TITLE: Multi-objective spatial tools to inform Maritime Spatial Planning in the Adriatic Sea

Daniel Depellegrin*, Stefano Menegon*, Giulio Farella, Michol Ghezzo, Elena Gissi, Alessandro Sarretta, Chiara Venier, Andrea Barbanti

Multi-objective spatial tools to inform maritime spatial planning in the Adriatic Sea, In Science of The Total Environment, Volume 609, 2017, Pages 1627-1639, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2017.07.264.

This manuscript version is made available under the CC-BY-NC-ND 4.0 license http://creativecommons.org/licenses/by-nc-nd/4.0/

Keywords: Cumulative Impacts, Sea use conflict analysis, Nutrient Dispersion modelling, Marine Ecosystem Services, Adriatic Sea.

14*Joined first authors

15Daniel Depellegrin (daniel.depellegrin@ve.ismar.cnr.it)

16Stefano Menegon (stefano.menegon@ve.ismar.cnr.it)

18Abstract

This research presents a set of multi-objective spatial tools for sea planning and environmental management in the Adriatic Sea Basin. The tools address four objectives: 1) assessment of cumulative impacts from anthropogenic sea uses on environmental components of marine areas; 2) analysis of sea use conflicts; 3) 3-D hydrodynamic modelling of nutrient dispersion (nitrogen and phosphorus) from riverine sources in the Adriatic Sea Basin and 4) marine ecosystem services capacity assessment from seabed habitats based on an ES matrix approach. Geospatial modelling results were illustrated, analysed and compared on country level and for three biogeographic subdivisions, Northern-Central-Southern Adriatic Sea. The paper discusses model results for their spatial implications, relevance for sea planning, limitations and concludes with an outlook towards the need for more integrated, multi-functional tools development for sea planning.

301.Introduction

Maritime Spatial Planning (MSP) is a rapidly expanding approach for ocean and coastal management. MSP is intended to be used on trans-boundary settings and across sectors to ensure efficient, safe and sustainable development of human activities at sea (EU Maritime Affairs, 2017). In order to conduct MSP, decision-makers and planners require an increasing amount of spatial data and tools for archiving, managing and analysing datasets. Moreover, MSP frameworks have an iterative character (Ehler and Douvere, 2009), that requires tools, designed to address multiple challenges of ocean management, that can be flexibly deployed in different stages of the MSP process and that are capable to assimilate and process novel datasets, as they become available (Yee et al., 2015).

In 2014, the European Commission adopted the European Strategy for the Adriatic-Ionian Region (EUSAIR) as macro-regional strategy to create synergies and foster coordination among territories in the Adriatic-Ionian Region (AIR). The EUSAIR recognized the necessity of MSP as a planning framework to foster blue growth and sustainable use of marine resources in the Adriatic Sea, one of the most crowded European Seas (MSP-Platform, 2017).

This paper presents a spatial toolset initially developed in the ADRIPLAN Project (2012-2015) and comprehensively extended through the RITMARE Project – Italian Research for the Sea (2012-2016), capable of addressing multiple challenges for sea planning and environmental management in the Adriatic Sea. The toolset is developed within the Tools4MSP modelling framework, a regularly updated MSP-oriented open source software suite (Menegon et al., 2016) and the SHYFEM model (Shallow water Hydrodynamic Finite Model; Umgiesser et al., 2004). The toolset addresses four key challenges for the Adriatic Sea: (1) assessment of cumulative impacts (CI) from anthropogenic sea uses on ecological components of the marine environment, (2) identification of sea use conflicts...
53(SUC), (3) application of a hydrodynamic model for total Nitrogen and Phosphorus (N and P) 54 dispersion mapping and (4) socio-ecological analysis of marine ecosystem services (MES) capacity 55 from seabed habitats. The paper presents datasets and methodologies applied in the models and 56 describes results for their geospatial implications, importance for sea planning and model limitations. 57 The paper concludes with a discussion on the current specificities of the toolset and its future 58 advancements towards more integrated and multi-functional modelling perspective.

59

60. Materials and Methods

61 The following section describes the methodology and datasets involved in the development of the 62 spatial tools. Geostatistical analysis and visualizations were performed in ArcGIS 10.1 (ESRI, 2017) 63 and ggplot2 library of R programming language (R-Cran Project, 2017).

64

65.1. The Adriatic Sea

66 The Adriatic Sea (25,2191 km²) is a semi-enclosed basin located in the North-Central Mediterranean 67 Sea (Schofield and Townsend-Gault, 2011). It is connected to the Eastern Mediterranean Sea through 68 the Strait of Otranto. The Adriatic Sea borders six countries: Italy (IT), Croatia (HR), Montenegro 69 (MT), Bosnia & Herzegovina (BH), Albania (AL) and Slovenia (SL). It is an extremely complex 70 system due to its geomorphological and ecological characteristics: lagoons, estuarine areas, coastal 71 high biodiversity habitats (e.g. Posidonia oceanica meadows, coralligenous assemblages; UNEP- 72 MAP-RAC/SPA, 2010; Telesca et al., 2015), deep-habitats (e.g. canyons, seamounts, deep-sea corals; 73 Danovaro et al., 2010; Turchetto et al., 2007), with a high variability along its north-south gradient. 74 Moreover, it is populated by benthic, demersal and pelagic fish species of high ecologic and 75 commercial value (Coll et al., 2010). The rivers with the most extended catchment area are the Po 76 (71,327 km²) and Adige (12,417 km²) in northern Italy, the Neretva river in Croatia (13,122 km²) and 77 the Drin river (13,067 km²) in Albania.

78 The Adriatic Sea is heavily exposed to anthropogenic pressures (EC, 2011) generated by a complex 79 suite of activities: maritime transport, port activities (Trieste, Venice, Koper, Rijeka, Ancona, 80 Brindisi, Bari or Vlorë), commercial fishery, aquaculture, especially in the lagoons of the Northern 81 Adriatic Sea and tourism (EC, 2011). In the future, an intensification of human activities could be 82 expected, leading to increased environmental pressures and sea conflicts: development of new port 83 infrastructures in Ploce (Croatia), Bar (Montenegro) and Vlorë (Albania), container traffic increase by 84 350% by 2020 (Barbanti et al., 2015), development of new cruising routes (Venice-Ravenna-Bari- 85 Sivola and Kotor), increase of aquaculture activities (Brigolin et al., 2017; EUSAIR, 2017), increased 86 grid connectivity through cabling and pipelines (IGI Poseidon Project, 2016; PCI Project, 2017), 87 potential renewable energy development (Schweizer et al., 2016), new hydrocarbon concessions, 88 establishment of LNG terminals and booming of coastal and cruise tourism (Caric and Mackelworth, 89 2014).

90 The spatial characterization of results was performed by dividing the Adriatic Sea into three 91 biogeographic subdivisions according to Bianchi 2004 (Figure 1): 1) The Northern Adriatic (NAd, 92 area = 44,434 km²; 17.6 %) delimited by the Conero Regional Park to southern tip of the Istrian 93 peninsula, covering the national sea boundaries of HR, IT and SL; 2) the Central Adriatic (CAD, area 94 = 13,2610 km²; 52.6%) delimited by the Gulf of Manfredonia to the coastal city of Dubrovnik, 95 covering the national sea boundaries of BH, HR and IT and 3) the Southern Adriatic (SAD, area = 96 9675,146 km²; 29.8%) delimited by the city of Otranto, covering the national sea boundaries of AL, HR, 97 IT and MT.
Objective 1: Cumulative impact assessment

