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Incorporating change in marine spatial planning: A review

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ABSTRACT

Marine/maritime spatial planning (MSP) is intended as a process to apply an adaptive ecosystem-based approach in order to manage the oceans towards the sustainable use of marine resources. Several policy documents and research articles have identified the need for MSP to address change, intended as dynamic aspects from different drivers. However, practical examples of MSP embracing change and dynamics are rare and the inclusion of system dynamics, environmental variability and future change in MSP remains challenging. Here, we conceptualize the multiple dimensions of change in MSP consisting in i) the dynamics of the marine and coastal social-ecological system (SES), and ii) the dynamics of the planning process. This study depicts the current state of scientific knowledge on incorporating change and dynamics in MSP through a systematic literature review. Efforts to actually incorporate change in MSP are mainly limited to environmental dynamics, while social and governance changes are rarely represented. Long-term temporal scales are only seldom considered, and climate change effects rarely incorporated in methods and tools to support MSP. We propose a tier-approach to include multiple response variables and scenario modeling to address socio-economic, environmental and governance change and dynamics within MSP.

1. Introduction

Marine/maritime Spatial Planning[1] (MSP) is the adaptive process of analyzing and guiding the spatial and temporal distribution of human activities in marine and coastal areas to achieve ecological, economic, and social objectives usually specified through a political process (Ehler and Douvere, 2009). The adaptive nature of MSP involves exploring alternative ways to meet management objectives (for example, through scenario analysis), predicting the outcomes of alternative management measures, implementing one or more of these alternative management options, monitoring to learn about the effects of management, and then using results to update knowledge and adjust management actions (Agardy et al., 2011; Douvere and Ehler, 2011; Ehler, 2014). MSP was initially stimulated by international and national initiatives for improving the effectiveness of Marine Protected Areas, e.g., the Great Barrier Reef Marine Park (Douvere, 2008), but subsequently has expanded to more broadly include ecosystem-based and area-based principles, integrated and adaptive management, and strategic and participatory processes (Ehler and Douvere, 2009). Reviews of applications to date, though conducted with different methodologies and objectives (i.e., Ansong et al., 2017; Collie et al., 2013; Domínguez-Tejo et al., 2016; Pınarbaşı et al., 2017), have generally reported a substantial heterogeneity in the implementation process on a global scale (Ansong et al., 2017; Buhl-Mortensen et al., 2017; Collie et al., 2013).

Leading international organizations, as UNEP (i.e., Agardy et al., 2011) and UNESCO (i.e., Ehler, 2014; Ehler and Douvere, 2009), have produced guidelines for the effective implementation of MSP around the world. MSP is designed as an adaptive process supporting learning (Ehler, 2014), improving the decision makers' and stakeholders' understanding of present and future issues and their ability to manage them (Ehler, 2014). Within an ideal MSP process, management and planning actions are revised and updated to adapt to changing environmental, social and economic conditions (Douvere and Ehler, 2011; Ehler, 2014). The United States Final Recommendations of the Interagency Ocean Policy Task Force for Coastal and Marine Spatial Planning (CMSP) highlights the need for MSP to apply an "adaptive

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[1] Marine spatial planning and Maritime spatial planning are used here as synonymous; "marine" is mostly used world-wide under the UNESCO-IOC initiative on marine spatial planning, while "maritime" is used under the European legislation.

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management (which calls for routine reassessment of management actions to allow for better informed and improved future decisions)", and that "CMSP would be adaptive and flexible to accommodate changing environmental conditions and impacts, including those associated with global climate change, sea-level rise, and ocean acidification; and new and emerging uses, advances in science and technology, and policy changes" (White House Council on Environmental Quality, 2010). In Europe, the EU MSP Framework Directive 2014/89/EC (MSPD, European Union, 2014) states that MSP needs to take into consideration "long-term changes due to climate change".

Along with the implementation plan, monitoring and evaluation are essential steps to assess the effectiveness of the plan in achieving its goals, as well as to incorporate in planning potential changes of the marine and coastal systems (Ehler, 2014). Thus, MSP needs to address change at different levels: i) at the *content* level, MSP operates in changing marine socio-ecological systems, whose drivers are both internal (i.e. social and ecological dynamics) and external (i.e. climate change); ii) at the *process* level, MSP – as the adaptive process of planning – should acknowledge change, and learn and adapt with changing conditions (Agardy et al., 2011). At both levels, uncertainty should be carefully assessed and explicitly incorporated in the decision-making process (Gissi et al., 2017; Stock and Micheli, 2016).

