

Introduction to Visualisation Issues and Tools

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Abstract

This text is part of unit 9 in a Masters-level course in 'Planning and Managing the Use of Space for Aquaculture' made by the AquaSpace project. It supports a slide sequence that introduces visualisation issues and tools in relation to planning for aquaculture. The unit includes examples of tools, and a conceptual framework to support the assessment, evaluation and interpretation of the potential visual impacts of aquaculture developments on seascapes. The data and examples are from the AquaSpace case study areas of Argyll and Bute, Scotland, UK, and south-east North Sea, Germany.

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1. Study Guide

This text was written during the H2020 Aquaspace project (2015-2018, contract no. 633476) for a Masters-level course in 'Planning and Managing the Use of Space for Aquaculture'. The course consists of a number of units; this unit introduces visualisation tools and associated issues. It includes definitions and descriptions of basic elements of visualisations, 3D models, and tools, and examples of a small set of basic GIS functions, and examples of its use as applied in Case Studies of the AquaSpace project. It is not a tutorial on the development of a 3D model, the use of a visualisation tool, or Geographic Information Systems (GIS).

The unit consists of a set of detailed slides, and the text that you are now reading, which provides a guide to the slide, plus additional reading and sources of information.

The learning outcomes for this unit are to be able to:

1. Explain why aquacultural developments are seen in particular ways within a landscape, and why this is important for spatial planning;
2. Critically describe a theoretical framework for these visualisation issues;
3. Select appropriate tools to investigate the issues.

2. Context

There are different uses of visualisation tools in relation to aquaculture developments: regulatory (e.g. Environmental Impact Assessments), public engagement and consultations, community input to local uses of land and sea. Recent guidance on visualisations for use in relation to aquaculture have been published by Scottish Natural Heritage (2018).

The European Commission's 'Strategic Guidelines for the sustainable development of EU aquaculture' (Slide 2) provide an overall context of identifying areas which are suitable for aquaculture. Associated with this are the requirements of regulations or good practice on public participation in decision-making,

and the protection or enhancement of natural resources, such as landscapes and seascapes.

The Aarhus Convention (Slide 3), signed in 1998, under the auspices of the United Nations Economic Commission for Europe (www.unece.org/env/pp/introduction.html)

established rights of people to:

- (i) participate in decisions that could have an impact on the environment;
- (ii) access to environmental information held by public authorities upon request. In addition, public authorities must actively collect and disseminate certain types of environmental information;
- (iii) access to justice regarding environmental matters to challenge a refusal or inadequate response to request for information; to challenge the legality of a plan or programme or a decision on a specific activity; or to challenge actions or omissions that contravene national environmental law.

Visualisation tools provide mechanisms to facilitate the right to participate, and support access to information.

The European Landscape Convention (www.coe.int/en/web/landscape), prepared under the Council of Europe in 2000, provides a framework and principles for the management, protection and promotion of landscapes (Slide 4).

It acknowledges that landscape is an important part of the quality of life for people everywhere - urban areas and the countryside, degraded areas and those of high quality, in areas recognised as being of outstanding beauty as well as everyday areas.

It also recognises "that developments in agriculture, forestry, industrial and mineral production techniques and in regional planning, town planning, transport, infrastructure, tourism and recreation and, at a more general level, changes in the world economy are in many cases accelerating the transformation of landscapes".

The development of aquaculture and associated infrastructure is another example of the pressures on landscapes.

Amongst its Articles, the Convention requires parties to establish procedures for the

participation of the general public, local and regional authorities, and other parties with an interest in the definition and implementation of the landscape policies.

As of 2018, 39 countries have ratified the Convention.

Visualisation tools have provided an increasingly important role in delivering on the Convention (e.g. public participation, visual impact assessments in EIAs).

3. Landscape Concepts

A framework is required for the discussion of aquaculture with respect to landscape and seascape.

The framework used in the AquaSpace project is a set of visual concepts, as described by Tveit et al., 2006, and Ode and Miller, 2011. These are based on theory, each concept of which is relevant to the visual quality of the landscape.

These concepts provide the basis for considering the contributions or impacts of aquaculture to the landscape and seascape.

