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Visual, seascape and landscape analysis to support coastal aquaculture site selection

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ABSTRACT

The visual impact of aquaculture is a controversial issue and in some countries must be assessed prior to any new development. However, at present, there are no definitive, objective methods used to evaluate the potential visual impacts of new aquatic farms and therefore assessment is difficult for both developers and regulators. This study presents a GIS based methodology for use in the visual assessment of a potential new coastal fish farm development, focusing on both sea cages and the associated land based structures. The methodology has been applied to a case study area, the Western Isles located off the North West coast of Scotland, which already has an extensive aquaculture industry and significant potential for future growth.

Using a two stage sequential modelling process, the methodology combines visual, seascape and landscape analysis within a GIS environment to produce spatial models indicating where there is the potential for new aquaculture development with minimal visual impact. The preliminary visual assessment model combines a series of Boolean viewsheds with landscape and seascape sensitivity models to assess the potential visibility across different user groups and the sensitivity of the area to visual change. The second stage focuses on an area identified from the preliminary model as having potential for development and then performs a more detailed analysis using a site specific proportional visual impact model. This model quantifies the impact by assessing the proportion of viewpoints from which the proposed development can actually be seen. Both stages of the modelling process provide valuable information and support for decision makers regarding the potential visual impacts of aquaculture.

Introduction

On-shore and offshore aquaculture activities have varying visual impacts on landscape and seascape quality and in recent years these visual impacts have become more important in relation to other environmental issues. The visual impact of aquaculture can be a contentious issue, particularly in remote or rural areas, and may be a source of conflict between those who value the industry as a livelihood and a source of income and those who wish to keep the area unspoiled (Kumar and Cripps, 2012).

Landscape impact assessment is normally a required element of an Environmental Impact Assessment (EIA) and it describes the likely impact of changes to the landscape from the type of activity being evaluated (Knight, 2009). Landscape sensitivity is used to assess the degree to which a landscape can accommodate the type of change being predicted (Knight, 2009) and, under the guidelines set out by the Landscape Institute and Institute of Environmental Management and Assessment (2002) in the UK, in order to fully assess landscape sensitivity it is necessary to assess the visual effects of any development.

Although assessment of the visual impact of a development is required as part of an EIA there remains no fully objective method to set a threshold for perceived adverse visual impacts of objects in the environment (Mouflis et al., 2008). The main existing techniques currently involve mapping of zones of visual influence, visual envelopes or visual corridors. These are often hand-drawn on to maps with annotations defining the important characteristics and highlighting possible changes that would occur if a development were to proceed. The information provided in a visual analysis should reflect the likely numbers of public receptors which can be wide ranging groups such as tourists or local communities, the significance of the view, and the likely sensitivity of the receptors. The significance of the view is defined by the proportion of the visual receptors within the study area which are likely to experience the new structures. Photomontages are employed to help visualize changes from particular locations and to examine methods to reduce adverse visual impacts. These methods are time consuming and are usually carried out by specialist landscape architects.

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Bishop and Hull (1991) identified five basic functions which are important in creating a concise visual assessment; clear identification of the various types of impacts, organization of spatially and temporally dispersed inventory data, prediction of impacts based upon potential land use decisions, a usable interface between these functions and the planner/manager and effective communication of potential impacts to the public and decision-makers. In the UK, these functions are further complemented by guidelines set by the Countryside Agency and Scottish Natural Heritage (2002). When assessing seascapes, specific guidance can be found in only a few studies, including Hill et al. (2001) and Grant (2006). The determination of seascape characters is also important for aquaculture planning in New Zealand (Rennie et al., 2009) and within marine spatial planning in Ireland (Flannery and Cinnéide, 2008). Scottish Natural Heritage (SNH) has conducted a pilot study in the Outer Hebrides assessing landscape and seascape capacity for aquaculture which informs the Aquaculture Supplementary Guidance and Local Development Plan for the area (ASH Design and Assessment, 2011).

Objective visual analysis can be based on a viewshed approach (Kim et al., 2004) which is a widely used technique in the Geographic Information System (GIS) environment (O'Sullivan and Turner, 2001). Viewshed analysis determines the visibility of pixels across a surface from selected viewpoints (Eastman, 2012). Successful implementation of viewshed techniques can be seen in a range of diverse studies such as determining visual impact of quarries (Mouflis et al., 2008), evaluating environmental amenities, particularly views and open space access and the impact this has on residential home sales (Sander and Polasky, 2009), optimal path route planning (Lee and Stucky, 1998), wind turbine placement (Benson et al., 2004; Devereux et al., 2008) and archaeological visualization (Wheatley and Gillings, 2000).