The theoretical principles and best practices for an adaptive MSP have been clearly identified and extensively discussed (see references above). However, concrete examples of MSP embracing change and dynamics are rare and the inclusion of system dynamics, environmental variability and future change in MSP remains challenging. In a review of 16 MSP processes, Collie et al. (2013) found that only 3 had actually implemented adaptive management principles (Ehler, 2014). Ansong et al. (2017) found that in only 5 of 39 MSP initiatives analyzed in their review the planning boundaries coincided with ecological boundaries in order to incorporate environmental dynamics in planning. Spatial and temporal ocean dynamics are yet not fully included in MSP practices, largely due to high costs of adopting dynamic decision-support tools in the decision-making processes (Pınarbaşı et al., 2017).

This study presents the results of a systematic review of the peer-reviewed scientific literature to detect gaps and future research needs to support MSP practices that account for system dynamics and future change, and to provide scientists and experts working in planning processes with methods for incorporating change and dynamics in MSP processes. Specifically, this review aims to: 1) assess MSP studies in peer-review literature explicitly including the consideration of change and dynamics, and, when relevant, analyze how change is addressed; and 2) document the major constrains and obstacle for the effective adaptation of MSP to future change. In the next section, a framework to interpret change and dynamics in MSP is proposed, considering the dynamics of the marine and coastal social-ecological systems within the MSP process.

2. Drivers of change in MSP: a two way process

To conduct a systematic literature review, we define here the concepts and terminology required to investigate change and dynamics in MSP. Change in MSP has multiple dimensions (Fig. 1): (1) the dynamics of the marine and coastal social-ecological system (SES); (2) the dynamics of the planning process.

The dynamics and change of SES, as the *system-to-be-planned* in the decision-making process, represent the first dimension of change. At the very core of MSP there are the multiple connections and dynamics of the environment, within the human system, and between the humans and the environment that form the SES (Agardy et al., 2011; Ehler and Douvere, 2009). Changes can be conceptualized as emerging from multi-level and cross-scale interactions and variability (Cash et al., 2006). Changes of SES derive from the interactions of dynamics over the spatial scale, and the temporal scale. Definitions of the scales are reported in Table A.1 (supplementary materials). The social dynamics includes the social, economic and political processes that play a role and intervene in molding SES dynamics. SES dynamics can be represented as the interplay between the social and the bio-physical processes at multiple spatial and temporal scales giving place to the complex quasi-stationary state of SES (Liu et al., 2007). Changes in SES state or condition (e.g. changes in standing biomass or species composition, or social perception of environmental problems) are led by the combination of drivers, ecosystem processes and dynamics on the two scales. MSP operates on SES, both inducing and incorporating change at multiple spatial and temporal scales within the planning process. Definitions of the scales and examples of real processes at multiple scales acting on or influenced by MSP are reported in Table A.2 and Figure A.1 (Supplementary materials).

The second dimension of change for MSP corresponds to the dynamics of the decision-making process, taking place in time and space, according to the planning steps synthesized by Maxwell et al. (2015) as follows: 1) assess, 2) design, 3) implement, 4) monitor, 5) evaluate, and 6) adjust. MSP is constructed on these six steps (Agardy et al., 2011; Ehler and Douvere, 2009), to analyze the existing conditions based on the best available knowledge on the marine and coastal systems subjected to the planning process (Agardy et al., 2011). The six MSP steps are, then, repeated in subsequent planning cycles. Gilliland and Laffoley (2008) recorded significant differences in the MSP timeframes, with no single rule to follow. Gilbert et al. (2015) recommend periodic review and modification of the MSP plan every five-seven years in order to adapt to unforeseen environmental effects. The EU MSP Directive 2014/89/EU indicates that Member States shall review maritime spatial plans at least every ten years (EC, 2014). Intermediate reviews within planning cycles are also conducted to assess new information or changing circumstances without having to review or revise the whole plan (Gilliland and Laffoley, 2008). To date, only 6 MSP initiatives have passed through one or more revision processes, among which the Great Barrier Reef Park[2] and the Dutch MSP initiatives[3].

In an attempt to incorporate both content- and process-types of dimensions of change, MSP anticipates possible future change via scenario analysis (Fig. 1). MSP is a way to "forward look" (Gilliland and Laffoley, 2008), intended as the act of planning to orient human action towards the future. MSP is initiated by visioning for marine and coastal management (Agardy et al., 2011). The vision for MSP is described in pragmatic terms by Douvere and Ehler (2009) as "what your marine area could or should look like in another 10, 20, 30 years from now" (p. 10), thereby representing "a consistent direction not only of what is desirable, but what is possible in marine areas" (p. 11). Visions are usually elaborated within a participatory process on a desirable future that aims to identify a set of goals and strategies to guide a planning effort (Alberti, 2008). In order to establish operational paths towards the vision, scenarios are elaborated in the planning phase by analyzing and assessing future conditions and potential changes driven by human actions (Ehler and Douvere, 2009), and assessing trade-offs between management alternatives in a transparent way (Guerry et al., 2012). Scenarios can be elaborated considering projections of changes or trends of human activities (Ehler and Douvere, 2009; Piante and Ody,

[2] The Great Barrier Reef Park followed several subsequent planning cycles, after the release of the Great Barrier Reef Marine Park Act of 1975. An extensive re-zooning process, the Representative Areas Program (1998-2003), started in the late 1990s after the results of the monitoring phase. The 2009 and 2014 Outlook Reports recollected key information for the elaboration of the "Reef 2050 Long-term Sustainability Plan", released in 2015 (source: http://msp.ioc-unesco.org, accessed at 10/10/17).

