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Many Points of View: Visibility Mapping for Marine Spatial Planning*

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Abstract

In order to manage and facilitate economic growth while safeguarding environmental objectives in the marine environment, new European legislation mandating the development of Marine Spatial Planning (MSP) using an ecosystem approach has been introduced. One critical component of the ecosystem approach is the inclusion of ecosystem services into management decisions. In order to contribute to the planning process a map of the visibility of the entire Scottish national Exclusive Economic Zone was produced using cumulative viewshed analysis and displayed using a novel dynamic web display system. The layer maps the spatial distribution of one aspect of cultural ecosystem services, the visual amenity of coastal areas and is being used in the Scottish Marine Spatial Planning process.

Keywords: Marine Spatial Planning, Viewshed analysis, ecosystem services

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1. INTRODUCTION

In order to facilitate economic development while safeguarding marine ecosystems and the ecosystem services they supply, the European Framework Directive on Maritime Spatial Planning (MSP) (European Commission, 2014a), a component part of the European Integrated Maritime Policy (IMP), mandates that European member states develop national Marine Spatial Plans for their Exclusive Economic Zones (EEZ). The Directorate General for Maritime Affairs has identified specific "Blue Growth" sectors where there is particular potential for economic growth to be stimulated thorough the IMP and facilitated through MSP, these include aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining (EC, 2017) many of which can have visual impacts on the marine environment. The directive requires member states to cooperate on a regional seas basis and to take an Ecosystem Approach (EA) to management, which is considered synonymous with Ecosystem Based Management (EBM) (Mee et al., 2015). The EA ideally takes a multi-sectoral focus, incorporates considerations of ecosystems services and recognises the tight coupling between social and ecological systems (Tallis, 2010).

Ecosystem services are the benefits obtained by humans from nature and these include provisioning services (such as the provision of fish for human consumption) as well as cultural service, the non-material benefits people gained from ecosystems, as well as regulating services (e.g. flood protection). Cultural services include active (e.g. swimming and aquatic recreation) and passive use values (such as the enjoyment of a view). Data are critical to implementation of the EA to management (Sarda et al., 2014). For European marine environments physical, chemical and biological data resulting from scientific research cruises and fish stock assessments are readily available and the spatial data infrastructure to facilitate broad access to marine data are well developed through international and national initiatives O'Higgins (2016). However, in many cases there is insufficient information particularly on the value, supply and demand of ecosystem services to fully support the EA (Pendelton, 2007; O'Higgins 2010; O'Higgins and Gilbert 2014) and recent EU initiatives to map ecosystems have been limited to terrestrial and freshwater domains (Maes et al, 2013).

In many cases critical information regarding human cultural values, which have the potential to inform planning, facilitate development and mitigate against conflicts are lacking or absent. Such missing information include spatial data describing small scale fisheries, and active and passive recreational use values (St Martin and Hall-Arber, 2008). There have been many attempts to find novel ways of incorporating different sets of values into the ecosystem approach to management and Marine Spatial Planning e.g. (Alexander et al., 2012; Mayer et al., 2014, Veidemane et al., 2017) but these initiatives constitute exceptions rather than norms. While collection of spatial information of local use values for particular ecosystems can facilitate planning in specific local contexts and help to solve location specific problems (eg. Potts et al., 2015), at the practical level it has generally not been feasible to collect visual amenity data encompassing a countries' entire EEZ, and regional governments and local authorities with responsibility for implementation of the EU policies and directives are often constrained by a limited amount of time and new resource to gather data (see for example EC, 2014b). Novel uses of existing information for incorporation into the development of marine spatial plans may well therefore play an important role in the emerging marine planning process.

Visual amenity is one critical parameter which has great potential to cause conflict in the marine planning process. The aim of this paper is to contribute to Marine Spatial Planning by illustrating a methodology for mapping of visibility of coastal waters, from land, a component of visual amenity, and to demonstrate the utility of this method as strategic planning tool to contribute to the MSP process.

2. METHODS

2.1 Study area

Though a devolved authority of the United Kingdom, Scotland has declared an Economic Exclusion Zone (EEZ) and, for the purposes of marine planning, has defined 11 marine regions extending over Scottish territorial water to a distance of 12 nautical miles (Figure 1). In order to establish marine spatial plans, regional planning partnerships are being developed in each of these regions.

