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Decision support tools in marine spatial planning: Present applications, gaps and future perspectives

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ABSTRACT

Evidence-based decision making is an essential process for sustainable, effective, and efficient marine spatial planning (MSP). In that sense, decision support tools (DSTs) could be considered to be the primary assistant of planners. Although there are many DSTs listed in tool databases, most of them are conceptual and not used in real MSP implementation. The main objective of this review is to: (i) characterize and analyse the present use of the DSTs in existing MSP implementation processes around the world, (ii) identify weaknesses and gaps of existing tools, and (iii) propose new functionalities both to improve their feasibility and to promote their application. In total, 34 DSTs have been identified in 28 different MSP initiatives with different levels of complexity, applicability and usage purposes. Main characteristics of the tools were transferred into a DST matrix. It was observed that limited functionality, tool stability, consideration of economic and social decision problems, ease of use, and tool costs could be considered as the main gaps of existing DSTs. Future developments are needed and should be in the direction of the specific need of marine planners and stakeholders. Results revealed that DST developments should consider both spatial and temporal dynamics of the ocean, and new tools should provide multi-functionality and integrity; meanwhile they should be easy to use and freely available. Hence, this research summarised current use, gaps, and expected development trends of DSTs and it concludes that there is still a big potential of DST developments to assist operational MSP processes.

1. Introduction

Due to the present and future demand for marine resources, human activities in the marine environment are expected to increase, which will produce higher pressures on marine ecosystems, as well as competition and conflicts among marine users [1–4]. This fact highlights the need for new management approaches, synergies, transnational coordination, visions, and actions [4]. At present, marine or maritime spatial planning (MSP) is considered as a promising management approach to transform conflicts into solutions, when managing multiple activities and users at sea [5]. MSP aims to balance the development of maritime activities and increase cross-border cooperation through transparency, clearer legislation, better coordination between administrations, and the early identification of impacts that can arise from the multiple uses of marine space [6]. Thus, MSP is a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process [7–9]. In addition, the widely accepted management philosophy of MSP is ecosystem-based management, which strives to support healthy and productive marine ecosystems [10–13]. Ecosystem-based MSP covers effective implementation of ecosystem management frameworks in planning processes and focuses on achieving sustainable management of marine resources [5]. This approach enhances other responsibilities and activities to reach sustainable development. Despite the limitations and questionable aspects, MSP has been already implemented in many countries around the world [14].

One of the earliest examples of MSP was the plan developed for the Great Barrier Reef Marine Park in Australia [15]. Since 1975, initial zoning plans have been produced for concerns about oil and gas exploration, limestone mining, overfishing and environmental protection. The United States is another pioneer country in MSP. In 2013, the federal government provided a policy guidance framework: National

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Table 1
Reviewed Marine Spatial Planning experiences for Decision Support Tools identification and application analysis MPA: Marine Protected Area.