The list of concepts is shown in Slide 5, together with photographs to illustrate landscapes of openness, coherence and imageability.

One of the 9 concepts is that of Stewardship (Slide 6). This is a concept which has been shown to be significant with respect to human preferences for landscapes. The concept of stewardship of farming and land management) has relevance to the characteristics of seascapes (e.g. aquaculture).

The concept of stewardship is summarised in terms of its dimensions, landscape attributes and indicators.

A proposed set of components of the concept of stewardship is shown in the context of seascapes.

4. Definitions

Sometimes, terms such as 3D, scientific visualisation and geovisualisation tools are used synonymously, but have different meanings. In Slide 7, definitions are provided

for three of the most common terms, and references to their sources.

5. Purposes

Evolution of the quality, nature and functionality 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.

Of these, 3D visualisations, associated tools, and their application in the context of public participation in environmental decision making, are steadily increasing in use. This also reflects continued reductions in price, increases in the capability and availability of computer hardware, visualisation software, and spatial databases.

However, there are certain requirements for the effective use of such tools. These include their role in the process of scenario development (e.g. participatory approaches), or assessment of implications (e.g. visual impacts of renewable energy, aquaculture).

Examples of the purposes of each type of use of visualisation tools, and related functions or outputs are summarised in Slide 8.

The requirements of the visualisation tools will not be the same for all purposes. The fit to purpose of tools will differ in terms of level of detail in a model (e.g. representation as schematic or photorealistic), interactivity (e.g. capability to fly, swim, or drive through an area, introduce or move individual features, switch on or off the representation of an aquaculture development to illustrate change), represent environmental conditions (e.g. viewing under different weather conditions or times of day or year), and viewing (e.g. as individuals or in groups).

MacEarchren and Kraak (2001) present a 'geovisualisation cube' (Slide 9) to describe the characteristics associated with visualisation materials with respect to the nature of the user and the implied level of expertise (here, assuming that experts and public are at opposite ends of that dimension), interaction (i.e. the level of interaction required), and information to be communicated. Drawing from the summaries of authors, the

requirements of 3D visualisation tools, often linked to wider ICT tools, are to:

- (i) provide access to up-to date information about a site or development.
- (ii) support inputs to discussion from the perspectives of different types of stakeholders (i.e. visually)
- (iii) visualise multi-dimensional environmental issues relating to different aspects of development (e.g. aesthetics, noise, water quality), often from different viewing perspectives.
- (iv) enable stakeholders to interact with or modify plans.

A checklist of model requirements and outputs is provided in Slide 10.

The level of detail of a model will differ according to its purpose, or the model and representation of the area or scene. Depending on the objectives of visualisations, there are high demands on computing resources.

An example of designing models of different levels of details image is shown in Slide 11. Three different representations are shown of the same landscape in Switzerland (based on work by Schroth *et al.*, 2011, and Sherman and Craig, 2003). The top image is developed in software to produce a simulation with detail to the level of individual plants in the foreground, whereas the bottom image is a stylised representation of the same landscape.

The relevant terminology for the representation of the different levels of detail is shown on the slide.

6. Visualisation Software

Numerous packages provide capabilities for the creation of visualisations (Slide 12). These use different types of spatial data as inputs, largely dependent upon purpose and topic. For example:

- (i) Computer Aided Design models of individual features (e.g. boats, fish cages);

- (ii) Digital Terrain Models for the topographic structure of 3D models (e.g. water catchments, lochs/lakes);
- (iii) Imagery for providing textures (e.g. aerial imagery for large area coverage, detailed textures for individual features of buildings, vegetation).

Visualisation software packages have different strengths and functionality (e.g. user programmable code for interactivity, high quality rendering of still imagery, design of walk/swim-throughs and export of movies).

Such strengths are reflected in their use (e.g. architectural or development design, regional/strategic level perspective views).

Some packages are Open Source (e.g. Google Earth), but most are commercial (e.g. VegaPrime, Maya).

Licensing and costs of visualisation packages vary considerably depending upon national and institutional (e.g. academic) arrangements.

Examples of applications of visualisation, shown in this Module, use the five software packages listed.

7. Hardware

In addition to the use of a computer screen for displaying visualisation materials, there are several forms of specialist hardware facilities.