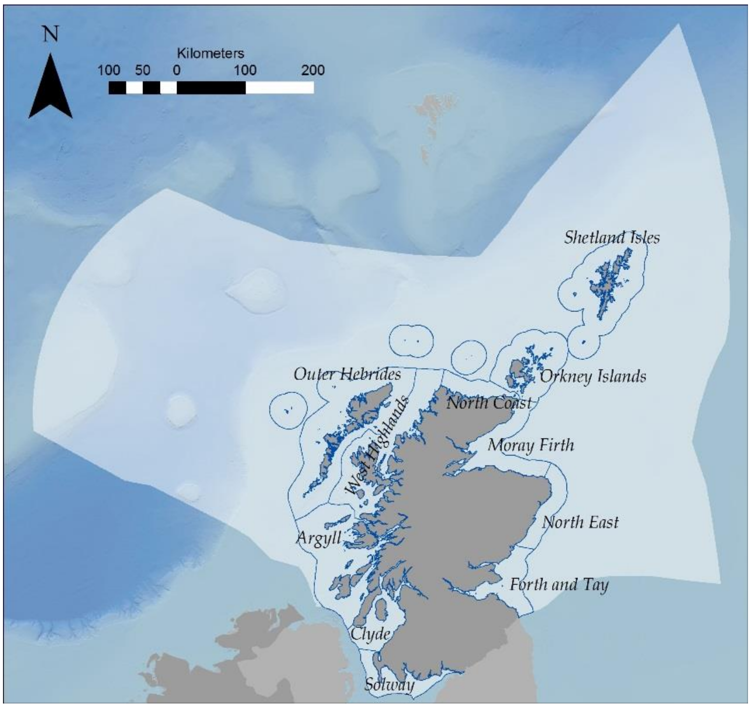
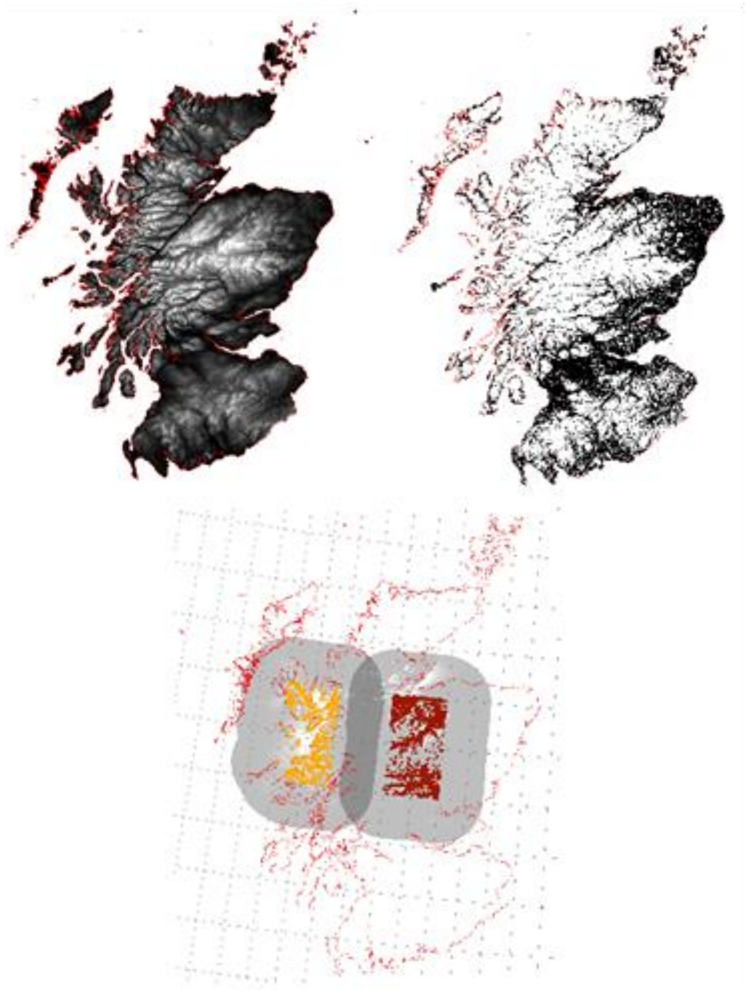


