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Addressing cumulative effects, maritime conflicts and ecosystem services threats through MSP-oriented geospatial webtools

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ABSTRACT

To solve conservation and planning challenges in the marine environment, researchers are increasingly developing geospatial tools to address impacts of anthropogenic activities on marine biodiversity. The paper presents a comprehensive set of built-in geospatial webtools to support Maritime Spatial Planning (MSP) and environmental management objectives implemented into the Tools4MSP interoperable GeoPlatform. The webtools include cumulative effects assessment (CEA), maritime use conflict (MUC) analysis, MSFD pressure-driven CEA and a CEA-based marine ecosystem service threat analysis (MES-Threat). The tools are tested for the Northern Adriatic (NA) Sea, one of the most industrialized sea areas of Europe using a case study driven modelling strategy. Overall results show that coastal areas within 0–9 nm in the Gulf of Trieste, Grado-Marano and Venice lagoon and Po Delta outlet are subjected to intense cumulative effects and high sea use conflicts mainly from port activities, fishery, coastal and maritime tourism and maritime shipping. Linking MES into CEA provided novel information on locally threatened high MES supporting and provisioning habitats such *Cymodocea* beds and infralittoral fine sands, threats to cultural MES are most pronounced in coastal areas. Results are discussed for their geospatial relevance for regional planning, resource management and their applicability within MSP and environmental assessment.

1. Introduction

Current conservation and planning challenges of the marine environments require flexible tools that ensure to different types of user the access, management, sharing, processing and visualization of a multitude of spatial and non-spatial datasets. Ideally, these datasets are stored within platforms capable to organize a multitude of data and convey them into easily and quickly accessible graphical user interfaces (GUI). The use of Maritime Spatial Planning (MSP, Directive 2014/89/EU) as practical process to achieve environmental, social and economic objectives and minimize conflicts (Hansen et al., 2017) in European seas has posed novel demands to amount, quality and sources of data. Despite the ongoing governance process, considerable work has been done by the scientific community for the development of Spatial Data Infrastructure (SDI; Fowler et al., 2010) in support of a knowledge-based implementation of national and regional plans.

In recent years the application of cumulative effects assessment and sea use conflict analysis have emerged as common analytical tools to support decision-makers in the development of spatial plans and in support of the ecosystem-based management of marine resources. This is also reflected in an emerging number of decision support tools enabling user to perform cumulative effects assessment in various contexts. An extended review of decision support systems performed by Krueger and Schouten-de Groot (2011) showed that out of the 118 tools in support of MSP, about 46 (39%) implement CEA models whether serving decision support or scenario analysis development and management priorities identification. Examples of MSP oriented decision support system include sector specific tools such as Windspeed (Spatial Development of Offshore Wind Energy in Europe; www.windspeed.eu) for the identification of suitable areas for wind energy in the North Sea, MARA (Marine Aggregate Extraction Risk Assessment framework; www.mara-framework.org.uk) for probabilistic environmental risk assessment or the Isis-fish (Krueger and Schouten-de Groot, 2011), a predictive tool of fish population development under different management scenarios. Other tools that allow more comprehensive CEA analysis include the HARMONY tool (Development and demonstration of Marine Strategy Framework Directive tools for harmonization of the initial assessment in the eastern parts of the Greater North Sea sub-

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region; Andersen et al., 2013) for human impact assessment in the eastern North Sea sub-region or the SYMPHONY tool (MSP Platform, 2016).

Sea use conflict analysis has been extensively applied in different geographical contexts (Hadjimitsis et al., 2015; White et al., 2012) based on different decision support systems, such as the GRID tool (Georeferenced Interactions Database; Gramolini et al., 2010) providing a platform to spatialize use-use conflict in sea areas, the MaRS geotool (Marine Resource System; www.thecrownestate.co.uk/mars) to support identification and resolution of spatial conflicts and AquaSpace that enables integrated assessment of risks and opportunities for proposed aquaculture sites (Gimpel et al., 2018).

Also the recent growth of ecosystem services research contributed to the development of several geospatial tools in support of decision making in coastal and marine environments, such as the habitat risk assessment (HRA) tool from Marine InVEST toolset (Integrated Valuation of Ecosystem Services and Tradeoffs), that enables user to assess risks to marine ecosystems generated by different human activities (Wyatt et al., 2017), the SolVES tool (Social Values for Ecosystem Services) for the analysis and mapping of non-market values of cultural ecosystem services (van Riper et al., 2012) or the MIMES model (Multi-Scale Integrated Models of Ecosystem Services) which supports MSP for tradeoff analysis among competing uses (Center for Ocean Solutions, 2011).