Two examples are provided here which were used in the AquaSpace project.

- (i) Virtual Landscape Theatre - a mobile curved screen projection facility, in which people can be 'immersed' in 3D models of an environment, used to explore or design landscapes and seascapes. It enables audiences of up to 16 to have a shared experience of the representation of the environment. Associated hardware is the use of voting handsets for recording the opinions of the audience about specific topics. Further details are available at: www.hutton.ac.uk/learning/exhibits/vlt
- (ii) Head Mounted Displays, sometimes referred to as Virtual Reality headsets (e.g. Oculus Rift), which are headsets in which the user can explore and experience a 3D environment. Only one

person can use a headset at a time, although other attendees can watch a version of the view as it is presented on a computer screen.

Each of these types of visualisation hardware have been used with audiences from public policy, industry stakeholders and public (including young people). Each has proven effective in achieving the aims of the activity, and engaging the audience (Slide 13).

8. Creation and Use of VR Model

Generally, the underlying spatial data for geovisualisations are a representation of the topographic surface, which can be of the sea floor as well as surface terrain. On to this topography textures are mapped, such as 'draping' it with representations of the surface (e.g. aerial photography) or features (e.g. trees, forests, buildings, etc.).

An example of the process used in the study of aquaculture was the creation of a unique 3D dataset for the Firth of Lorne and Loch Linnhe area of the west coast of Scotland.

This used the latest sea floor mapping bathymetry (INIS Hydro, www.inis-hydro.eu) (Slide 14, top right image), merged with that of the surrounding terrain surface using Ordnance Survey elevation data, enabling a continuous representation of the earth's surface (Slide 14, bottom left image).

Associated with the topographic surface maps, aerial imagery and contextual details were built into the spatial database, together with land and sea designations (e.g. Slide 14, bottom centre image).

The overall model created was referred to as the AquaSpace Virtual Reality Coastal Model.

The model could then be used within different types of visualisation tools for engagement with public audiences, such as the Virtual Landscape Theatre (Slide 14, bottom right image).

The input data are transformed for reading into relevant 3D modelling tools. These modelling tools have different approaches to importing the data.

In Slide 15, the images show wireframe representations of the 3D model of the seascape around Loch Linnhe. The model comprises terrestrial topography and the seafloor merged into one dataset. This wireframe is imported into the relevant software package.

Included in the model are two types of fish cages, shown in their correct geographic locations.

9. Seascape Characteristics

Ephemeral characteristics of landscapes and seascapes are important for the visual coherence and interpretation when representing seascapes. This is significant when interpreting changes in the uses of land and sea within a seascape; landscape preferences; and, ensuring a high level of credibility of the visualisation imagery with audiences.

Factors of significance with respect to provision of a credible landscape scene, and enabling interpretation in relation to stewardship, coherence, naturalness, visual complexity, are: the presence of shadows, reflections off the water, the movement of waves (and associated changes in reflections), shadows (e.g. of moving wind turbine blades or features moving across the water), and weather.

Findings from research by Bishop and Miller (2007) showed that distance and contrast were found to be very good predictors of perceived impact of wind turbines, and thus clarity of the view is important, and thus whether to represent prevailing weather conditions is relevant to consider.

Slide 16 shows visualisations in which the types of ephemeral characteristics are represented in the visualisations (e.g. shadows, waves, reflections). The images are from the AquaSpace Virtual reality Coastal Model of the Loch Linnhe area of the west coast of Scotland, UK.

The focus of attention is on use of the sea, not the detail of the surrounding vegetation or buildings. The terrain provides context and a backdrop to most of the uses of the model, and

thus the visualisations. Therefore, the level of detail of the terrain is lower than that of the features in the loch (e.g. using aerial imagery as data on terrain textures).

In Slide 16 ...

(i) The left image shows a view of the loch in which a hypothetical offshore wind farm has been constructed (as an example of a potentially competing use of the coastal waters). The still image is from an interactive 3D model in which there are clouds (moving), a water surface which is animated (i.e. surface waves), and supports reflections off the water surface (e.g. of wind turbines and clouds) and shadows cast across it (e.g. from wind turbines). The height and frequency of the waves can be modified in the model design (i.e. to represent different weather conditions), as can the speed of movement, and types of clouds.

