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A user's guide to coping with estuarine management bureaucracy: An Estuarine Planning Support System (EPSS) tool

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ABSTRACT

Estuaries are amongst the most socio-economically and ecologically important environments however, due to competing and conflicting demands, management is often challenging with a complex legislative framework managed by multiple agencies. To facilitate the understanding of this legislative framework, we have developed a GISbased Estuarine Planning Support System tool. The tool integrates the requirements of the relevant legislation and provides a basis for assessing the current environmental state of an estuary as well as informing and assessing new plans to ensure a healthy estuarine state. The tool ensures that the information is easily accessible for regulators, managers, developers and the public. The tool is intended to be adaptable, but is assessed using the Humber Estuary, United Kingdom as a case study area. The successful application of the tool for complex socio-economic and environmental systems demonstrates that the tool can efficiently guide users through the complex requirements needed to support sustainable development.

1. Introduction

Estuaries are globally important areas as they provide numerous resources which serve a number of stakeholder interests including industry, tourism, and biodiversity. However, due to their position at the interface of marine and freshwater ecosystems they are also particularly vulnerable to anthropogenic stressors (Elliott and Whitfield, 2011). The increase in the range and intensity of human activities in coastal areas has increased pressure on estuarine and associated coastal resources, often with adverse effects on the environment and society (Lonsdale et al., 2015; Borja et al., 2010a, 2010b; Lotze, 2010; Halpern et al., 2008; Berger and Hodge, 1998). To prevent unacceptable impacts occurring, and thereby ensuring the sustainable management of the anthropogenic pressures present, governance (regarded as policies, politics, administration and legislation) has been developed to mitigate against their associated adverse effects. Governance is only one aspect necessary for sustainable use and development of coastal areas and the involvement and engagement of other stakeholder groups, such as Non-Governmental Organisations (NGOs), science, industry and the public, is essential to ensuring the marine environment is managed sustainably.

These governance obligations (*e.g.* national legislation, and international conventions and, in the case of Europe, directives) are implemented by the relevant agencies (Lonsdale et al., 2015). Effective governance should ensure that environmental function and services are maintained whilst considering the needs of users and stakeholders, which could be conflicting. To achieve this task, regulators need to make effective decisions regarding the relevance and priorities of stakeholder interests, relevant regulations and other environmental and societal considerations – often based on a limited evidence base and within specific time frames. Sustainable management of terrestrial and marine stressors through the application of impact assessment (including cumulative impact assessment) and thresholds are needed to ensure that the ecosystem services and societal goods and benefits are available for future generations and for the long-term survival of ecosystem functions, that are currently being degraded (Perminova et al., 2016; Elliott and Whitfield, 2011; Counsell and Haughton, 2006; Cicin-Sain and Belifiore, 2005; Cooper and Sheate, 2002; Shriberg, 2002).

In the UK, the main legislative driver for providing a more sustainable use of marine resources is currently provided by the Marine and Coastal Access Act 2009 and through the development of Marine Spatial Plans (MSP) (Defra, 2013) but it does not, as yet, implement a fully holistic view of the sustainable use of an area or ecosystem such as envisaged by the Marine Strategy Framework Directive (Directive 2008/56/EC), Water Framework Directive (2008/32/EC), Marine and Coastal Access Act and the UK Marine Plans. The aim of the presented work was, therefore to analyse and interrogate the management of a

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complex and urbanised estuary with a view to providing a toolbox to aid decision makers in taking a holistic approach to that management. In particular, there is the need to take the existing piece-meal and sectoral approach into a coherent and holistic framework in which the elements are retained but linked for the benefit of estuarine users and managers alike.

Several tools have previously been developed worldwide that aid planners, decision makers and developers in the management of the marine environment. Examples include the Marine Spatial Plans for England (MMO, 2014a, 2014b), Marine Scotland's Impact Assessment Tool (Marine Scotland, 2012), Options for Delivering Ecosystem-Based Marine Management (ODEMM) Project Pressures Assessment (PA) (Robinson and Knights, 2011), Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) (Tallis and Polasky, 2009) and Artificial Intelligence for Ecosystem Services (ARIES) (Villa et al., 2014). These provide the context for licensing and management decisions in the marine environment. However, they have limitations regarding their scope and applicability; most importantly the tools only focus on only one environmental or legislative aspect without integrating all the regulatory requirements of potential developments.

