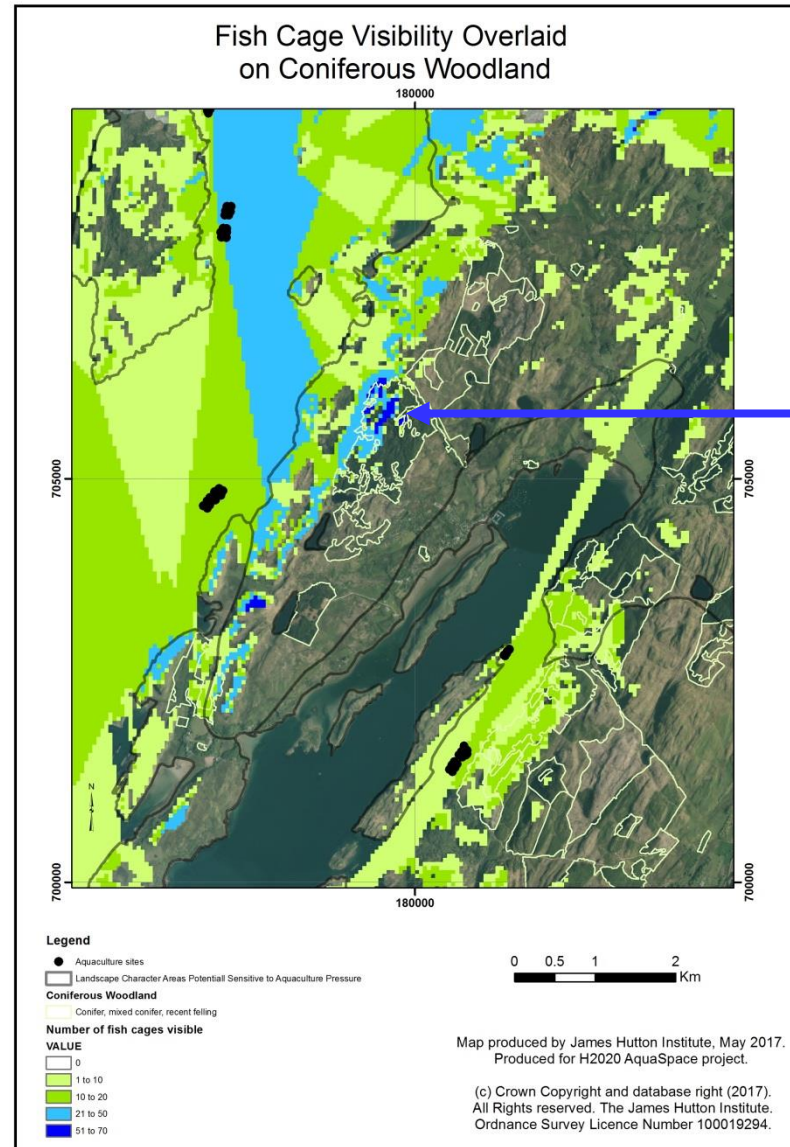


Number of fish cages visible, overlaid on landscape character areas identified as sensitive to aquaculture related development

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



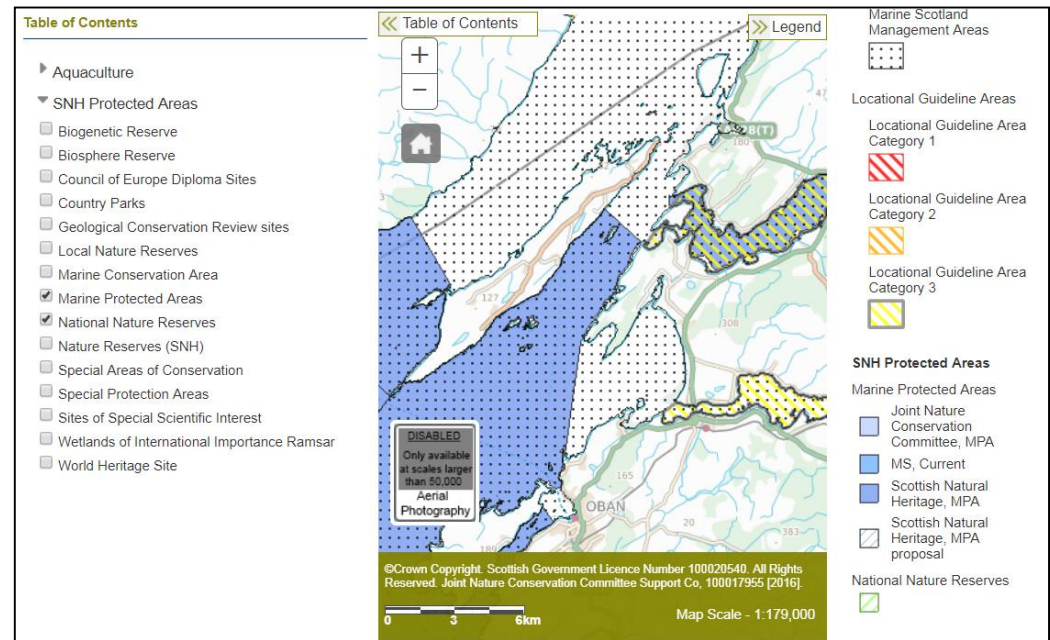
# Aquaculture and Seascapes: Conclusions

- 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>

# Further Reading

- General introduction
  - Heywood, I., Cornelius, S. and Carver, S. (2011) An Introduction to Geographical Information Systems, Prentice Hall 4<sup>th</sup> Edition, pp. 480.
- Senior managers and technology specialists
  - Tomlinson, R. (2013) Thinking About GIS: Geographic Information System Planning for Managers. 5<sup>th</sup> Edition. ESRI.
- ArcGIS desktop software
  - [www.esri.com/software/arcgis/arcgis-for-desktop](http://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](http://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=zIYHu60Z\\_ZQ](http://www.youtube.com/watch?v=zIYHu60Z_ZQ)
- Digitising in ArcMap (14mins) [www.youtube.com/watch?v=YYwhX-jhthk](http://www.youtube.com/watch?v=YYwhX-jhthk)
- Vector Buffers in ArcMap (5mins)  
[www.youtube.com/watch?v=PdRvCYMKQBk](http://www.youtube.com/watch?v=PdRvCYMKQBk)
- Selecting features in ArcMap (6mins)  
[www.youtube.com/watch?v=9rTN710KLfw](http://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)



Overview ▾

The Toolbox

Masters and CPD modules

Library ▾

Case studies ▾

## The Toolbox



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- **Materials**

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- **Data**

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- **Graphics**

- ESRI, [www.esri.com](http://www.esri.com), Slide 25

- **Video links**

- [Don Boyes](#), University of Toronto



For more information about  
the AquaSpace Masters module  
and spatial planning toolbox,  
visit our website:

[www.aquaspace-h2020.eu](http://www.aquaspace-h2020.eu)



Horizon 2020

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