Figure 1: Scotland's marine territories and regions

2.2 Analysis

A viewshed is a geographical area that is visible form a particular location, viewshed analysis uses the elevation value of each cell of a digital elevation model to determine visibility to or from another cell. In order to explore the visibility of Scotland's Exclusive Economic Zone from land a viewshed analysis was performed in Arc GIS 10.2. Refractivity, the level of deviation of light as it passes through the atmosphere, was set to 0.13 (the default) and the curved Earth option was used, a similar viewshed analysis tool is available in QGIS. Elevation data from the EU-DEM (Digital Elevation Model) was obtained from the European Environment Agency (http://www.eea.europa.eu/data-and-maps/data/eu-dem), the data have a 1 arc second (approximately 30m) resolution (Fig 2a). The UK Ordnance Survey Open Data buildings layer (https://www.ordnancesurvey.co.uk/business-and-government/products/opendata.html), provides polygons for every building in the UK, data were extracted for the whole of Scotland and converted to point data resulting in a total of 1.26M locations (Fig2b). In order to achieve manageable analysis times, given the large size of the data sets and large amount of processing required, data were further subdivided into blocks based along lines of latitude and longitude. A buffer of 50km was constructed around each block, the ‘extract by mask’ tool was used to extract the buffered areas from the Digital Elevation Model and the analysis for each block was conducted using these buffered subsets (Fig 2c). As a final step the buffered viewshed areas were combined using the weighted sum tool in the Spatial Analyst toolbox, with a weight of ‘1’ being assigned to each raster. Areas of missing data were filled using nearest neighbours interpolation.

Figure 2 a) The Digital Elevation Model for Scotland. b) The buildings layer from the Ordnance survey. c) Example of the division of the buildings layer by latitude and longitude and the generation of the buffered overlay.



The resulting product was a layer with approximately 30m resolution containing spatial information on the visibility of marine locations, expressed in terms of the number of buildings with a view of any given location. Throughout the analysis the numerical units for the term ‘visibility’ represent the number of buildings with a view of a particular location, or number of views.

In order to visualize the data on the web, a novel technique was developed to enable more rapid interpretation of the data, this tool can be viewed at http://griffith.ucc.ie/demtools/. The user interacts with the system using web-GIS. As the user explores maps in the web-GIS (i.e. pan and zoom), map portrayal requests are sent to the server using the Web Map Service (WMS) standard. The architecture supports normal WMS requests and extended WMS requests concerning the viewshed datasets. This extension is called WMS-View and is a special use case extension of the WMS standard supporting the portrayal of View datasets. View requests are routed to the WMS-View server. The View layers are registered in the WMS server broker. Therefore, the broker knows which data layer requests to delegate to the WMS-View server. After the resampled data is extracted from the WCS server, the WMS-View server then starts the process of rendering the raw data into a View image. Because the data subset is smaller in size, subsequent rendering steps are relatively quick to process. A number of extra parameters extending WMS are used to inform the rendering process. First, a colour ramp file is generated. Special WMS-View parameters inform the choice of colour ramp, and what viewshed values to assign to the colour ramp. Viewshed values can be configured by the user or else automatically calculated from the subsetted data. After the colour ramp is generated, the WMS-View server renders the raw data into a viewshed colour map image. Also, a supporting legend PNG image is generated using the same colour ramp. Once the map is ready, it is sent back as part of the original WMS GetMap response to the client web-GIS. Using the WMS GetMap request the WMS-View server automatically builds a WCS (Web Coverage Service) request for the dataset. Some of the key parameters from the original WMS request are the bounding box extent and the image height and width. Using these same parameters, a WCS request is executed by the WMS-View server. In this use case, this returns raw DEM data of the geographical area in the resolution of the user’s view extent. In essence, WCS is retrieving and resampling just the required part of the larger View dataset at the required resolution.