[3] The first initiative on MSP in the Dutch part of the North Sea was released in 2005, the North Sea chapter in their national 'Spatial Planning Policy Document', followed by the Policy Document on the North Sea (2009); finally, the North Sea Policy Document 2016 – 2021, including the Netherlands long term vision (2050), was released in 2015 (source: http://msp.ioc-unesco.org, accessed at 10/10/17).

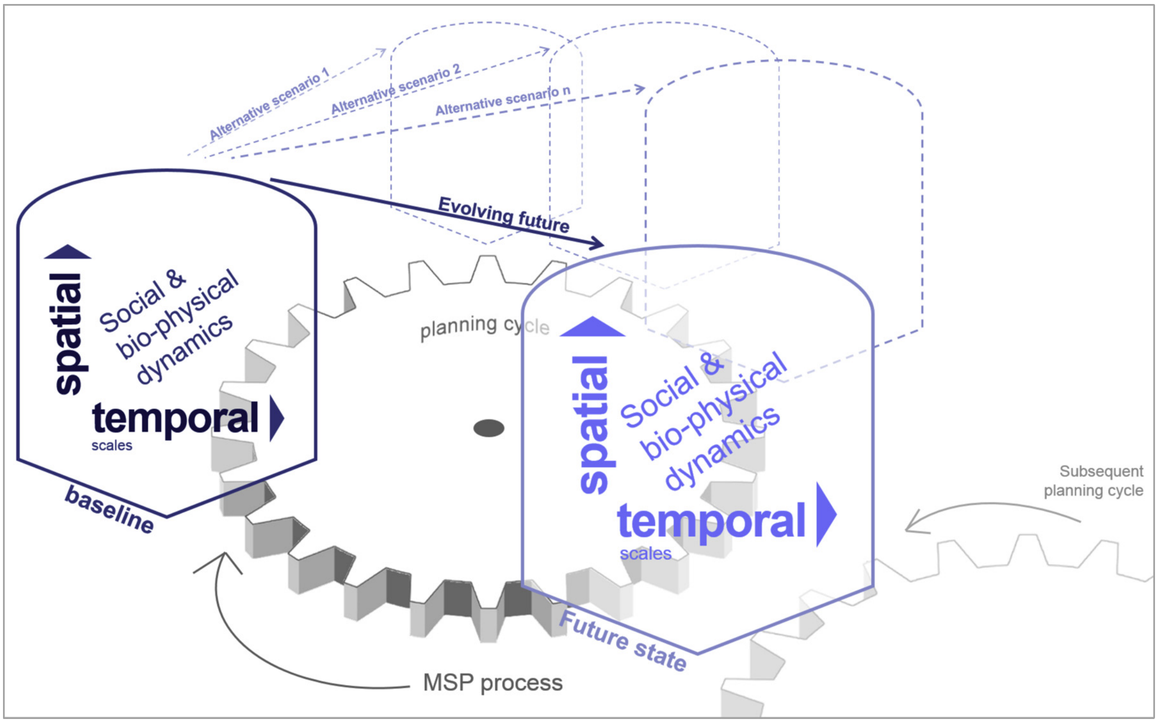

Fig. 1. Diagram representing the multiple dimensions of change in MSP: 1) the dynamics and change (e.g. from a current baseline to a future state) of the social-ecological system, as the "object" of the decision-making process, because of evolving social and bio-physical dynamics along spatial and temporal scales; 2) the dynamics of the adaptive planning process. In order to face change, marine spatial planning adopts the elaboration of alternative scenarios to explore potential future change of the marine and coastal social-ecological system.

2015), or considering climate change projections (Craig, 2012). Management scenarios are usually expressed as alternative spatial sea use configurations (Ehler and Douvere, 2009) "that projects the future use of marine space based on a core set of goals, objectives, and assumptions about the future" (p. 63). MSP and marine spatial plans are elaborated making value judgement about how marine resource will be managed (Gilliland and Laffoley, 2008; Maxwell et al., 2015).