One of the first applications of CI occurred in 1980s for the Wadden Sea (Dijkema et al., 1985). Since then, its application has become a widespread modelling technique for cumulative impact assessment on global (Halpern et al., 2008), seabasin (Andersen and Stock, 2013) and regional (e.g. Holon et al., 2015) scale. The CI algorithm applied in this research is provided by Andersen and Stock (2013). For more detail on the CI assessment in the study area and the algorithm adopted we refer to the supplementary material (see Appendix S1). In Table 1 the MSP stocktake for CI assessment and the indicators used were presented. The MSP stocktake includes 28 environmental components \(E\) and 15 human uses \(U\) at sea. Moreover, the \(U\) stocktake includes 18 pressures \(P\) that are defined as disturbances causing temporary or permanent alterations to one or multiple ecosystem components. The \(P\) were adopted from the Marine Strategy Framework Directive (MSFD, 2008/56/EC, Annex III, Table 2). The units of measurement for the spatial indicators \(E\) and \(U\) include dummy indicators of presence/absence \(P/A\), weighted dummy indicators \(wP/A\) and intensity indicators \(I\) based on proxy indicators \(PR\). For intensity indicators, a \(\log(x+1)\) transformation and a rescaling from 0 to 1 was used. Full \(E\) and \(U\) geospatial datasets can be downloaded under Menegon et al. (2017a). The sensitivity \(s\) is defined as the combination of the direct and indirect impact extent of a pressure generated by anthropogenic activities, its impact level defining the degree of disturbance and recovery time of environmental component subject to the pressure (Andersen and Stock, 2013). At the current stage the CI model incorporates 516 sensitivities \(s(U, P, E)\). Each of the sensitivities includes a distance model \(m(U, P, E)\). The distance model uses a 2D Gaussian spatial convolution to model isotropic propagation of impacts across the study area. The CI spatial model implemented can take into account the dispersion of the pressure generated by each
125 single human use over six buffer distances (local, 1 km, 5 km, 10 km, 20 km and 50 km). The CI
126 model functions are available under the Tools4MSP modelling framework/toolbox, an open source
127 geopython library available in its latest version on GitHub (Tools4MSP, 2016). The CI operates on a
128 cell grid resolution of 1 km x 1 km using the standardized European Environmental Grid (EEA,
129 2012013). CI scenario runs can be also performed from the ADRIPLAN Portal (data.adriplan.eu) using
130 the built-in tool with a resolution of 10 km x 10 km.

131

| Dataset | Indicator |
|---------|-----------|
| Aquaculture1,2,3, Cables and Pipelines1,2,3, Coastal Defence Work1,3, Dumping area for dredging2, LNGs2, Military areas2, Off-shore sand deposit2,3, 8, 9, 10, Oil and Gas Extraction2, 11, 12, 13, 14, Oil and Gas Research2, 11, 12, 13, 14, Renewable Energy facilities (Offshore Wind farms)2, 8, 15 | P/A |
| Coastal and Maritime Tourism’ | I/PR – distance from the marinas and number of boats/marinas |
| Coastal and Maritime Tourism’ | I/PR – distance from the marinas and number of boats/marinas |
| Naval Based Activities’ | I/PR – distance from the cargo ports and port capacity |
| Maritime Transport’ | I – Traffic density (vessels/year) |
| Small Scale Fishery’ | I – fishing effort expressed in 5 classes of intensity: from very low to high |
| Trawling16 | 1 – hours of activities calculate through Vessel Monitoring System (VMS) |
| Marine Mammals17, Giant Devil Ray17, Nursery Habitats18, Turtles19, seabed habitats20 | P/A |
| Seabirds21 | w/P/A |

135 Veneto Region (www.regione.veneto.it); 1 SHAPE – Shaping a Holistic Approach to Protect the Adriatic Environment between coast and
136 sea (www.shape-ipayproject.eu); 1 ICMMR – Hellenic Centre for Marine Research (www.hcmmr.gr); 1 OTE S.A. – Hellenic Telecommunication
137 Organization (www.ripe.net); 1 SIT – Apulia Region (www.sit.puglia.it); 1 OGS – Istituto Nazionale di Oceanografia e di Geofisica
138 Sperimentale (www.ogs.trieste.it); 1 CNR-ISMAR – Italian National Research Council – Institute of Marine Sciences (www.cnr-ismar.it); 4
139 MIPAFF – Italian Ministry of Agriculture, Food and Forests (www.politicheagricole.it); 4 EMODnet – Italian Ministry of Economy, Sector for Mining and Geological Research (www.petroleum.me); 10 CHA – 142 Croatian Hydrocarbons Agency (www.azu.hr); 10 MISE – Italian Ministry for Economic Development (www.sviluppoeconomico.gov.it).
143 RAE – Regulatory Authority for Energy, (www.rae.gr); 16 Blue Hub, JRC in-house platform to exploit big data in the maritime
144 domain (www.bluehub.jrc.ec.europa.eu); 17 UNEP-MAP-RAC/SPA, Regional Activity Center for Specially Protected Areas; 18 MEDISEH
145 MARE Project (www.mareaproject.net/medviewer); 18 EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu).

147 | Objective 2: Sea use conflict analysis |

148 The analysis of SUC is important to locate conflict areas, setup conflict mitigation strategies and
149 guide decision makers in the definition of planning processes that can aid sustainable ocean zoning
150 concepts (Bruckmeier, 2005; Moore et al., 2017). The methodology for sea use conflict analysis is
151 based on 15 sea uses (Table 1) using the FP7 project methodology named COEXIST – Interaction in
152 European coastal waters: A roadmap to sustainable integration of aquaculture and fisheries
153 (COEXIST, 2013). The following operational steps were considered: (1) classification and assignment
154 of numerical values to five traits (mobility, spatial (horizontal), vertical and temporal scale, location);
155 (2) assignment of rules to calculate level of conflict for pairwise combinations and (3) calculation of
156 total conflict score for each pairwise use combination within a single grid cell. Similar to the CI
157 assessment, also sea use conflict analysis is implemented through the Tools4MSP open source
158 geopython library freely available on GitHub (Tools4MSP, 2016). Cell grid resolution of the SUC
159 model is 1 km x 1km (EEA, 2013). Customized SUC scenario runs can be run also from the
160 ADRIPLAN Portal (data.adriplan.eu) on a 10 km x 10 km resolution. For further details on the
161 methodology we refer to Gramolini et al. (2010).

162

163 | Objective 3: Nutrient dispersion model |

164 The open source, 3-D hydrodynamic model named SHYFEM (Shallow water Hydrodynamic Finite
165 Model; Umgiesser et al., 2004) was used to model total nutrient dispersion (Nitrogen – N and
166 Phosphorus – P) from rivers into the Adriatic Sea, considering a simple decay reaction to represent the
167 first step dynamic of substances in the water sea. A detailed description of SHYFEM equations can be
168 found in https://sites.google.com/site/shyfem/. SHYFEM has been applied in several settings such as
169 the Lagoon of Venice (Ghezzo et al., 2011) or the Black Sea (Dinu et al., 2011). SHYFEM solves the
shallow water equations in a 3D formulation, using a finite element technique (Bajo et al., 2014). The domain has been represented by a computational grid counting 87,016 nodes and 158,180 triangular elements deployed for the Adriatic Sea, including Venice and Grado-Marano lagoons and the Po deltaic system (see Appendix S2). The vertical discretization of the domain counts 33 z-layers of same thickness around 1.5 m (surface) until the depth of 100 m and progressively growing under this depth until 70 m depth. Climatic and hydrological conditions, such as wind forcing, precipitations and thermal conduction for the year 2014, were retrieved from the MOLOCH Model from the Institute of Atmospheric Sciences and Climate of the National Research Council of Italy (ISAC-CNR, 2017). Catches of N and P inputs (N and P in mg l\(^{-1}\)) to the Adriatic Sea are presented in Appendix S3. For each river, a mean annual discharge rate was retrieved, whereas for lagoons and delta systems outlets a mean annual time series was adopted. In total, 80 rivers of the Adriatic Sea Basin (IT – 62; HR – 7; AL – 7; SL – 3; MT/AL – 1) were collected. Geospatial datasets for catchment area and river length were retrieved from EEA datasets on large and other rivers (EEA, 2009a and 2009b) and from the European river catchment datasets (EEA, 2008; Figure 2). The total N and P load was retrieved from stations of the European Environment Information and Observation Network (EEIONET, 2008, 2010, 2011 and 2013) and regional environmental protection agencies (ARPA-FVG, 2013). N and P concentrations were collected from monitoring stations in proximity of river mouths or, in absence of a monitoring station at the river mouth, the nutrient concentrations closest to the river mouth was adopted. The bathymetry was retrieved from the European Marine Observation and Data Network (EMODnet, 2017) and from regional environmental protection agencies of Veneto and Friuli-Venezia-Giulia Region. Finally, a log normalization \[\log(1 + NP_{\text{Total}})\] of total N and P was performed in order to generate a Total N and P index (TotN&P; Menegon et al., 2017b).
The capacity of marine habitats to provide marine ecosystem services (MES) was assessed using a 208MES matrix approach (Table 2). The capacity of marine habitats to provide ecosystem services is 209defined as the long-term potential of ecosystems to provide services that support directly and 210indirectly human wellbeing (Schröter et al., 2012). The MES matrix combines 13 MES on the x-axis 211defined according to Salomidi et al. (2012) and 23 EUNIS (European Union Nature Information 212System) seabed habitats for the Adriatic Sea retrieved from EUSeaMap (www.emodnet- 213seabedhabitats.eu/) on the y-axes. The matrix approach is a popular technique applied in the 214Mediterranean (Salomidi et al., 2012) and the North and Eastern Atlantic Sea (Galparsoro et al., 2014) 215for rapid assessment of MES capacity of seabed habitats.