3. RESULTS: MAPPING THE VIEW

Figure 3 illustrates the results of the viewshed analysis showing the overall national picture as well as a detailed map for a subset of the region. The Scottish EEZ covers an area of 470,641 km^2 of which 103,108 km^2 (20%) is visible from one or more buildings. Eighty three percent (241,653 km^2) of Scotland's visible coastal area can be viewed from fewer than 100 buildings with 1% (2,914 km^2) of the visible area being viewed from 4,800 or more buildings.

Figure 3: Viewshed maps showing non-zero values for a) the coast of Scotland, with red bounding box showing the location of b) the Argyll marine region in Western Scotland. Note the different values for legend colours at different zoom levels.

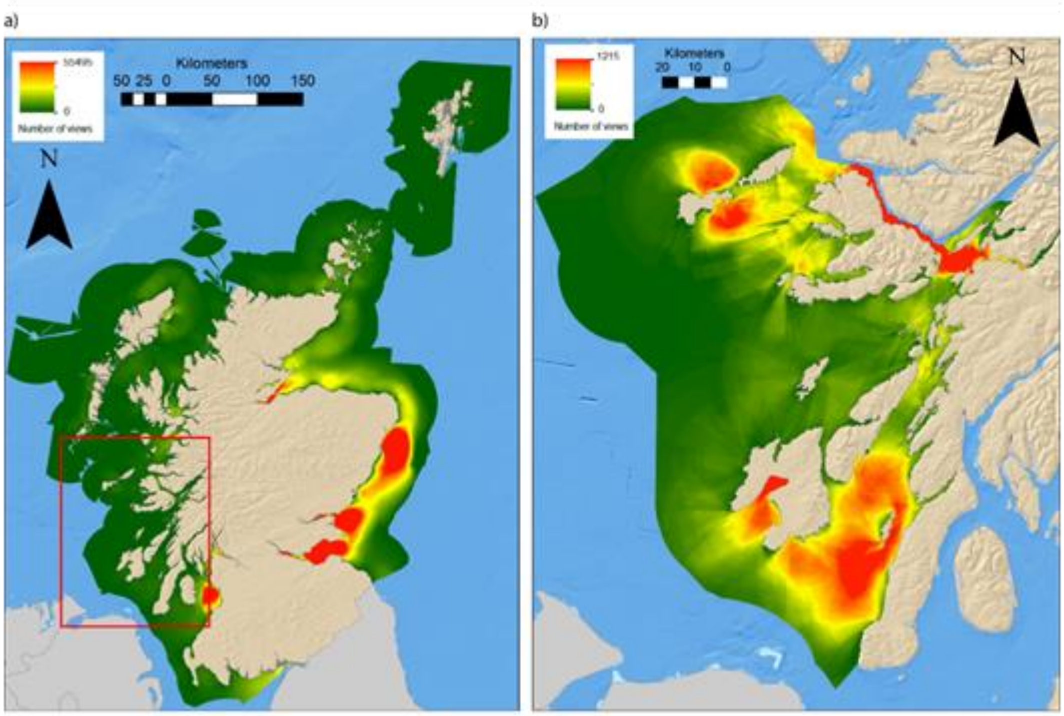


Table 1 summarises the characteristics of the visibility sites for each marine region. The regions in the East had highest mean number of views (>1000) while those in the West and North had lowest visibility (<1000), a single region in the west, the Clyde (near the city of Glasgow, Scotland's largest city), has the highest maximum number of views, from 34,583 buildings.

Table 1: Intercomparison of the visibility of marine regions.

	Area (km^2)	Max (views)	Mean (views)	St Dev
Forth and Tay	4485	29109	4701	5008
North East	3153	14068	3565	3552
Moray Firth	5870	7664	1293	866
Clyde	4273	34583	955	1499
Solway	12310	2557	549	579
North Coast	2444	1262	303	246
West Highlands	10410	1757	188	233
Orkney	9256	1646	180	217
Outer Hebrides	20850	1707	109	192
Argyll	12050	1215	84	101
Shetland	3721	188	27	29