The level of detail of the wind turbines (e.g. clearly identifiable ladders and safety barriers on the access platform) is compatible with that of the water surface (i.e. there is coherency between the detail of the waves and that of the fish cages).

(ii) The right image shows three rectangular fish cages of an actual fish farm located in the loch. Each cage in the model is in their correct georeferenced location. The movement of the water is around the cages.

The level of detail of the cage (e.g. clearly identifiable fencing around the upper part of the cage) is compatible with that of the water surface (i.e. there is coherency between the detail of the waves and that of the fish cages).

10. AquaSpace Virtual Reality Model

The AquaSpace VR Coastal Model was created to enable the exploration of hypothetical uses of land and sea, designed around a real place of south Loch Linnhe, in coastal west Scotland.

Use of a real rather than hypothetical area enables:

- (i) the use and testing of real observation data,

- (ii) testing the compilation of novel databases that involve seafloor and terrestrial surfaces,
- (iii) a real context of uses of land and sea with which to discuss potential impacts of change with stakeholders and the public,
- (iv) the inclusion of real aquaculture developments, and discussion of issues that arise.

The use of a 3D model enables:

- (i) the inclusion of features associated with hypothetical developments (e.g. aquaculture expansion, renewable energy, leisure and recreation),
- (ii) the exploration of options for combining features for their compatibility or incompatibility,
- (iii) testing of public opinions of potential future uses of land and sea.

The AquaSpace VR Coastal Model is used to provide 'safe space' for audiences to explore environments that are inaccessible to most people (e.g. a fish cage, offshore wind turbine).

To inform groups of stakeholders or public, the AquaSpace Virtual Reality Coastal Model is used in the Virtual Landscape Theatre, and for individuals it is implemented for use in VR Headsets (Slide 17).

In Slide 18, the images show extracts from a tour of the hypothetical wind turbines placed in the Loch Linnhe coastal area.

Left image: discussing the dimensions of renewable energy structures (e.g. wind turbines).

Right image: navigating the audience towards the access platform on an offshore wind turbine.

The AquaSpace Visualisation Tool provides an interface to support the design and development of options for uses of land and sea. The aim is to enable the creation of seascapes by stakeholders and, or the public.

The Visualisation Tool provides:

- (i) preset scenarios of development of aquaculture and renewable energy (offshore wind turbines and tidal energy systems),

- (ii) preset viewpoints for viewing the seascape from above or below the surface of the water,
- (iii) features for adding into the 3D model, and ‘drag and drop’ of the features into places at the choice of participants (relevant icon in green),
- (iv) the drag and drop tool can also be used to identify places where participants do not want particular types of development (relevant icon in red)

The image in Slide 19 shows the interface to the AquaSpace Visualisation Tool.

11. Seascape Creation

The process of participants from stakeholder and public audiences creating seascapes uses the AquaSpace seascape design tool, part of the AquaSpace Visualisation Tools.

The implementation of the AquaSpace Visualisation Tool in virtual reality environments has been designed to enable:

- (i) the display of a 3D model,
- (ii) navigation through the model,
- (iii) switching between scenarios of selected different uses of the land and sea (e.g. switching on and off wind turbines in a hypothetical development, wave energy development, aquaculture developments),
- (iv) adding new features (e.g. wind turbines, fish farm cages, leisure craft) and relocating them within the model (i.e. ‘drag and drop’ features in the model).

The seascapes designed are saved, and participants use voting handsets to record answers to set questions about what and why they chose certain options. Examples of it in use and the screen are shown in Slide 20.

12. Public Engagement

Visualisation tools and models were used in public engagement events to raise awareness of aquaculture, and the identification of issues associated the uses of land and sea (Slide 21).

Presenting audiences with scenarios of potential future uses of coastal areas provides a basis for talking through opportunities,

conflicts and the identification of new ideas for uses of land and sea.

Discussing issues which link above and below water elicits opinions and feedback on synergies. For example, siting aquaculture in the vicinity of areas of other forms of natural resource exploitation (e.g. visual and audio evidence of quarries) and primary production (e.g. visual evidence of forestry and agriculture).