By explicitly addressing this issue, MSP acknowledges the two dimensions of change within the decision-making process, in order i) to anticipate surprises due to non-linear behaviors of SES (Liu et al., 2007), ii) to avoid regime shifts (Craig, 2012) iii) to control potential harms of human activities on the capacity of marine ecosystems to provide ecosystem services (Guerry et al., 2012). In reality, changes of SES (dimension 1) happen independently from the timeframe of the planning process (dimension 2), which is meant to guide and orient the SES towards envisaged future configurations.

3. Material and methods

The systematic literature review was conducted according to the following steps: (1) define the research questions (Table 1); (2) develop a search protocol (i.e. targeted databases and search terms); (3) screen the results of the literature search based on a predetermined set of criteria; (4) conduct the analysis (O'Leary et al., 2015; Pittman and Armitage, 2016). We elaborated the questions guiding our research in relation to the review general objectives (Table 1).

Here, for change and dynamics – as synonymous – it is intended all the dynamic features of marine and coastal environments from a social-ecological perspective (e.g. oceanographic variability, changes in human ocean use, climate change), including planning and management processes as changing features as well. In order to perform the review, changes were categorized according to the type of dynamic feature they would entail, elaborating on Cash et al., (2006) as follows: i) environmental changes; ii) changes in human uses of the sea; iii) economic changes; iv) changes in the planning process; v) governance changes; vi) social or societal changes; vii) legislative/regulatory

Table 1
Objectives of the systematic literature review and related research questions. The section where each question is addressed in the paper is also included.

Objectives	Research questions	Section
Systematic literature review of the studies related to MSP		
1) to assess the current state of the art on studies including change and dynamics in MSP	1a) How has the number of relevant publications changed over the study period?	4.1
	1b) What are the main characteristics of these studies (e.g., geographical location)?	
2) to explore the current understanding of the dimensions of change and dynamics in MSP	2a) Do MSP studies address or discuss dynamic aspects?	4.2
	2b) What kind of dynamics or change? At what spatial, temporal and social level is the dynamic or change studied?	4.3
	2c) What methods are used to incorporate/address change and dynamics in MSP?	
Analysis of the results of the systematic literature review		
3) to assess the major challenges, constrains and limitations for an effective adaptation to future changes.	3a) What are the main challenges identified in the literature for addressing change and dynamics in MSP?	5
	3b) How widespread are these challenges?	
4) to provide practical guidance on how to address change in MSP	4a) What methods or tools are most effective/promising for addressing change?	

changes; viii) changes in data framework or management.

Literature was searched using two databases (the ISI Web of Science [WOS] and Scopus) in the time frame 2004 – 2017 (cut-off date 31 November 2017). The queries were performed using the following search string: terms ((marine OR maritime) AND (spatial) AND (plan*)). The queries focused on article titles only, and considered as document types only research articles or reviews. The keywords were chosen to sample literature directly related or referring to MSP as a decision-making process. Keywords such as "ecosystem-based management" were not included, because the concept embraces a wider range of practices not necessarily related to spatial planning for multiple uses, as for example ecosystem-based fishery management (e.g., Pikitch et al., 2004). Terms as "zoning" were also not included, because zoning represents the operational measure to regulate the use of the sea as the outcome of a planning process (Douvere, 2008).

After removing duplicates from the combination of 239 results in SCOPUS and 257 results in Web of Science, the search of the literature yielded a total of 243 studies. These 243 studies were then screened by reviewing their titles, citation information and abstracts, and, when needed, by reading the full article in order to remove not relevant papers.

The remaining papers (n = 202) were analyzed in three phases. First, the studies were classified by their general characteristics (step 1, Table 2). Second, they were screened to verify whether the planning exercise, application, or conceptual discussion addressed dynamic aspects or change as conceptualized in Section 2 above, or, in contrast if it was static (e.g., based on static habitat maps) (question 1, step 2, Table 2). Each study was analyzed for the type of change or dynamics considered, if any, according to the criteria reported in Table 2 (step 2). Finally, in step 3 (Table 2), each study was investigated for the general approach used to address dynamic aspects. For example, if the change or dynamics were acknowledged but operationally ignored in the planning process (ignore), or if they were incorporated in planning (include). For the studies incorporating change, methods and tools were reported, with the identification of the spatial, temporal and social level of the dynamics considered.

Results were analyzed with respect to i) the state of the art of incorporating change and dynamics in MSP, ii) the types of change and dynamics addressed in MSP studies, and iii) the methods and tools used to incorporate change and dynamics in MSP.

4. Results

4.1. The state of the literature on MSP with respect to change and dynamics

The number of studies on MSP has increased markedly in recent years: of the 202 studies identified and retained in our search between 2004–2017 (Table B.1, Supplementary materials), 74% (n = 149) were published in the last five years (Fig. 2). The number of MSP studies addressing change and dynamics follow a similar trend of increase through time (Fig. 2), with a majority published in the last five years (73%).