This study focuses on assessment of visual impact for coastal finfish farming, an activity which involves both land and offshore based structures. The overall aim is to develop GIS-based models for the objective analysis of visual risk with a view to minimizing negative visual impacts on the wider environment.

The study area

The study area for this research was the Western Isles or Isles of the Hebrides, which are renowned for their "stunning combination of striking landscapes with an elemental beauty" (http://guide.visitscotland.com/). Located off the North West coast of Scotland (Fig. 1), the five main islands of the group, Lewis, Harris, North Uist, Benbecula, South Uist and Barra, have a combined coastline length of 2103 km and are currently home to an extensive aquaculture industry which produced 37,069 tonnes of Atlantic salmon in 2011 and which has significant potential for future growth (Scottish Government, 2011).

Model components and development

Visual impact assessment was based on analysis of visual sensitivity, landscape sensitivity and seascape sensitivity, from which two GIS-based models were developed as a two-stage process acting in sequence, to represent the potential for sea cages and associated land based structures. The first stage is a preliminary visual model where a series of Boolean viewsheds are combined with landscape and seascape sensitivity models to produce an overall visual impact model. This model can also be used to identify areas that would be suitable for aquaculture development. The second and final stage is a site-specific visual impact model which uses proportional viewsheds for more detailed quantitative examination of a selected potential aquaculture area identified from the preliminary visual assessment model. All model components were developed in the IDRISI Selva GIS environment (Clark Labs, Worcester, MA) and all layers were geo-referenced to UTM-29N with a spatial resolution of 30 m.

Preliminary Boolean visual assessment model

The preliminary visual model identifies those areas which would have minimal impact on views and scenery following the development of either sea cages or land based structures. The preliminary model has three components: a Boolean viewshed model, a landscape sensitivity model and a seascape sensitivity model (Fig. 2). The landscape and seascape sensitivity models are interchangeable depending on whether the model is being used to assess the potential for land structures or sea cages. Each component can be used for individual assessment purposes in addition to their contribution to the overall model.

Boolean viewsheds

When assessing the visual impact of an aquaculture development it is essential to consider both elevation and distance of any viewpoint to the development (Grant, 2011), both of which can be taken into account using viewshed models. A Boolean viewshed model determines all of the visible cells from either single or multiple viewpoints across an elevation surface and assigns a value of 1 to all visible cells and 0 to non-visible cells (Eastman, 2012). While this viewshed analysis process can explore and quantify any defined visual envelope, there are no specific guidelines for calculating visual limits for aquaculture. A visual limit of 10 km is recommended for single storey houses by SNH, Scottish Society of Directors of Planning and Scottish Renewables Forum (2006) and was used in this study for land based structures. As sea cages have a lower profile than buildings, a 5 km visual limit is considered more appropriate given the visibility of structures at sea level and the curvature of the earth (Bohren and Frazer, 1986). The potential visibility of a cage could vary depending on the proposed size, type and colour of a structure; therefore if necessary the model could be adapted to use a different visual limit if required.

From an analysis of the study area six input layers representing key viewpoints were developed: A roads, B roads, minor roads, ferry routes, buildings and important viewpoints. It is necessary to consider transport links in this visual analysis as they are vital routes for the local community and also tourists who may want to admire the scenery as part of their journey. The roads and building layers were extracted from the Ordnance Survey Land-Line data from Edina Digimap (http://edina.ac.uk/digimap/) and the ferry route layer was digitized from data published by the ferry operator. The important viewpoints layer was taken from a previous study by Benson et al. (2004) which contained 47 ground-truthed points representing a variety of important viewing areas such as walks, dramatic coastlines, monuments and other popular viewpoints.

The Digital Elevation Model (DEM) used for this study was Landform profile 1:10,000 scale data sourced from Edina Digimap (http://edina.ac.uk/digimap/) which provided height data as 5 m vertical interval contours with ±1 m accuracy. Minor errors in the source data were corrected by converting the contour vectors to points and then creating a final DEM by interpolation. The DEM was further modified by increasing the height of those pixels representing built structures to allow for observations from the first floor of a building.

An additional DEM was produced for the ferry routes which used the original DEM but modified it to take into account the height of the ferry. The "observer height" from a ferry will vary depending on the swell, position in the water, ship size, etc. Caledonian MacBrayne PLC currently operate five different ferries within the