Added value is obtained by engaging stakeholders and public audiences of all ages in science and research.

Example topics identified by public audiences in engagement events, such as those using the Virtual Landscape Theatre, were:

- (i) the compatibility of aquaculture and farming in many coastal landscapes, in the appropriate places;
- (ii) unknown potential of impacts of changes in land use on the quality of water in areas of aquaculture.

Slide 22 illustrates an example of the type of impacts in relation to compatible uses of land and sea in close proximity.

13. Visualisation

i) At Site level

A 3D model, with content of a high level of detail, has been implemented in a virtual reality environment (Slide 23).

The level of detail enables user recognition of individual features and its components (e.g. netting around the above water structures of the fish cage, spacing in the netting, ties of netting onto frame of cage, individual fish and the detail of the texture of the fish, wash from the propeller of the dinghy, etc.).

The model is imported into a virtual reality environment. This enables functionality for interacting with the model, examples of which are:

- (i) navigation through the model using hand consoles;
- (ii) triggering individual actions (e.g. switching on and off the dinghy engine, ‘jumping’ on and off the dinghy);

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(iii) switching on and off the feeder system.

Visualisation tools have been used to raise awareness and understanding of aquaculture.

Prototype model is courtesy of Anders Bøe, Norwegian University of Science and Technology, implemented by the James Hutton Institute.

The site level 3D model is used in visualisation tools that enable:

- (i) new information about aquaculture sites to be obtained by the user, generally the public;
- (ii) the identification of issues that people associate with aquaculture in relation to landscapes and seascapes;
- (iii) feedback on the visualisation tool and the constituent 3D model themselves.

A summary of the feedback on what was learnt about aquaculture, the issues identified, and on the tool and 3D model are summarised on Slide 24.

ii) At Regional level

To support interpretation of information of aquaculture and landscapes at a regional level relevant data were imported for use in Google Earth.

In addition to the basemap data provided in Google Earth data included are:

- (i) natural heritage designations of relevance to marine spatial planning and landscapes (e.g. National Scenic Areas, Landscape Character Assessment, RAMSAR, Marine Protected Areas, Marine Consultation Areas, World Heritage Sites);
- (ii) the locations of the fish cages, and their details, and feeder stations in the case study area in Scotland, UK, of Argyll and Bute;
- (iii) derived data (e.g. output of visibility calculations representing the number of fish cages visible across the case study area and its immediate surroundings).

In Slide 25, the left image shows the visibility of fish cages (shown as points), draped across aerial imagery representing land cover and use in the area between Loch Melfort and Isle of Shuna in Argyll and Bute.

The right image shows an overview of northern Argyll and Bute, overlaid with selected natural heritage designations and Landscape Character Assessment (LCA), and a query box of an LCA unit.

The data on fish cages in Google Earth can be accompanied by additional imagery relating to an aquaculture development. This could include alternative layouts of the fish cages.

In Slide 26, an example is shown of the previous locations of 10 fish cages at a fish farm in the west coast of Scotland, UK, in the left image, and a scenario of expansion of the fish farm with the addition of three cages as shown in the right image.

The user can switch between layouts, providing the basis for questions about landscape preference or visual impacts.

The use of the Google Earth interface takes advantage of a widely available software resource, with low entry cost for its use, and a number of well-understood ways of the user adding their own data.

Therefore, the Google Earth approach provides the infrastructure of a visualisation tool, means of tailoring its use for a specific interest, area or audience, and ease of dissemination via the internet to an international audience.

With respect to aquaculture in seascapes, participant reactions to changes in layout were greatest when the proportion of the field of view of the observer in which cages were visible, and identifiable, increased significantly (e.g. conveying a visual impression of enclosure of an area of coastline by cages).

There was limited participant recognition of expansion, when viewed as though standing at the coast, due to low contrasts between structures and the background (e.g. water, land use). The size of larger structures (e.g. feeder stations was more evident).

14. Dissemination

The tools are used to facilitate the dissemination of research findings.

The Aquaspace visualisation toolset has been used in public engagement events designed for different types of audiences. Their content and

use can be tailored to suit the purpose of the event, the context of the venue, as well as the audience.