The papers cover 195 case studies from 34 marine provinces and related marine ecoregions (Fig. 3, Table B.2, Supplementary materials). 44% of the case studies are located in Northern European Seas (n = 85). The Mediterranean Sea (n = 21), the Cold Temperate Northwest Atlantic (n = 12), the Cold Temperate Northeast Pacific and the Atlantic coasts of Spain and Portugal (n = 9 each) also emerge as largely represented, with 26.6% of case studies. Studies addressing change and dynamics have a similar broad geographic representation. Examples were found in a majority of provinces where MSP studies have been conducted, though the largest fraction is from Europe and North America (Fig. 3). Approximately 35% of the studies (n = 72) use empirical data, 32% (n = 65) are general concept papers, and 15% (n = 31) use modeling tools, while reviews represent only 8.4% (n = 17) of the total sample. 5% are concept papers based on specific case studies or models. Papers considering case studies are a vast majority (66.3% of the sample, n = 134).

Most studies focus on spatial scales of ~100 s kms (34%), or ~1000 s kms (26%). Only 9 studies cover regional spatial scales (~10,000 s km).

4.2. Change and dynamics in MSP studies

We identified 78 studies (38.6%) that mention change or dynamic aspects in the use of the marine space (Fig. 4). A majority of these studies (60%) considers ecological change, such as seasonal and spatial variability in species abundance and distribution (Punt et al., 2009; Smith et al., 2011; Tancell et al., 2016), as well as whale migration routes (Petruny et al., 2014), dispersal of individuals (Punt et al., 2009), connectivity (Crochelet et al., 2013; da Anadón et al., 2011; Filgueira

Table 2
description of the criteria adopted in the 3 steps of the literature review.

Criteria	Description
Step 1 - General description of each study	
General descriptors	authors (list of first three authors), publication year
Type of study	review; concept paper; empirical (e.g. mapping, analysis of use data); modeling (e.g. Marxan with zones, GIS); mix of approaches
Spatial scale of the study	10 s, 100 s, 1000s, or 10,000 s km
Location	Geographic location: e.g. Gulf of Lyons, the North Sea, etc.
Marine ecoregion	following Spalding et al., 2007 (e.g. Temperate North Atlantic, Temperate North Pacific, Mediterranean Sea)
Step 2 – Dynamics and change addressed in each study	
Dynamics and change	Does the study address or discuss dynamic aspects? (yes/no)
Dynamic type	For studies that do address change, what types of dynamics are included, e.g. does the study address oceanographic variability (fronts, upwelling currents) or animal movement, or future scenarios of change (e.g., climate change, human population growth).
Dynamic level	For studies that do address change, what type of dynamic or change are taken into consideration (Fig. A1, Supplementary materials): environmental changes; changes in human uses of the sea; economic changes; changes in the planning process (plan); governance changes; social or societal changes; legislative/regulatory changes; changes in data framework or management.
Step 3 – Methods and tools used to incorporate dynamics and change in MSP	
General approach used to address dynamic aspects	Ignore (the study acknowledges dynamics, but does not explicitly include in planning) or include (directly incorporates dynamics in planning)
Method used	When dynamic aspects are included, what method or tool are used to incorporate change in MSP?
temporal scale	What is the temporal scale of the study? i) short term (i.e. seasons within a year); ii) medium term (i.e. 1 to 20 years); iii) long term (from 20 to 100 years)
social scale	What type of actors are considered? a1) individual, a2) groups, a3) community; what governance level? b1) local, b2) sub-regional, b3) national, b4) international (Sattler et al., 2016)