Table 2. MES capacity matrix including EUNIS habitats and 12 ES according to Salomidi et al (2012) and Galparsoro et al (2014). Index 218scores of the MES Matrix are available under Menegon et al., 2017a.

| Code | Habitat Description                                         | Area (km²) | %   | Ecosystem function | Raw material | Disturbance protection | Water quality | Marine biodiversity | Nutrient cycling | Ecosystem resilience | MES_cap |
|------|------------------------------------------------------------|------------|-----|-------------------|--------------|------------------------|---------------|-------------------|-----------------|----------------------|----------|
| A3   | Infralittoral rock and other hard substrata                | 254.2      | 0.1 | 2                 | 2            | 2                      | 2             | 2                 | 2               | 2                    | 23       |
| A4   | Circalittoral rock and other hard substrata                | 501.1      | 0.2 | 2                 | 2            | 1                      | 2             | 2                 | 2               | 0                    | 21       |
| A4.26/32 | Med. coralligenous communities moderately exposed to or sheltered from hydrodynamic action | 488.2 | 0.2 | 2                 | 1            | 2                      | 0             | 2                 | 2               | 0                    | 19       |
| A4.27 | Faunal communities on deep moderate energy circalittoral rock | 5.7    | 0.0 | 2                 | 1            | 1                      | 1             | 2                 | 2               | 1                    | 20       |
| A5.13 | Infralittoral coarse sediment                             | 409.8      | 0.2 | 2                 | 2            | 0                      | 0             | 0                 | 1               | 0                    | 10       |
| A5.14 | Circalittoral coarse sediment                              | 101.4      | 0.0 | 2                 | 2            | 0                      | 0             | 0                 | 1               | 1                    | 7        |
| A5.23 | Infralittoral fine sands                                   | 8836.1     | 3.6 | 2                 | 1            | 0                      | 0             | 0                 | 0               | 0                    | 1        |
| A5.25 | Circalittoral fine sand                                    | 5742.8     | 2.4 | 2                 | 2            | 0                      | 0             | 0                 | 0               | 0                    | 1        |
| A5.26 | Circalittoral muddy sand                                  | 10213.5     | 4.2 | 2                 | 2            | 0                      | 0             | 0                 | 0               | 1                    | 1        |
| A5.33 | Infralittoral sandy mud                                    | 1137.3     | 0.5 | 2                 | 0            | 0                      | 1             | 0                 | 0               | 0                    | 6        |
| A5.34 | Infralittoral fine mud                                     | 721.8      | 0.3 | 1                 | 0            | 0                      | 0             | 0                 | 0               | 0                    | 1        |
| A5.35 | Circalittoral sandy mud                                    | 17461.8     | 7.2 | 2                 | 0            | 0                      | 0             | 0                 | 0               | 1                    | 6        |
| A5.36 | Circalittoral fine mud                                     | 22474.0    | 9.2 | 2                 | 0            | 0                      | 0             | 1                 | 0               | 0                    | 6        |
| A5.38 | Med. bioconiosis of muddy detritic bottoms                 | 5792.7     | 2.4 | 1                 | 0            | 0                      | 0             | 0                 | 0               | 0                    | 1        |
| A5.39 | Med. bioconiosis of coastal terrigenous muds               | 34218.9     | 14.0 | 2             | 0            | 0                      | 0             | 1                 | 0               | 0                    | 6        |
| A5.46 | Med. bioconiosis of coastal detritic bottoms               | 39083.3     | 16.0 | 2             | 0            | 0                      | 0             | 1                 | 0               | 0                    | 7        |
| A5.47 | Med. communities of shelf-edge detritic bottoms            | 38045.8     | 15.6 | 2             | 0            | 0                      | 0             | 1                 | 0               | 0                    | 5        |
| A5.531 | Cymodocea beds                                           | 622.7      | 0.3 | 2                 | 1            | 2                      | 2             | 2                 | 2               | 2                    | 23       |
| A5.535 | Posidonia beds                                            | 413.8      | 0.2 | 2                 | 1            | 2                      | 2             | 2                 | 2               | 2                    | 23       |
| A5.5353 | Facies of dead "mattes" of Posidonia oceanica without much epiflora | 17.4     | 0.0 | 2                 | 1            | 2                      | 2             | 2                 | 2               | 2                    | 23       |
| A6.3 | Deep-sea sand                                              | 1618.6      | 0.7 | 2                 | 1            | 0                      | 0             | 0                 | 0               | 0                    | 3        |
| A6.4 | Deep-sea muddy sand                                       | 499.3      | 0.2 | 2                 | 1            | 0                      | 0             | 0                 | 0               | 0                    | 3        |
| A6.51 | Med. communities of benthal muds                          | 45403.5    | 18.6 | 0               | 0            | 0                      | 0             | 0                 | 0               | 0                    | 3        |
Results

Results of model application are illustrated in Figure 3 and 4. Figure 3 (a-d) presents geospatial model results, comparing model indexes on country level and for each biogeographic subdivision and Figure 4 (a-d) illustrates for each model, the variation of index scores as function of distance from coastline.
Figure 3. Left: Geospatial results of tools application for the study area: a) CI assessment; b) SUC analysis; c) TotN&P nutrient dispersion model and d) MES capacity from seabed habitats. Right: Comparison of model results for each subdivision. Boxplots show maximum/minimum outliers, boxes enclose first and third quartiles and box centres define median. Abbreviations: AL – Albania; BH – Bosnia & Herzegovina; HR – Croatia; IT – Italy; MT – Montenegro; SL – Slovenia.
41Geospatial results presented in Figure 3a indicate that high CI scores are dominant in the sea areas of Friuli-Venezia Giulia, Veneto and Emilia Romagna Region, located in the Italian NAd. Maximum CI scores reach 9.5. The Slovenian Coastal Karst Region has a maximum CI score of 6 and the Croatian Istria Region a CI score of 4.8. In proximity of the port of Ancona (Marche Region) in Italy more localized high CI scores are evident. On average, the Slovenian sea space has the higher CI scores (x̄ = 4) compared to Italy (x̄ = 2.3) and Croatia (x̄ = 2). In the CAd, CI scores are highest in Italian sea areas with a range from 0.2 to 5.9. Especially in proximity of the port of Pescara (Abruzzo Region) CI scores are relevant. For the Croatian sea areas CI score range from 0 to 4.2, with high scores in proximity of Zadar port (Dalmatia). Bosnia & Herzegovina has a negligible CI scores. On average, the Italian sea space has the highest CI score (x̄ = 1.6), followed by Croatia (x̄ = 1.2) and Bosnia & Herzegovina (x̄ = 0.4). In the SAd, the CI scores for Italian sea areas range from 0 to 6.4, followed by Albania (score 2.3), Croatia (score 2) and Montenegro (score 1.7). In particular, coastal areas of the Apulia Region register highest CI scores in proximity of Bari and Brindisi ports. On average, the CI score is highest in Italy (x̄ = 1.7) followed by Albania and Croatia (x̄ = 0.6 respectively) and Montenegro (x̄ = 0.3).