The demonstrations enable participants to:

- (i) obtain hands-on experience of the virtual reality environments used in the research and public engagement regarding aquaculture; and
- (ii) learn about key findings relating to spatial planning of aquaculture and multiple uses of land and sea whilst protecting environmental quality.

Factors to consider when designing dissemination using such tools are:

- (i) Key messages to be conveyed (e.g. specific research findings; information about research approach; advance information on upcoming research activities, so partially participant recruitment);
- (ii) Audience (e.g. age; geography of origin; expertise in topic; knowledge of area of interest; restricted mobilities or capabilities);
- (iii) Event (e.g. multi-purpose event; single purpose dedicated to the one topic);
- (iv) Venue (e.g. public hall with several events going on in parallel, thus creating competing noise; context of lighting, layout, access);
- (v) Timescale (e.g. 5 minutes – visiting politician; 30 minutes, 1 hour, etc.); scheduled event (e.g. every hour, or ‘drop-in’);
- (vi) Means of recording event (e.g. video, photographs), feedback forms, and ensuring relevant ethical clearance (e.g. permission to photograph).

These considerations will inform the selection of hardware (e.g. large enough for Virtual Reality theatre, desk space for Head Mounted Displays), approach to communicating messages, and the support materials required.

The 3D models used will support the nature of the activity of dissemination (e.g. reprise the approach of the research activity, representing the key findings).

Associated tasks are addressing issues of ethical clearance (e.g. of photographs) and health and safety relating to the event.

15. Main Findings

Key findings (Slide 30) on issues relating to seascapes and aquaculture, derived from work using visualisation tools with stakeholder and public audiences are:

- (i) positive associations between aquaculture development and other forms of primary production within the same views (e.g. farming, forestry, renewable energy production);
- (ii) positive contributions of aquaculture developments to seascapes where there are associations with evidence of good stewardship of natural resources, visual complexity (e.g. add interest to a scene), coherence (e.g. link to cultural roles in crofting areas of north and west Scotland);
- (iii) perceptions of negative contributions to seascapes where aquaculture development was perceived as poor stewardship and management of resources, reducing the naturalness of a scene (e.g. with increased human intervention), or incoherent in the composition of a seascape;
- (iv) other negative associations were where aquaculture was perceived as being intrusive (e.g. where there were competing activities such as leisure and recreation, historically significant features or inconsistent with a sense of remoteness).

16. Future Opportunities

Future development, opportunities and uses of visualisation is being enabled by the rapid development of tools, at a cost which makes them more accessible to wider audiences.

New types of tools are emerging that increase the scope for new applications. Tools that enable more efficient approaches to planning (e.g. aquaculture) are being sought, and transformations in planning being promoted (e.g. Scottish Government Digital Task Force considering transformations in planning).

In education, schools and university courses are having VR headsets purchased for uses beyond ICT. The OECD, EU and national

governments are stressing the need for innovation to contribute to addressing societal challenges, including rural issues and increasing employment (Slide 31).

17. Further Study

Extensive reading on the general topic of geovisualisation is available online. A general introduction to visualisation in geographically related applications is provided by Dykes et al. (2005). Further reading on the general topic of visualisation for communication is provided, by Carl Steinitz in his book “A Framework for Geodesign: Changing Geography by Design”.

See www.hutton.ac.uk/learning/exhibits/vlt for details of the Virtual Landscape Theatre (VLT) This includes information about the hardware, software and the applications of virtual reality with public and stakeholder audiences.sz

Details of the references, video materials, together with hyperlinks to relevant WW sites, are provided on Slides 35 and 36.

Further information on the visualisation tools developed by the AquaSpace project is available in the Toolbox page of the [AquaSpace website](#).

An introduction to Geographic Information Systems (GIS) is provided in unit 5 of this Masters Module.

18. Acknowledgements

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- (i) James Hutton Institute, UK.
- (ii) Map images use data from Ordnance Survey under licence to James Hutton Institute.
- (iii) Google Earth and data suppliers
- (iv) Aquaculture site model from Anders Bøe, Norwegian University of Science and Technology
- (v) Thanks to all the participants at the stakeholder, public engagement and dissemination events at which the visualisation tools were tested and used.

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