The very diverse suites and packages of geospatial tools pose considerable opportunities in the development of new generation decision-support systems for strategic planning and environmental conservation in the marine domain. However this diversity is source of difficulties in identifying suitable tools addressing specific decision-making objectives, may produce a fragmented utilization of several tools leading to input and output procedures that can require a costly data treatment for harmonizing the processing workflow.

In this research we present the functionalities of three webtools implemented in the Tools4MSP Geoplatform (tools4msp.eu), namely Cumulative Effects Assessment (CEA), Maritime Use Conflict (MUC) analysis and a Marine Ecosystem Services Threat analysis (MES-Threat). The webtools were tested in a case study for the Northern Adriatic (NA) Sea, one of the most crowded sea areas of Europe. The application of webtools is presented using a stepwise workflow based on a structured case study driven modelling strategy. The paper is organized as follows: Section 2 presents the overall workflow, the theoretical background of the webtools and the stepwise procedure for the webtools' setup, in Section 3 the geospatial and geostatistical results of the model setup are presented and Section 4 discusses the results for their relevance in MSP, environmental management and the applicability of the webtool along EIA and SEA.

2. Materials and methods

2.1. The Tools4MSP Geoplatform

The Tools4MSP Geoplatform is a community-based, open-source portal, based on GeoNode (GeoNode Development Team, 2018), a web-based Content Management System (CMS) for developing geospatial information systems (GIS) and for deploying spatial data infrastructures (SDI). The aim of the Geoplatform is to provide an operational set of webtools that can assist decision-makers and strategists in undertaking MSP-oriented case studies and support the development of environmental management strategies.

The webtools are integrated as GeoNode Plugin into the Geoplatform, that provides a graphical user interface (GUI) facilitating the usability of the Tools4MSP core functionalities for different user communities (Menegon, 2018a). The Plugin reflects the Tools4MSP modelling framework (Depellegrin et al., 2017; Menegon et al., 2016), a python-based Free and Open Source Software (FOSS) which combines several FOSS projects for geodata processing and scientific modelling: (1) NumPy and SciPy for efficient numerical computation (van der Walt et al., 2011); (2) Pandas and GeoPandas for data structures manipulation and data analysis (McKinney, 2010); (3) OWSLib which implements the client-side for OGC web services standard interfaces (OWSLib Development Team, 2018); (4) Rectifiedgrid for efficient 2D grid-based analysis (Menegon, 2018b) and (5) the interactive visualization of the Tools4MSP results are created through Bokeh (Bokeh Development Team, 2018). The Tools4MSP software package can be freely downloaded from github (https://github.com/CNR-ISMAR/tools4msp).

In order to demonstrate the functionalities of the Tools4MSP Geoplatform, we present four operational steps for its utilization (Fig. 1): (Step 0) Webtool selection depending on the scope and objectives of the analysis; (Step 1) case study area selection, available for different geospatial scales (from sea basin to regional level); (Step 2) dataset configuration defining human uses, environmental components and MSFD-pressures themes used for modelling and (Step 3) generation of geospatial and statistical outputs to be used for data curation and re-analysis within a dedicated GIS software such as Quantum GIS (QGIS Development Team, 2018).

2.2. Step 0: webtools selection

This step allows user to select a comprehensive set of webtools available in the Geoplatform (Fig. 2) namely a Cumulative Effects Assessment (CEA), Maritime Use Conflict (MUC) analysis and Marine Ecosystem Services Threat analysis (MES-Threat). In Fig. 2 (right) the buttons to prompt user to the webtool model run. In the following section a detailed description of theoretical and methodological background of the webtools is provided.

2.2.1. Cumulative effects assessment (CEA)

The Tools4MSP Geoplatform implements a Cumulative Effects Assessment (CEA) for the analysis of cumulative effects generated by anthropogenic activities on marine environmental components. Its implementation is based on archetypical CEA implementations proposed in various geographical scales (Halpern et al., 2008; Andersen et al., 2013). In detail, we define CEA as a systematic procedure for identifying and evaluating the significance of effects from multiple pressures and/or activities on single or multiple receptors (Judd et al., 2015). The CEA incorporates two major improvements, such as the modulation of propagation of pressures through a distance model $M(U_i, P_j, E_k)$ based on 2D Gaussian spatial convolution and the distinction of sensitivity scores ($s_{j,k}$) into sensitivity values combined with use-specific relative pressure weight ($w_{i,j,k}$). The CEA algorithm implemented in the Geoplatform is described in Eq. (1). The algorithm takes into account an additive effects combination, meaning that cumulative effects correspond to the sum of individual effects on an environmental component (CEAA-ACEE, 2016), and considers a linear response of the environmental component to the pressure. The CEA score on a single grid cell is calculated as follows:

$$CEA = \sum_{k=1}^{n} d(E_k) \sum_{j=1}^{m} s_{j,k} eff(P_j, E_k) \tag{1}$$