29In figure 3b, results from sea use conflict analysis show that in the NAd the Italian sea space has the highest SUC score range, from 0 to 44, followed by Croatia (score 18) and Slovenia (score 12). Average SUC scores are equal in Italy and Slovenia (x̄ = 2). For Croatia SUC scores are negligible. In the CAd, highest SUC score are located in Italy (score 39), followed by Croatia (score 27). Bosnia & Herzegovina has a negligible SUC score. The average SUC score is highest in Italian sea area (x̄ = 2). In the SAd Italy has the highest SUC score (score 31), followed by Albania (score 12) and Montenegro (score 2). In figure 3c, results from nutrient dispersion model for riverine inputs of N and P are presented in a form of TotN&P index. Maximum nutrient loads are located in the NAd in proximity of the Po Deltaic System (score 1). Slovenian and Croatian sea areas have similar TotN&P score of 0.2 and 0.3 respectively. In the CAd highest scores are located in Italy (score 0.8) followed by Croatia (score 0.6) and Bosnia & Herzegovina (score 0.4). Especially the coastal area of the Dalmatia Region in Croatia and in localized areas of the Marche and Abruzzo Region coasts are affected. The highest average TotN&P score is located in Bosnia & Herzegovina (x̄ = 0.3). In the SAd the TotN&P index is highest in Albania (score 0.7), followed by Montenegro (score 0.6) and Italy (score 0.3). Croatia has negligible TotN&P scores. The highest average TotN&P score is located in Albania (x̄ = 0.7), followed by Montenegro (x̄ = 0.6) and Italy (x̄ = 0.3).

23The spatial distribution of riverine input data applied for hydrological modelling is presented in Figure 2 and a detailed overview of the riverine dataset including discharge rate (m³s⁻¹), catchment area (km²), river length (km), mean N and P concentrations (mg l⁻¹) is presented in supplementary material (see Appendix S3). In the NAd 49 (IT – 44; HR – 1; SL – 4) rivers were defined, in the CAd 109 rivers and in the SAd 8 rivers (AL – 7; MT/AL – 1). In total, the drainage area of the Adriatic Sea covers 238,000 km². The rivers with biggest drainage area are the Po (74,000 km²), the Neretva in Croatia (13,121 km²), the Drini in Albania (13,067 km²) and the Adige river in Italy (12,400 km²). The total drainage area of those rivers covers 109,000 km², about 46% of the total drainage area of the Adriatic Sea. Other rivers of relevance are theurgeon river (6,056 km²) at the 28border with Albania and Montenegro, the Drini river (5,912 km²), Piave (4,433 km²) at the Italian NAd, the Cetina river (3,869 km²) in Croatia and the Ofanto river (2,777 km²) in the SAd. The majority of the 284rivers coming from the Italian Apennines in the CAd and SAd and from the Dinaric Alps along the southeastern Adriatic Sea catchment area have a torrential hydrological regime (Cosic et al., 2004; Guarnieri et al., 2016).

27In Table 2 the MES capacity matrix is presented along their spatial extent. The highest ES capacity scores provided by marine habitats are as follows: A3 – infralittoral rock and other hard substrata (25.4 km², 0.1%), A5.535 – Posidonia beds (413.8 km², 0.2%), A5.531 – Cymodocea (622.7 km², 2900.3 %), A5.5353 – Facies of dead “mattes” of Posidonia oceanica without much epiflora (17.4 km², 2910.0%), A4 – Circalittoral rock and other hard substrata (501.1 km², 0.2%), A4.27 – Faunal communities on deep moderate energy circalittoral rock (5.7 km², smaller than 0.0 %) and 293A4.26/A4.32 – Med. coralligenous communities (488.2 km², 0.2%). Marine habitats with low MES capacity are related to deep sea environments: A6.1 – Deep-sea rock and artificial hard substrata (80.9 km², 0.0%); A6.2 – Deep-sea mixed substrata (82.3 km², 0.0%); A6.3 – Deep-sea sand (2,141.1 km²,
Results in Figure 3d presents MES capacity map. The highest capacity in the NAd is located in Italy (score 23), followed by Croatia (score 10) and Slovenia (score 7). Whereas average scores are similar for all three countries (x̄ ranges from 6 to 7). In the CAd, maximum MES capacity scores are located in Italy and Croatia (score 23 respectively). To notice is that Bosnia & Herzegovina has the highest score of 9, followed by Italy and Croatia with 6 respectively. In the SAd maximum MES capacity scores are located in Italy and Albania (score 23 respectively), followed by Croatia and Montenegro (score 9). On average MES capacity scores in the SAd are lower compared to NAd and CAd (x̄ = 3 for Italy and Montenegro; x̄ = 2 for Albania and Croatia).

In Figure 4 (a-d), the mean (μ) index scores as a function of distance from coastline (in km) are presented. Distance from coast was considered from the continental coastline to the midline sea boundary. For this reason Venice lagoon, the Grado-Marano lagoon and the aquifer of Comacchio in Italy were not included in the analysis. In the NAd, the highest mean CI score (μ = 5.3) is located in Slovenia at a distance of about 11 km from coast, whereas for Italy the highest mean CI (μ = 3.9) is located at a distance of 8 km.

Similarly, to the NAd, the highest mean CI score for the CAd is located at 10 km from Italian coasts (μ = 2.5). For the Croatian CAd, the highest mean CI is located offshore, at 75-80 km distance from coast (μ = 1.8). In the SAd, the highest mean CI scores are located at 6 km distance from Italian coasts (μ = 3.2), whereas for Croatia at 20 km from coast (μ = 1.7). For Albania, the highest mean CI scores (μ = 1.4) are located at 54 km from coast, while Montenegro mean CI scores (μ = 1) occur at 44 km distance from coast.

The highest mean SUC score (μ = 5.4) is located at about 15 km from Italian coasts, followed by Slovenia (μ = 2.6) at 7 km distance and Croatia (μ = 2.5) at about 30 km distance. On overall the CAd registers the highest mean SUC scores of the entire study area in offshore areas located between 80-90 km from Croatian coasts (μ = 2.7). For Italy, the highest SUC scores are located at 10 km (μ = 3233.2). In the SAd, the highest mean SUC scores (μ = 6.2) are located at 5 km from Italian coasts, followed by Albania (μ = 1.3) at 54 km distance, Montenegro (μ = 1.1) at 42 km distance and Croatia (μ = 0.4) at 25 km distance.

The highest mean TotN&P index scores are located in Italian NAd with mean values of about 0.4 within the 1 km distance from coast. Highest TotN&P scores for Slovenia (μ = 0.2) area are found at 2881 km from coast. In the CAd, the highest TotN&P index scores were found in Bosnia & Herzegovina (μ = 0.3), followed by Italy (μ ranging from 0.1 to 0.2) at 2 km from coast and below (μ = 0.1) from 300 coastline in Croatia. In the SAd, the highest mean TotN&P index score are found in Montenegro (μ ranging from 0.2 to 0.3) at 3 km from coast, in Albania (μ = 0.2) and in Italy (μ lower than 0.1) at 1 km 3222 from coast.