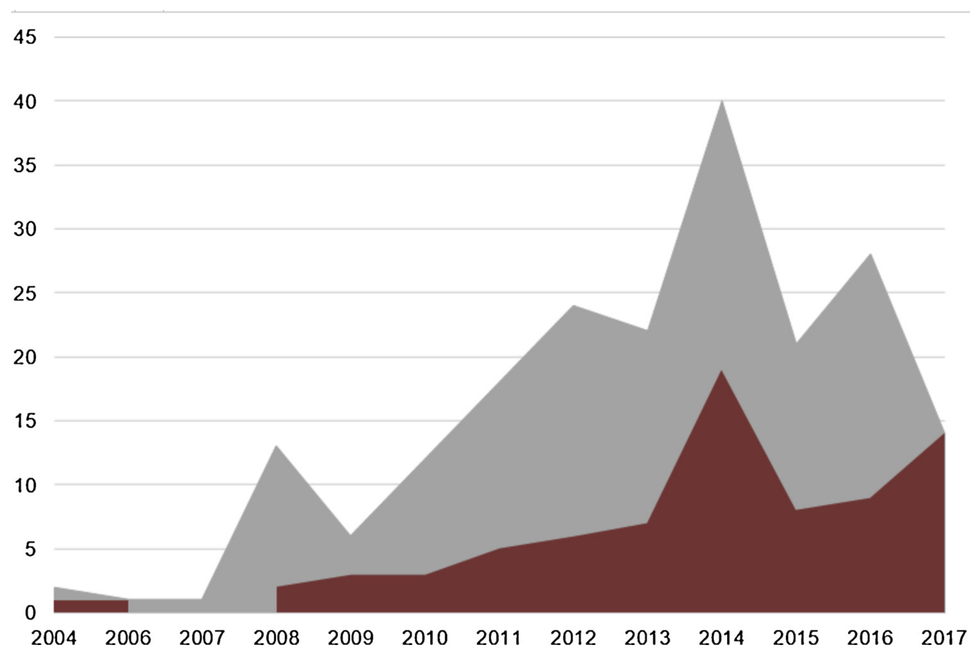

Fig. 2. Number of papers on MSP published since 2004 (in grey), and number of papers on MSP that incorporate change and dynamics since 2004 (in red) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

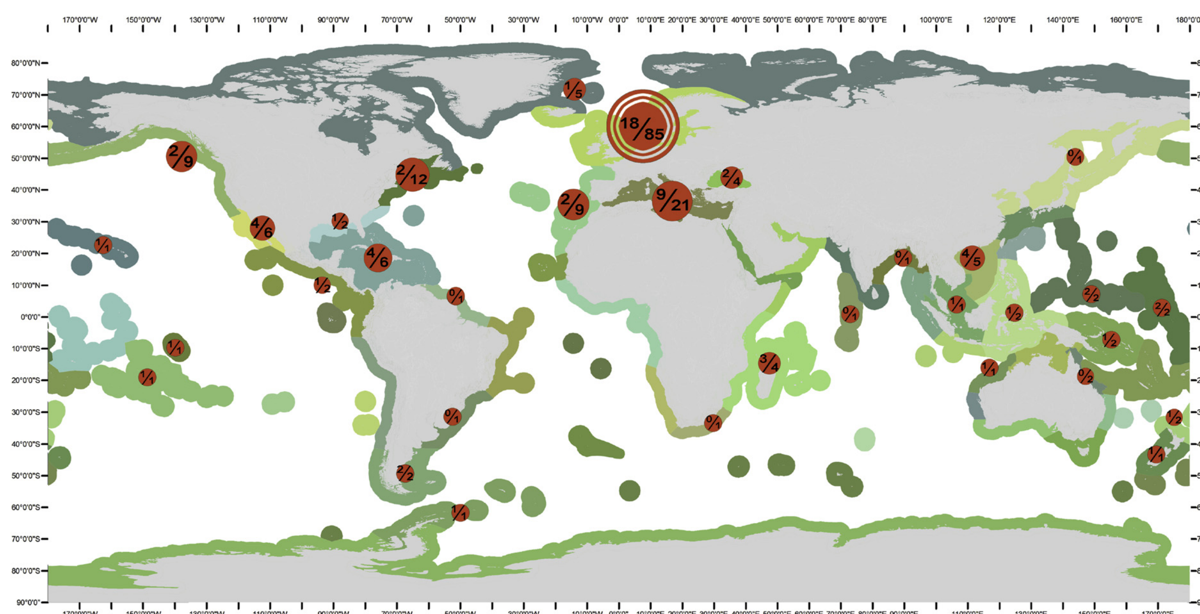

Fig. 3. Geographical distribution and related number of studies (in orange circles) per marine provinces (*sensu* Spalding et al., 2007); numbers in the circles indicate the studies that incorporate change and dynamics in MSP (numerator) on the total number of studies on MSP (denominator) in each marine province (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

et al., 2015; Foley et al., 2010), effects of climate change (Becker et al., 2012; Craig, 2012; Halpern et al., 2012), and change in human threats to species/habitats (Arkema et al., 2014).

Approximately one fourth of these studies focus on governance and regulatory/legal issues (23.3%, n = 17), such as governance regime change (Merrie and Olsson, 2014; Norse, 2010), regulatory shift and new policy demand (Mayer et al., 2013; Nutters and Pinto da Silva, 2012), institutional innovation and power dynamics (Jentoft, 2017), changes in planning process (Kenchington and Day, 2011; Kidd and Shaw, 2014; Mills et al., 2015), social learning processes (Mills et al., 2015; Olsen et al., 2011; Peel and Lloyd, 2004; St. Martin and Hall-Arber, 2008), and vulnerable and dynamic nature of MSP governance (Smythe, 2017).