4. DISCUSSION

The viewshed analysis illustrated above has clear potential to contribute to the process of MSP and is being incorporated into the Scotland's National Marine Plan Interactive. To our knowledge this represents the first ever attempt to map the visibility characteristics of the marine environment at a national scale. Incorporating ecosystem services into the management of the marine and coastal environments is an important element of the EA which is implicit within the MSP directive (EC, 2014a) as well as requirement of the Marine Strategy Framework Directive (MSFD) (EC, 2008) and also considered critical to achieving sustainable development (Millennium Ecosystem Assessment, 2003; Worm et al., 2006; Atkins et al., 2011). Yet to date European attempts to map ecosystem services have considered the supply side of ecosystem services production only and have not dealt with ecosystem services from marine habitats (Maes et al., 2013). The cumulative viewshed layer for Scotland described here depicts one facet of the cultural ecosystem service of visual amenity, identifying both the supply (visible marine areas) and demand (number of views) of sea views from Scotland's buildings. Sea views affect the price of accommodation (Fleischer, 2011) and the visual impacts of marine development has been shown to affect house prices (Sims et al., 2008) and these maps therefore provide a spatial representation of ecosystem services whose values are internalised within the Scottish real estate sector. The “Not In My Back Yard (NIMBY)” effect is often important in development decisions for marine areas (Alexander et al., 2010) and the maps produced here indicate the number of individual properties whose view is potentially directly affected by development in a location and relates to the likelihood of objections to development by affected property owners.

However, views from properties are not the only component of visual amenity. Landscape and scenic impacts are an important consideration in Scottish marine planning. Under Scottish national planning policy “the special characteristics of the isolated coast” have been afforded particular protection (Scottish Government, 2010). Tourism is a major industry in many parts of Western Scotland (Visit Scotland, 2014), and many individuals (whether tourists or locals) may actively seek out remote and scenic views where building densities (and numbers of views) are low. A similar national scale viewshed analysis based on visibility from important areas of recreational use (e.g. mountain tops), could provide an important layer to complement the spatial information generated in this analysis and further contribute to MSP for Scotland. Falconer et al. (2013) took a similar approach to our analysis (with a more limited spatial scale) but also incorporated sites with high recreational amenity value.

The method presented above makes use of existing datasets to explore one aspect of the social dimension of ecosystem services production. There is a legal responsibility on the part of all EU nations to develop coherent approaches to marine spatial planning and environmental protection on a regional basis (EC, 2008; EC 2014a) and a mandate to make environmental data publicly available and to develop spatial data infrastructure under the Aarhaus convention and the INSPIRE directive (EC, 2007). All the datasets used in this study were publicly available for download and analysis. While EU DEM covers the entire area of Europe, the buildings data for the UK (but not including Northern Ireland) have only recently been made publicly available for open use through the Ordnance Survey OpenData Initiative (Lilley, 2011). Thus the analysis is only partially complete and does not include views of Scottish marine waters from buildings in the North of Ireland. At the European level the public availability of data still varies from state to state. Extending this analysis to all area of the Irish Sea for, example, would require data for the UK (including Northern Ireland) as well as the Republic of Ireland, where the same type of data would require a financial outlay. Spatial data infrastructure and differences in national spatial data policies currently remain an obstacle to implementing this approach at the larger regional spatial scales foreseen by the MSP and MSFD (EC, 2008, 2014b) directives.

This study has a strictly limited scope, it only considered the views from buildings. In terms of marine spatial planning, and the ecosystem approach to management, the data developed in this study represent a single layer of socially relevant data at the national scale for incorporation into GIS. This layer adds to the number of criteria available on which to base planning decisions, but should not be considered in isolation from other layers (for example on visibility from recreational sites). This study can inform planning decisions through explicit recognition of the spatial qualities of one component of the ecosystem services provided by visual amenity and can complement localised spatial techniques designed to inform specific local planning problems.

5. CONCLUSION

The analysis above illustrates a potentially useful and relatively low cost means of generating information which can be used to elucidate some aspects of ecosystems service values for coastal environments, inform Marine Spatial Planning and facilitate development in the coastal zone. As the “blue growth agenda” places increasing demands on marine space, mapping the social dimension of ecosystem services supply is becoming increasingly important. The increasing free availability of high-quality data products is enabling new avenues for policy relevant spatial research and analysis.

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