The highest mean MES capacity scores in the NAd are located at 1 km distance from coast in Italy (μ = 15) and Croatia (μ = 7.4) and at 10 km from coast for Slovenia (μ = 6.7). In the CAd, the highest mean MES capacity scores are located within 5-10 km distance from coast in Italy (μ = 9.8), Croatia (μ = 6.5) and Bosnia & Herzegovina (μ = 9). In the SAd, the highest mean MES capacity scores are located within 1-2 km from coast for Italy (μ = 17.5), 1-2 km for Croatia (μ = 7.5), at 25 km for Albania (μ = 4) and 3-5 km in Montenegro (μ = 8).
3.1. Overall spatial considerations

The NAd covers 25.2% of the total study area and can be considered as a regional hub. It is the smallest biogeographic subdivision, but is subjected to the most intensive anthropogenic pressures in its coastal and offshore areas, including shipping traffic, coastal and maritime tourism, oil and gas research and extraction, cables and pipelines, aquaculture, trawling and small-scale fishery. Moreover, there is a considerable land-sea interaction deriving from commercial port activities such as Venice (Veneto Region), Trieste (Friuli-Venezia-Giulia), Ancona (Marche Region), Koper (Coastal Karst Region) and Rijeka (Istria Region), the presence of mass tourism resorts (Veneto and Emilia...
processes in coastal and offshore areas of the NAd. Among the river basins integrated in the database, the Po river basin has the biggest extension (71,137 km²; see Appendix S3). The Po plain is subjected to intensive anthropogenic-driven modifications as it hosts 15.7 million inhabitants and its industrial, agricultural and service sectors produce about 40% of the national GDP (ADPO, 2017). The basin plays a determining role in eutrophication phenomena in the Adriatic Sea, especially in the coastal segment of 90 km from the Po Deltaic System to Ravenna, and it is subjected to seasonal eutrophication phenomena affecting coastal water quality (ADPO, 2006). Anthropogenic influence in terms of cumulative impacts, sea use conflicts and inputs from riverine runoff is most evident in coastal areas at distance from 1 to 15 km (Figure 4a, b and c). The MES capacity in coastal area is 62among the lowest of the study area, rapidly decreasing from coastal areas and getting more stable towards offshore areas (Figure 4d). Exception is Slovenia, where MES capacity remains almost constant for the entire sea space.

3.2. Future developments

3.2.1. Development of CI assessment tools

Whereas the tools currently available for CI assessment are useful for the characterization of CI over relatively large areas in coastal and offshore areas, they appear insufficient for the assessment of CI in small-scale coastal and marine environments, such as the NAd. To address this limitation, the following initiatives need to be undertaken.

At the current stage, the MSP stocktake applied in the CI and the SUC model need to be further extended including datasets on alien species, diving activities, underwater cultural heritage sites, artificial reefs or oil spill simulations for sea areas at highest oil spill risk. Moreover, future development scenarios from new shipping routes, new port developments and extensions, coastal
Hydrodynamic models are getting increased attention due to their potential support in MSP (Mohn et al., 2011), MSFD (Garcia-Gorriz et al., 2016) and WFD (Tsakiris and Alexakis, 2012). The presented hydrodynamic model has capabilities to provide information in support of EU MSFD descriptors, as they can determine indicators for past, present and future conditions, estimate future impact scenarios, fill data gaps and support the design of monitoring campaigns (MSFD Modelling Framework, 2017; Pirrodi et al., 2015). In particular, hydrodynamic modelling capabilities can be important for addressing MSFD descriptors that are not place specific (Gilbert et al., 2015), such as eutrophication (D5), contaminants (D8), contaminants in seafood (D9), marine litter (D10) and energy, in terms of noise pollution (D11). In support of MSP in the study area, the presented nutrient dispersion model is part of a comprehensive research effort for the integration of full range of pressures derived from land-based activities (e.g. urban cities, coastal tourism, catchment areas) into a socio-economic model. Similarly, to other CI assessments, the results from the hydrodynamic modelling will be an integrative component of the CI assessment in form of land-based activities. A major advantage of the presented hydrodynamic model, compared to other CI assessments in the Mediterranean (Micheli et al., 2013), is the comprehensive dataset of rivers, discharge rates and N and P concentrations coupled to the model that can be implemented as pressure from land-based activities into the CI model. This allows a flexible deployment of nutrient dispersion scenarios also on regional and local scales, considering anthropogenic activities, such as coastal tourism or aquaculture and the ecological components that can be impacted by coastal water quality. Moreover, the presented nutrient dispersion model is a valuable test case for ecosystem services research in the study area, as model results can be used as proxy for the analysis of three MES in particular: 1) regulation of water flows (e.g. water purification and mass transport of water) associated to river plume especially in coastal areas of the NAd (e.g. Po and Adige river), the CAd (Neretva river) and SAd (Drin river), 2) waste treatment and assimilation, due to dilution and dispersal of toxicants through hydrodynamics processes (Hattam et al., 2015) and 3) through the coupling of biogeochemical model for the generation of indicators for microbial reduction and cycling of excess nutrients (Liquete et al., 2016). The presented MES capacity model is a rapid screening methodology for the analysis and mapping of marine ES on large spatial scale. Results show that in general seabed habitats in proximity of coastal areas provide the majority of MES (Table 2, Figure 3d and 4d). In particular marine habitats featuring seagrasses of Posidonia and Cymodocea spp. beds can be considered as coastal areas with high MES capacity, although relatively limited in space (0.5% of the total study area). Seagrass meadows play an essential ecological role and are fundamental for supporting biodiversity conservation, nursery and habitat conservation, provision nutrient cycling and are responsible for photosynthesis processes (Campagne et al., 2015). In this context, the presented model can inform planners on the ecological functioning of coastal areas and provide baseline information for the development of ecosystem-based management strategies, required by the MSFD. For marine conservation planning, the presented MES model requires further methodological and dataset integrations related to field measurements on benthic communities distribution coupled with predictive model to assess benthic community distribution (Puls et al., 2012), assessment of ecological multi-functionality through geostatistical techniques (Schröter and Remme, 2016), development of habitat fragmentation models to better understand ecological resilience, identification of socio-economic proxy indicators that link ecological functioning and services to human well-being and 5) extension of sensitivity analysis implemented in the presented CI model, by defining the sensitivity of a benthic habitat from anthropogenic pressures on key stone species specific sensitivities and their ecological function.
In future, the increasing demand for integrated planning tools in MSP will require an augmented availability of high quality datasets and improved methodological procedures. Similarly, the presented modelling framework needs to transit from its modelling specificities towards a more integrated and multi-functional perspective taking into account different stages of an MSP process (Pinarbaşı et al., 2017). In this context, the spatial data infrastructure (SDI) of the ADRIPLAN Portal (www.data.adriplan.eu; Menegon et al., 2016) is based on GeoNode software (www.geonode.org), an open source geospatial content management system, and the presented Tools4MSP python library (www.github.com/CNR-ISMAR/tools4msp) for geospatial modelling provide a favourable context for more integrated and multi-functional modelling objectives for sea use planning and environmental management: First of all, GeoNode eases geospatial data management and a high level of customization of the Portal to user needs by promoting data-sharing among its users and by integrating web mapping applications. Second, the design of the Tools4MSP library allows to extend the currently available modules (CI and SUC models) with additional analytical modules deployable to any study area. These modules can include scenario analysis, sector-oriented modules, socio-economic investigations, models supporting economic valuation of the marine environment or support stakeholder engagement through Public Participatory GIS (PPGIS) exercises. At the current stage, customized CI and SUC scenarios can be run on the ADRIPLAN Portal based on the Tools4MSP libraries. This has an essential role in the future improvement of the analytical tools, through sharing of codes, development of user/developer communities and enable critical reflection on conceptual and methodological constrains among expert. Forth, the combination of an integrated geospatial data platform and the modelling library ensures a high degree of interoperability among modelling components and datasets.