Socio-economic aspects (e.g. future trends of economic sectors) are the focus of 16.4% of the papers addressing change (n = 12), with 22 additional studies that couple socio-economic aspects with other dynamics, such as environmental ones. Only 3 studies (Kocur-Bera and Dudzinska, 2014; Tsilimigkas and Rempis, 2017; Zaucha, 2014) focus on data management, structured in order to be able to monitor and detect change and dynamics for MSP.

4.3. Methods and tools to incorporate dynamics and change in MSP

Among the 78 studies that acknowledge change and dynamics in MSP, 60.3% (47 studies, 23.2% of the total sample) directly incorporate change and dynamic features (e.g. connectivity, future projections) in

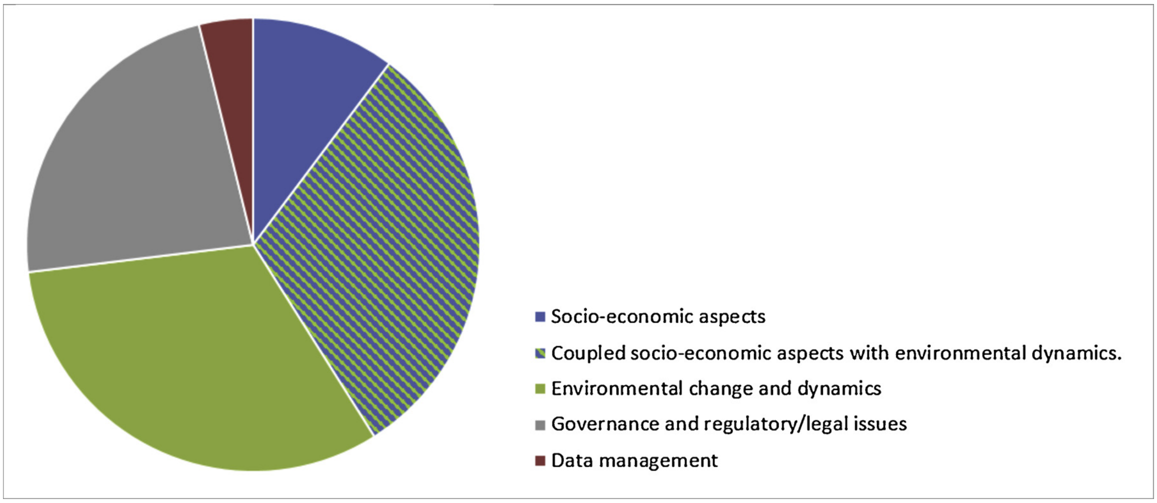

Fig. 4. Type of change and dynamics considered for the 78 studies (38.6% of the sample) that do address change and dynamics.

planning. These studies can be grouped in 3 tiers considering the level of integration of multiple change and dynamics.

Tier 1 (n = 14) groups the studies that focus on a single response variable (e.g. habitat suitability, connectivity, single-use future projections, etc.). Studies of tier 1 adopt methodologies and tools such as biogeochemical modelling (Filgueira et al., 2015, 2014) or mapping projections of new time and spatial demands for marine areas and resources (Lee et al., 2014; Zhenren, 2014), to produce knowledge – in form of maps – that will inform the MSP process. For example, St. Martin and Hall-Arber (2008) map local knowledge of fishing patterns from the past to present, while Hoi (2014) maps seawater temperature, marine currents, geological conditions, sedimentation regime, species biodiversity index, and structure of fauna and flora to be integrated in marine biodiversity zoning and conservation planning.

While studies of tier 1 limit their focus to detecting evidence of change, studies belonging to tier 2 (n = 23) try to link changes in the drivers with the potential effects of these changes (e.g. cause-effect dynamics, planning and management scenarios, multiple future projections and potential future conditions under several hypothesis). Often, decision support systems such as Marxan (Mazor et al., 2014; McGowan et al., 2013; Parker et al., 2015), Invest (Guerry et al., 2012), multi-criteria decision analysis (Gimpel et al., 2013; Tammi and Kalliola, 2014; Tuda et al., 2014), and bio-economic models (Rassweiler et al., 2014), all integrated with GIS techniques, support the analysis of the effects of change and dynamics in MSP.

Studies grouped in tier 3 (n = 10) provide the most complete framework trying to connect socio-economic, governance and environmental aspects within cause-effect dynamics. Foley et al. (2010) discuss the integration of ecological principles in each phase of the MSP process, in addition to considering environmental conditions and dynamics in the baseline analyses. Khan and Amelie (2015) propose diagnostic tools consisting of a matrix of indicators with respect to social, economic, governance and natural systems to depict adaptation readiness of the Seychelles to climate change. The indicators focus on key attributes of the systems (diversity, complexity, dynamics, scale, and sensitivity), to depict both process and outcome-based adaptation tracking (Ford et al., 2013; Khan and Amelie, 2015). Mayer et al. (2013) reflect on MSP as a process of change and adaptation of the setting, the actions, and the participants, incorporating social learning as a key aspect of the MSP process in the face of change. From the application of a game-based, quasi-experimental study on MSP in the North Sea (fictitious setting of the MSP process simulation), they observed a variety of changes in the game-based interventions, evidencing different strategies, policy change and policy-oriented learning of the participants.