Scale	Plan/Initiative name	Reference
International	BaltSeaPlan	Fetissov, Aps and Kopti [38], Göke and Lamp [39], A. Schultz-Zehdenn [30], Jörg and Lamp [40]
International	Trilateral Wadden Sea Plan	Common Wadden Sea Secretariat [41]
National	China Territorial Sea zoning	Feng, Chen, Li, Zhou and Yu [19]
National	Barbuda Blue Halo	SeaSketch: http://www.seasketch.org/projects (accessed 15.02.17)
National	New Belgium Marine Spatial Plan (2014)	Belgian Royal Decree [23]
National	Germany Spatial Plan for North Sea and Baltic Sea	BFN [21,22,42]
National	Israel Marine Spatial Plan Pilot	Israel Institute of Technology [20]
National	The Netherlands National Water Plan	Ministry of Infrastructure and the Environment [24]
Local	Rezoning of the Great Barrier Reef Marine Park	Great Barrier Reef Marine Park Authority [15]
Local	Habitat Risk Assessment Module: Belize Case	Rosenthal, Verutes, Arkema, Clarke, Canto, Rosado and Wood [43]
Local	Eastern Scotian Shelf Integrated Ocean Management Plan (ESSIM)	ESSIM Planning Office [44] SeaSketch: http://www.seasketch.org/projects/ (accessed 15.02.17)
Local	Galapagos Marine Reserve Zoning, Ecuador	Direction of the Galapagos National Park [45]
Local	Sea Change, Hauraki Gulf New Zealand	SeaSketch: http://www.seasketch.org/projects (accessed 15.02.17)
Local	Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands	Norwegian Ministry of the Environment [46]
Local	Irish Sea Pilot Project	Kidd [47], Kidd and McGowan [48], Vincent [49]
Local	MPAs in the Channel Islands National Marine Sanctuary	Airamé, Dugan, Lafferty, Leslie, McArdle and Warner [50]
Local	Gulf of Mexico	Beck and Odaya [51]
Local	Massachusetts Ocean Plan	MassGIS (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/) MORIS (http://www.mass.gov/eea/agencies/czm/program-areas/mapping-and-data-management/moris) North East Ocean Data (http://www.northeastoceandata.org/) (accessed 15.02.17) Altman, Boumans, Roman and Kaufman [52]
Local	Channel Islands National Marine Sanctuary Education and Outreach Platform	SeaSketch: http://www.seasketch.org/projects (accessed 15.02.17)
Local	Washington Marine Spatial Plan	SeaSketch: http://www.seasketch.org/projects (accessed 15.02.17)
EU Project	BONUS BALTSPACE Project	[37], SeaSketch: http://www.seasketch.org/projects (accessed 15.02.17)
EU Project	PartiSEApate Project	http://www.partiseapate.eu/ (accessed 15.02.17)
EU Project	Vectors Project: Ecosystem Model	http://www.marine-vectors.eu/ (accessed 15.02.17)
EU Project	Coexist Project	Coexist: http://www.coexistproject.eu/coexist-results/tool (accessed 15.02.17)
EU Project	MASPNOSE Project - Maritime Spatial Planning (MSP) in the North Sea	https://www.wur.nl/en/show/maspnose-maritime-spatial-planning-in-the-North-Sea.htm (accessed 15.02.17)
EU Project	AquaCross Project: Trade Off´s in Ecosystem Based Fisheries in the North Sea	AquaCross Website: http://aquacross.eu (accessed 15.02.17)
EU Project	BALANCE – Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning	Andersson, Korpinen, Liman, Nilsson, Piekäinen and Huggins [53]
EU Project	ADRIPLAN: Adriatic Ionian Maritime Spatial Planning	Barbanti A. [54], Menegon, Sarretta, Barbanti, Gissi and Venier [55] ADRIPLAN Website: http://adriplan.eu/
EU Project	MESMA: Monitoring and evaluation of spatially managed marine areas	Buhl-Mortensen, Galparsoro, Vega Fernández, Johnson, D'Anna, Badalamenti, Garofalo, Carlström, Piwowarczyk, Rabaut, Vanaverbeke, Schipper, van Dalfsen, Vassilopoulou, Issaris, van Hoof, Pecceu, Hostens, Pace, Knittweis, Stelzenmüller, Todorova and Doncheva [27]

Policy for the Stewardship of the Ocean, Coasts, and Great Lakes [16]. Additionally, responsible authorities of several states (Oregon, Massachusetts and Rhode Island) have planned the human use of their marine space within their marine waters (three nautical miles of the coast). One of the most well-known MSP cases in United States is the state of Rhode Island, which used a previously-existing federal law as a legal framework for policy guidance: the Coastal Zone Management Act of 1972 [17]. The Massachusetts Ocean Management Plan has been revised and re-published recently [18]. In Asia, China has implemented the National Marine Functional Zoning Scheme for the period from 2001 to 2020 [19]. A pilot project, the Israel Marine Plan (IMP), was completed in November 2015 [20]. At the European scale, the Maritime Spatial Planning directive [6] is legally binding for Member States to complete their maritime spatial plans by 2021. In this legislation, the European Commission and DG MARE use the term “maritime spatial planning” to underline the holistic and cross-sectorial nature of MSP and to differentiate their work from that of the environmentally-oriented authority, DG Environment (*in this paper we use both terms with the acronym of MSP). Several countries in Northern Europe, such as Germany, Norway, Belgium, and the Netherlands have already implemented their plans [21–25]. Furthermore, some eastern European countries such as Lithuania, Poland and Latvia have quite advanced MSP achievements [26]. Apart from the political initiatives, research projects are also contributing significantly to different aspects of the MSP development and implementation. The main objectives of such projects have been to provide knowledge, science-based approaches and tools to improve the capacity of countries and to support the implementation of MSP. Many projects have developed analytical frameworks, guidelines, and recommendations for countries that are initiating MSP [13,26–30].

During these MSP processes, experiences have demonstrated that marine spatial planning should be a continuous, iterative, and adaptive participatory process, comprising a set of actions including research, analysis and planning, financing, implementation, monitoring, and evaluation of the plan. It has been stated that all of these individual functions must be carried out for successful management [13,27,31]. This process frequently requires planners to undertake essential tasks, such as specifying spatial and temporal boundaries, mapping important areas, identifying spatial conflicts of use, defining scenarios, and designing management actions at different stages of the MSP implementation process [32]. Moreover, it has been observed that DSTs can be used to simplify these tasks [33]. The aforementioned characteristics