3.4. Model limitations

The results of the presented models are not free of limitations. At the current stage uncertainty analysis is performed as a three-levelled general uncertainty analysis for the CI model (Gissi et al., 2016; 2017) adopted from the typology development by Walker et al., (2003). In future, a similar uncertainty analysis needs to be considered for the other models, in order to increase the credibility of the modelling approach for stakeholders involved in the planning process.

All the presented datasets and model outputs are resampled on a 1 km x 1 km cell grid, that can be considered of acceptable resolution for the proposed macro-regional analysis, however for countries with small sea spaces, such as Slovenia and Bosnia & Herzegovina, regional/local scale analysis is required using high quality datasets and higher cell grid resolution. In the SUC model, the within-grid spatial uncertainty is particularly evident, as two or more sea uses within a 1 km x 1 km grid can potentially coexist, without creating conflicts. This can be source of artificial conflicts in the model output. The spatial extent of the study area required intensive data aggregation procedures to perform model runs, nevertheless modelling uncertainties related to limited data availability remain. The datasets on human uses and environmental components implemented for the CI and SUC model were based on a multitude of datasets from different spatial scales (macro-regional to national and regional/local level). In order to reduce this uncertainty, the amount of human and environmental datasets for CI and SUC implemented in the eastern segment of the study area need to be aligned with the more complete datasets of its western segment (Italian sea space). In the nutrient dispersion model additional datasets on N and P concentrations are lacking for torrential rivers of Apulia Region in SAd and need to be further complemented. The EMODnet (2016) seabed habitat map applied in the MES model is lacking spatial data coverage for Albanian coastal areas and needs to take into consideration the low habitat confidence level of the habitats, especially in the eastern segment of the study area.
516(Populus et al., 2017) The nutrient dispersion model has limitation in the nutrient concentration
517datasets, as the applied dataset considers a combination of average discharge rates and modelled
518discharge rates based on timeseries (see Appendix S3). This does not allow to include seasonal
519overflow events in the model. Furthermore, a higher detail on nutrient transport and dispersion could
520be achieved through the implementation of a nearshore wave model. In the MES model limitations are
521mostly related to the three levels of information associated to the habitat (physical variables, habitat
descriptors and habitat type), that determine the level of confidence and therefore the actual nature of
the habitat (EMODnet, 2016). Other limitations are related to the lack of knowledge on ecosystem
services provision in deep sea environments (Thurber et al., 2014), especially in the SAd subdivision
and the application expert-based elicitation for the scoring of MES capacity (Hamel and Bryant 2013).

526
5274. Conclusions
528This research presents a set of geospatial models designed to address thematic objectives in sea
planning and environmental management in the Adriatic Sea. In future, the development of tools need
30to shift from a multi-objective perspective, towards a multi-functional approach. In sense, that model
functionality and modelling processes need to become more integrative and interoperable among
so tools. In this context, open source ADRIPLAN Portal and the Tools4MSP modelling framework can
accelerate this multi-functional perspective as they enable sharing of codes, datasets, models and
facilitate the knowledge exchange among expert communities. We conclude that a multi-functional
approach includes, but is not limited to the following model integrations: MES – CI integration. MES
36capacity model can be used as initial step to extend the sensitivity analysis implemented in the
37presented CI model, by linking the sensitivity of a seabed habitat to single or multiple pressures as a
38function of the specific service it supplies. CI – TotN&P integration. This includes the integration of
the CI model with N and P dispersion model to represent land-based activities and their pressures on
40target environmental components. Hydrodynamic models can easily feed CI models with spatial
explicit indicators for anthropogenic pressures from other land based activities (e.g. toxic compounds,
heavy metals or pathogens). CI – SUC integration. This includes the analysis of CI generated in high
conflict sea areas or in areas of synergies among uses. SUC – MES integration. MES framework can
provide methodological advancement and support a better understanding of human-nature interaction
and support the analysis of trade-offs and synergies among uses concentrating in the same sea area.

46MES – TotN&P integration. Hydrodynamic models can be used to quantify regulating ES (e.g. water
purification, waste treatment, coastal water quality).

54
549Acknowledgement
550This research is partly financed by the Italian National Flagship Project RITMARE – Italian Research
for the Sea (Ricerca ITaliana per il MARE, 2012-2016). Authors would also like to thank our intern
Md. Monzer Hossain Sarkar from the Erasmus Mundus Master Course on Maritime Spatial Planning
and support the analysis of trade-offs and synergies among uses concentrating in the same sea area.