Recent marine and estuarine management throughout Europe has focussed on a set of concepts and tools to simplify the process of impact assessment and to communicate the results of such assessments to scientists, regulators, policy and decision makers as well as the public (Torresan et al., 2016; Whitfield et al., 2012; Elliott and Whitfield, 2011; Atkins et al., 2011; Svarstad et al., 2008; Counsell and Haughton, 2006). These concepts and tools for managing estuarine, coastal and marine areas include: sectoral management schemes (Environment Agency, 2008a, 2008b; Apitz et al., 2006; Fujii, 2007); ecosystem services and societal benefits (Elliott and Whitfield, 2011; Atkins et al., 2011; Austen et al., 2009; Beaumont et al., 2007); environmental integrative indicators (Ware et al., 2010; Aubry and Elliott, 2006), and the 10-tenets for successful and sustainable management (Elliott, 2013; Barnard and Elliott, 2015). Taken together, many of these principles and philosophies are now being combined in the DAPSI(W)R(M) as an integrated system at a conceptual level (Elliott et al., 2017). However, despite being central to the integrated implementation of several EU directives and national governance mechanisms, these tools are not currently integrated into one unifying and operational tool (Borja et al., 2013a; Borja et al., 2011; Townsend et al., 2011; Borja et al., 2010b; Hering et al., 2010; Mee et al., 2008; Borja and Elliott, 2007; Apitz et al., 2006).

The disadvantage of not having all the requirements in one tool is that there is a risk of omissions in the final assessment. Furthermore, it creates many unnecessary steps, delays and inefficient use of resources if the information on the requirements is not easily accessible in a centralised location. In contrast, having the legislative scoping carried out by an automated tool gives a consistent, auditable and efficient approach for all parties and allows transparency in the decision-making process.

For the study presented here, the conceptual framework described in Lonsdale et al. (2015) was used as the basis for a Geographic Information System (GIS)-based tool. Management tools have been recently developed to aid in environmental management, however given the potential for overlap in activities, potential conflicts and policy objectives, by having these as separate tools, there can still leave gaps in knowledge for developers and decision makers. There is currently no universal tool that can guide a developer/decision maker through the process and highlight where receptors, activities, legislative requirements *etc.* are in relation to a development. The paper aims to answer the research question of 'can one tool be developed to bring together the multi-disciplinary element of managing an estuarine environment?'.

To achieve the above aim, the objectives of this study are to:

1. Use maps and matrices for estuarine relevant features (*e.g.* habitats, uses, users, ecosystem services, *etc.*) to summarise the knowledge and understanding of the baseline(s) environmental condition of the estuary;
2. Investigate the different management schemes and frameworks and integrate these into a novel and integrated framework;
3. Build on the EPSS framework developed by Lonsdale et al. (2015) so that the tool will identify current ecosystem services and determine the societal goods and benefits acquired from the system;
4. Develop software that provides a practical application of the EPSS framework including the identification and advice on potential impacts of developments in the Humber Estuary; and
5. Use the EPSS tool to identify the current level and extent of ecosystem services and societal benefits that are provided by the Humber Estuary.

2. Method for developing the EPSS tool

The EPSS software comprises an interactive GIS tool that can analyse the inputs by using an interactive interface and tabular information (*i.e.* 'look-up tables') in relation to a development, to provide guidance and advice regarding the potential environmental and social impacts of such a development. The tool was developed in ArcGIS for Desktop 10.1 and scripts were produced in Python 2.7. The script has been written to use the look-up tables so no data are hard-coded in the script. This allows the tool to be adapted to include changed or novel legislation or different locations, thereby reducing maintenance investment. The main sequential stages of the tool development are described below.

2.1. Data

Environmental and regulatory data were obtained from a number of regulatory, government, privately-owned and scientific publication sources (Supplementary Information Table 1) to provide the current baseline information for the Humber Estuary used to inform the tool development and carry out its operational testing. The minimum data requirements for the tool are the conservation designations (Special Areas of Conservation, Special Protection Areas, Sites of Special Scientific Interest, Marine Conservation Sites, and sites protected under the RAMSAR Convention), marine sediment testing data, Water Framework Directive (WFD) status, objectives and reasons for waterbodies not reaching Good Ecological Status/Good Economical Potential (under the WFD), the look-up table consolidating the environmental legislations, dredged material disposal sites and sites protected for their archaeological or cultural importance. In addition, in the case of the Humber estuary, the data sources also included information relating to other developments which have been granted consent or are in the planning process, areas of the estuary that are routinely dredged and the location of recreational activities. The tool provides a robust assessment using the data sets available but can also run with missing data fields or null values, to account for locations *e.g.* offshore areas where there are no *e.g.* conservation designations within 5 km and these are highlighted as part of the output.

All data layers were projected into the British National Grid coordinate system to allow the necessary functions to be performed such as defining the spatial extent of the project area.

2.2. Identification of receptors

In the EPSS tool, receptors are defined as ecological (*e.g.*