546
550References
5511. ADPO (Autorità di bacino del Fiume Po), 2017. Presentazione del Bacino del Po (In Italian). Web: http://www.adbpo.it/on-
multi/ADBPO/Home/libacinoDelPo.html, accessed 24/05/2017.
2. ADPO (Autorità di bacino del Fiume Po), 2006. Caratteristiche del bacino del fiume Po e primo esame dell’impatto ambientale
delle attività sulle risorse idriche. Web: http://www.adbpo.it/download/bacino_Po/AdbPo_Caratteristiche-bacino-Po_2006.pdf,
3. Andersen, J. H., and Stock, A. (eds.) (2013). Human Uses, Pressures and Impacts in the Eastern North Sea. Technical Report,
Danish Centre for Environment and Energy, Aarhus University, Roskilde, 13.
4. ARPA-FVG, 2013. Acque superficiali interne. Web: http://www.arpaeweb.fvg.it/asi/gmapsasi.asp, accessed 23/10/2016.
5. ARPA-E. 2013. Arpae Emilia Romagna. Report acqua dolci 2010-2013. Web: http://www.arpae.it/cms3/documenti/_cerca_doc/acqua_dolci_2010-13/dat/2013_cvs, accessed 23/10/2016.
6. Bajo, M., Ferrarin, C., Dinu I., Umgussner, G., Stanica, A., 2014. The water circulation near the Danube Delta and the Romanian
coast modelled with finite elements. Cont. Shelf Res., Volume 78, 15 April 2014, Pages 62-74.
7. Barbanti, A., Campostrini, P., Musco, F., Sarretta, A., & Gissi, E., 2015. Developing a Maritime Spatial Plan for the Adriatic
Ionian Region. Zenodo. http://doi.org/10.5281/zenodo.48231.
8. Bianchi, C.N., 2004. Proposta di suddivisione dei mari italiani in settori biogeografici. Notiziario SIBM, 46: 57-59.
9. Brigolin, D., Porporato, E. M. D., Prioli, G., and Pastres, R. 2017. Making space for shellfish farming along the Adriatic coast. – ICEJ. O. Mar. Sci. doi:10.1093/icesjms/fsx018.
10. Bruckmeier, K., 2005. Interdisciplinary conflict analysis and conflict mitigation in local resource management. Ambio. 2005
11. Mar; 34(2):65-73.
12. Bužančič, M., Nincićević Gladan, Ž., Marasović, I., Kušpišić, G., Grebc, B., 2016. Eutrophication influence on phytoplankton community composition in three bays on the eastern Adriatic coast. Oceanologia, Volume 58, Issue 4, October–December 2016, Pages 302–316.
13. Campagne, C.S., Salles, J-M., Boissery, P., Deter, J., 2015. The seagrass Posidonia oceanica: Ecosystem services identification and economic evaluation of goods and benefits. Mar. Pollut. Bull., Volume 97, Issues 1–2, 15 August 2015, Pages 391-400.
14. Caric, H., Mackelworth, P., 2014. Cruise tourism environmental impacts: The perspective from the Adriatic Sea. Ocean Coast. Manage., 102 (2014) 350-363.
15. COEXIST. 2013. COEXIST, Interaction in coastal waters. Web: http://www.coexistproject.eu/, accessed 23/05/2017.
16. Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram F., Aguzzi, J., et al., 2010. The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats. PLoS ONE 5(8): e1842. https://doi.org/10.1371/journal.pone.001842
17. Danovaro, R., Company, J.B., Coralinesdi, C., D'Onghia, G., Galli, B., Gambi, C., et al., 2010. Deep-Sea Biodiversity in the Mediterranean Sea: The Known, the Unknown, and the Unknowable. PLoS ONE 5(8): e1832. https://doi.org/10.1371/journal.pone.001832.
18. Depellegrin, D., Pereira, P., 2016. Assessing oil spill sensitivity in unsheltered coastal environments: A case study for Lithuanian-Russian coasts, South-eastern Baltic Sea. Mar. Pollut. Bull., Volume 102, Issue 1, 15 January 2016, Pages 44-57.
19. Dijkema, K.S., Danikers, N., Wolff, W.J., 1985. Cumulatie van ecologische effecten in de Waddenzee (in Dutch). RIN-rapport 85/13.
20. EC. 2011. The potential of Maritime Spatial Planning in the Mediterranean Sea” Case study report: The Adriatic Sea. Web: https://ec.europa.eu/maritimeaffairs/faira/sites/maritimeaffairs/files/docs/body/case_study_adiatic_sea_en.pdf, accessed 23/04/2017.
21. EEA, 2013. European Environmental Agency Reference Grid. Web: http://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2, accessed 23/04/2017.
22. EEA, 2009a. WISE LARGE rivers and large lakes. Web: http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-large-lakes#tab-metadata, accessed 16/10/2016.
23. EEA, 2009b. Zipped shapefile with WISE other large rivers and tributaries, vector line. Web: http://www.eea.europa.eu/data-and-maps/data/wise-large-rivers-and-larges-zipped-shapefile-with-wise-other-large-rivers-and-tributaries-vector-line/zoom/wise-shapefile-with-wise-other-large-rivers-and-tributaries-vector-line, accessed 16/10/2017.
24. EEA. 2008. European river catchment. Web: https://ec.europa.eu/environment/water/monitoring/catchments/wise-rivercatchments-1, accessed 24/05/2017.
25. Ehler, C., Douvere, F., 2009. Maritime Spatial Planning a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6 Paris, France.
26. EMODnet, 2017. Portal for Bathymetry. Bathymetry Viewing and Download service. Web: http://portal.emodnet-bathymetry.eu/, accessed 23/04/2017.
27. EMODnet, 2016. EMODnet Phase 2 – Final report. Web: https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/seabed_habitats_final_report.pdf.
28. ESRI. 2017. Works Smarter with ArcGIS. Web: http://www.esri.com/arcgis/about-arcgis, accessed 23/04/2017.
29. EU Maritime Affairs, 2017. Maritime Spatial Planning. Web: https://ec.europa.eu/maritimeaffairs/policy/maritime Spatial_planning_en, accessed/23/04/2017.
30. EUSAIR. 2017. European Strategy for the Adriatic-Ionian Region. Web: http://www.adriatic-ionic.eu/, accessed 23/04/2017.
31. Foster, S.D., Dunstan, P.K., Althaus, F., Williams, A., 2014. The cumulative effect of trawl fishing on a multispecies fish assemblage in south-eastern Australia. J. Appl. Ecol., Volume 52, Issue 1, February 2015, 129-139.
32. Galparsoro, I., Borja, A., Uyarra, M.C., 2014. Numerical modelling of sediment transport in the Adriatic Sea. Ocean Coast. Manage. 54 (2011), 350-363.
33. García-Gorriz, E., Macias Moy, D., Stips, A., Miladinova-Marinova, S., 2016. Assemblage in south-eastern Australia. J. Appl. Ecol., Volume 52, Issue 1, February 2015, 129-139.
34. Garcia-Gorriz, E., Macias Moy, D., Stips, A., Miladinova-Marinova, S., 2016. JRC Marine Modelling Framework in support of the Marine Strategy Framework Directive: Inventory of models, basin configurations and datasets. JRC Technical Report, EUR27885, doi:10.2788/607272.
35. Ghezzo, M., Sarretta, A., Sigivini, M., Guerzoni, S., Tagliaipretta, D., Umgiesser, G., 2011. Modeling the inter-annual variability of salinity in the lagoon of Venice in relation to the water framework directive typologies. Ocean Coast. Manage. 54 (201), 706-719.
36. Gilbert, A.J., Alexander, K., Sardà R., Brajzinskaite, R., Fischer, C., Gee, K., Jessop, M., Kershaw, P., Los, H.J., March Morla, D., O’Mahony, C., Pihlajamäki, , Rees, S., Varjopuro R., 2015. Lithuanian-Russian coasts, South-eastern Baltic Sea. Mar. Pollut. Bull., Volume 102, Issue 1, 15 January 2016, Pages 44-57.
37. Gigli, D., D’Onghia, C., Pernice, G., et al., 2010. The impact of water quality changes on the socio-economic system of the Guadiana Estuary: an assessment of management options. Ecol. Soc., 17(3): 38.
38. Gillett, B.S., Frazier, M., Potapenko, J., Casey, K.S., Koenig, K., Longo, C., Lowndes, J.S., Rockwood, R.C., Selig, E.R., Selkoe, K.A., Walbridge, S., 2015. Spatial and temporal changes in cumulative human impacts on the world’s ocean. Nature Communications 6:7615 | DOI: 10.1038/ncomms8615.
39. Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D’Agrosa, C., 2008. A global map of human impact on marine ecosystems. Science 319(5865): 948–952. pmid:18276889
40. Hamel, P., Bryant, B.P., 2017. Uncertainty assessment in ecosystem services analyses: Seven challenges and practical responses. Ecosystem Serv. , Volume 24, April 2017, Pages 1-15.
Oral, N., Simard, F., 2008. Legal mechanisms to address maritime impacts on Mediterranean biodiversity. Malaga, Spain: IUCN

Tools4MSP, 2016. Tools to support Maritime Spatial Planning. Web:

Thurber, A.R., Sweetman, A. K., Narayanaswamy, B. E., Jones, D.O.B., Ingels, J., Gissi, E., Venier, C., 2016. Geospatial dataset for Cumulative Impact assessment, Sea Use conflict analysis and Marine Ecosystem Services assessment in the Adriatic Ionian Region [Data set]. Zenodo.

Menegon, S., Ghezzo, M., Depellegrin, D., 2017b. Cumulative Impact Analysis: affinamento della metodologia e delle stime di impatti cumulativi. Zenodo. https://doi.org/10.5281/zenodo.569815.

Menegoni, S., Saretta, A., Barbanti, A., Gissi, E., Venier, C., 2016. Open source tools to support Integrated Coastal Management and Maritime Spatial Planning. PeerJ Preprints 4:e2245v2 https://doi.org/10.7287/peerj.preprints.2245v2.

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A.A., 2013. Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. PLoS ONE 8(12): e79889. https://doi.org/10.1371/journal.pone.0079889.

Mohn, C., Kotta, J., Dahl, K., Gök, A., Błażewskas, N., Ruszkule, A., Åps, R., Petissov, M., Janssen, F., Lindblad, C., Piotrowski M., Wan, Z., 2011: Modelling for Maritime Spatial Planning: Tools, concepts, applications. BalticSeaPlan Report 19.

Moore, S.A., Brown, G., Kobryn, H., Strickland-Munro, J., 2017. Identifying conflict potential in a coastal and marine environment using participatory mapping. J. Environ. Manage., Volume 197, 15 July 2017, Pages 706-718.

MSP-Platform, 2017, Eastern Mediterranean. Web: http://msp-platform.eu/sea-basins/east-mediterranean, accessed 23/05/2017.

Mohn, C., Kotta, J., Dahl, K., Gök, A., Błażewskas, N., Ruszkule, A., Åps, R., Petissov, M., Janssen, F., Lindblad, C., Piotrowski M., Wan, Z., 2011: Modelling for Maritime Spatial Planning: Tools, concepts, applications. BalticSeaPlan Report 19.

Menegoni, S., Saretta, A., Barbanti, A., Gissi, E., Venier, C., 2016. Open source tools to support Integrated Coastal Management and Maritime Spatial Planning. PeerJ Preprints 4:e2245v2 https://doi.org/10.7287/peerj.preprints.2245v2.

Menegon, S., Ghezzo, M., Depellegrin, D., 2017a. Geospatial dataset for Cumulative Impact assessment, Sea Use conflict analysis and Marine Ecosystem Services assessment in the Adriatic Ionian Region [Data set]. Zenodo.

http://dx.doi.org/10.5281/zenodo.826675.

Menegoni, S., Saretta, A., Barbanti, A., Gissi, E., Venier, C., 2016. Open source tools to support Integrated Coastal Management and Maritime Spatial Planning. PeerJ Preprints 4:e2245v2 https://doi.org/10.7287/peerj.preprints.2245v2.

Menegon, S., Ghezzo, M., Depellegrin, D., 2017b. Cumulative Impact Analysis: affinamento della metodologia e delle stime di impatti cumulativi. Zenodo. https://doi.org/10.5281/zenodo.569815.

Menegoni, S., Saretta, A., Barbanti, A., Gissi, E., Venier, C., 2016. Open source tools to support Integrated Coastal Management and Maritime Spatial Planning. PeerJ Preprints 4:e2245v2 https://doi.org/10.7287/peerj.preprints.2245v2.

Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A.A., 2013. Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. PLoS ONE 8(12): e79889. https://doi.org/10.1371/journal.pone.0079889.

Mohn, C., Kotta, J., Dahl, K., Gök, A., Błażewskas, N., Ruszkule, A., Åps, R., Petissov, M., Janssen, F., Lindblad, C., Piotrowski M., Wan, Z., 2011: Modelling for Maritime Spatial Planning: Tools, concepts, applications. BalticSeaPlan Report 19.

Moore, S.A., Brown, G., Kobryn, H., Strickland-Munro, J., 2017. Identifying conflict potential in a coastal and marine environment using participatory mapping. J. Environ. Manage., Volume 197, 15 July 2017, Pages 706-718.

MSP-Platform, 2017, Eastern Mediterranean. Web: http://msp-platform.eu/sea-basins/east-mediterranean, accessed 23/05/2017.

R-Cran Project, 2017. The Comprehensive R Archive Network. Web: http://cran.r-project.org/, accessed 23/04/2017.

Moore, S.A., Brown, G., Kobryn, H., Strickland-Munro, J., 2017. Identifying conflict potential in a coastal and marine environment using participatory mapping. J. Environ. Manage., Volume 197, 15 July 2017, Pages 706-718.

MSP-Platform, 2017, Eastern Mediterranean. Web: http://msp-platform.eu/sea-basins/east-mediterranean, accessed 23/05/2017.

R-Cran Project, 2017. The Comprehensive R Archive Network. Web: https://cran.r-project.org/, accessed 23/04/2017.

Salomidi, M., Katsanevakis, S., Borja, A., Braeckman, U., Danals, D., Galparsoro, I., et al., 2012. Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone towards ecosystem-based marine management. Ecol. Indic., 2012, Vol. 12, Issue C, pages 449-463.

Salomidi, M., Katsanevakis, S., Borja, A., Braeckman, U., Danals, D., Galparsoro, I., et al., 2012. Assessment of goods and services, vulnerability, and conservation status of European seabed biotopes: a stepping stone towards ecosystem-based marine management. Ecol. Indic., 2012, Vol. 12, Issue C, pages 449-463.

Schweizer, J., Antonini, A., Govoni, L., Gottardi, G., Archetti, R., Supino, E., Berretta, C., Casadei, C., Ozzi, C., 2016. Investigating the potential and feasibility of an offshore wind farm in the Northern Adriatic Sea. Appl. Energy, 2016, vol. 177, doi:10.1016/j.apenergy.2016.05.060.

Schweizer, J., Antonini, A., Govoni, L., Gottardi, G., Archetti, R., Supino, E., Berretta, C., Casadei, C., Ozzi, C., 2016. Investigating the potential and feasibility of an offshore wind farm in the Northern Adriatic Sea. Appl. Energy, 2016, vol. 177, doi:10.1016/j.apenergy.2016.05.060.

Schofield, C., Townsend-Gault, I., 2011. From sundering seas to arenas for cooperation applying the regime of enclosed and semi-enclosed seas to the Adriatic. Geoaeria 17/1 (2012) 13-24.

Schröter, M., Remme, R.P., 2016. Spatial prioritisation for conserving ecosystem services: comparing hotspots with heuristic optimisation. Landsc. Ecol., February 2016, Volume 31, Issue 2, pp 431-450.

Schröter, M., Remme, R.P. & Hein, L., 2012. How and where to map supply and demand of ecosystem services for policy-relevant outcomes? Ecol. Indic., 23, pp. 220-221.

Schweizer, J., Antonini, A., Govoni, L., Gottardi, G., Archetti, R., Supino, E., Berretta, C., Casadei, C., Ozzi, C., 2016. Investigating the potential and feasibility of an offshore wind farm in the Northern Adriatic Sea. Appl. Energy, 2016, vol. 177, issue C, pages 449-463.

Stamoulis, K.A., Delevaux, J.M.S., 2015. Data requirements and tools to operationalize marine spatial planning in the United States. Ocean Coast. Manage., 116 (2015) 214-223.

UNEP/MAP RAC/SPA, 2010. The Mediterranean Sea Biodiversity: state of the ecosystems, pressures, impacts and future priorities. By Bazzari, F., Ben Haji, S., Boero, F., Cebrian, D., De Juan, S., Liman, A., Leonart, J., Torcha, G., and Raas, C., Ed. RAC/SPA, Tunis, 100 pages.

Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neves, J., Neve
75. Populus, J., Vasquez, M., Albrecht, J., Manca, E., Agnesi, S., Al Hamdani, Z., Andersen, J., Annunziatellis, A., Bekkby, T., Braschi, A., Doncheva, V., Drakopoulou, V., Duncan, G., Inghilesi, R., Kyriakidou, C., Lalli, F., Lillis, H., Mo, G., Muresan, M., Salomidi, M., Sakellaritiou, D., Simboura, M., Teaca, A., Tezcan, D., Todorova, V., Tunesi, L., 2017. EUSeaMap, a European broad-scale seabed habitat map. 174 p. http://doi.org/10.13155/49975.

76. Pals, W., van Bernem, K.-H., Eppel, D., Kapitza Pleskachevsky, H., Riethmüller, R., Vaessen, B., 2012. Prediction of benthic community structure from environmental variables in a soft-sediment tidal basin (North Sea). Helgoland Mar. Res., September 2012. Volume 66, Issue 3, pp 345-361.

77. Umgiesser, G., Melaku Canu D., Cucco, A., Solidoro, C., 2004. A finite element model for the Venice Lagoon. Development, set up, calibration and validation. J. of Mar. Sys., Vol. 51, 123-145, doi:10.1016/j.jmarsys.2004.05.009.

78. UNEP-MAP-RAC/SPA, 2015. Adriatic Sea: Important areas for conservation of cetaceans, sea turtles and giant devil rays. By Holcer, D., Fortuna, C.M., Mackelworth, P.C. Ed. RAC/SPA, Tunis: 39pp.

79. UNEP-MAP-RAC/SPA, 2010. Report presenting a georeferenced compilation on bird important areas in the Mediterranean open seas. By Requena, S. and Carboneras, C. Ed. RAC/SPA, Tunis: 39pp.

80. Walker, W.E., Harremoës, P., Rotmans, J., van der Sluijs, J.P., van Asselt, M.B.A., Janssen, P., Krayer von Krauss M.P., 2003. Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support. Integr. Assess., 4 (1) (2003), pp. 5-17, 10.1076/iaij.4.1.5.16466.

81. Yee, S.H., Carriger, J.F., Bradley, P., Fisher, W.S., Dyson, B., 2015. Developing scientific information to support decisions for sustainable coral reef ecosystem services. Ecol. Econ. 115, 39-50.