With respect to the temporal scale, the majority of studies incorporating change (78.7%) addresses short-medium time scales (i.e., within management scenarios at 15–20 years). Four studies address change and dynamics on a short-term temporal scale, mainly considering ecological variability (Filgueira et al., 2015, 2014; Tancell et al., 2016), and seasonal changes in fishing effort (Campbell et al., 2014). Only 3 studies incorporate long-term change in MSP. Littaye et al. (2016) incorporate change over long-term dynamics while visioning for MSP with stakeholders on the western tropical Pacific; Sherman et al. (2016) include long-term monitoring data and scientific research as one sector in MSP. Olsen et al. (2014a,b) discuss the State of Rhode Island's marine spatial plan built upon 30 years of management experience from the Rhode Island Coastal Program, towards a vision for the future of the oceans related to the MSP implementation process.

With respect to the studies incorporating socio-economic or governance aspects, the social level relates mainly to groups of stakeholders representing maritime sectors, both at local and national levels. Studies considering community engagement in MSP by St. Martin and Hall-Arber (2008) address fishing communities and their resource use and management in the Gulf of Maine (US). They focus on depicting and visualizing “community resource areas” built on local ecological knowledge, in order to include the human dimensions of the sea in the planning process. The article by Gee et al. (2017) address cultural values at sea, to incorporate them in MSP along with ecological and economic values. They propose a community-based approach to identify and map ‘culturally significant areas’, which represent community history and change, because cultural values are created and assigned by groups and/or communities acting in specific cultural and temporal contexts. Only Mayer et al. (2013) address individual learning process of MSP professionals and practitioners through a gaming simulation process on MSP.

5. Discussion: challenges in incorporating change and dynamics in MSP

Our review shows that MSP is a recent topic in scientific literature, currently expanding worldwide. Seemingly, MSP is also a recent practice, with 60 countries that are currently involved in MSP (Ehler, 2017), and the number of initiatives is projected to increase. Although recent, the practice of MSP is going to shape the use of the marine resources over c.a. 60% of Exclusive Economic Zones of the world oceans (Frazão Santos et al., 2019).

The database used for analyzing the contribution of scientific research in this framework are not extensive, because the results of MSP processes are not necessarily targeted to scientific publication. MSP are politically-driven processes that can last more than 10 years. MSP documents are usually made public during the process under the approval of the responsible authority, with the goal of communicating to the general public the contents of the plan (rights and duties). The scientific literature on MSP analyzed typically reports on advanced findings on MSP. For this reason, even if not potentially representative of all existing MSP processes and practice, we used this body of work to identify emerging challenges from the best available science on MSP theory and practice worldwide. Nevertheless, our database has good representation of MSP processes, as it covers 58 MSP initiatives worldwide, compared, for instance, with the 39 analyzed by Ansong et al. (2017), and 28 by Pınarbaşı et al. (2017) (Table B.3 in Supplementary materials).

Despite potential limitations, our findings show that few studies incorporating change in MSP adopt decision support tools (DST), and most of these apply DST to simulate environmental dynamics and potential cause-effect relationships in tier 2 group of studies. Similarly, analyzing the application of DST in real MSP initiatives, Pınarbaşı et al. (2017) found that DST are scarcely used, because of the limited resources and capacity of the planning authorities to put DST into practice. To ensure effective integration of science into policy, scientists should carefully consider the scope of models and tools for MSP in order to frame their research into a decision-making process. MSP is a problem-oriented activity that is called to answer to planning and management objectives on an evidence-based process (Domínguez-Tejo and Metternicht, 2018).

Because of the double dimension of change entailed in MSP, both in terms of dynamic features of social-ecological systems and dynamic planning process in time, the challenge for scientists is to produce relevant knowledge for decision making. This should not simply result in the understanding of the system to be planned, but also in exploring the potential consequences of alternative actions addressing planning objectives. According to Starfield (1997), models can be approached in two different ways: as a faithful representation of reality, with the unreducible limit of simplifying complex dynamics into mathematical models; or as a problem-solving tool, meaning to explore the potential consequences of specific – planning – hypotheses. Scientists working to incorporating change in MSP should orient their research on DST as problem solving tools, *sensu* Starfield (1997). The analysis of the 3 tiers of methods in our review shows that only 10 studies out of 202 connect socio-economic, governance and environmental aspects within cause-effect dynamics, i.e. trying to connect the double nature of change entailed in MSP, the dynamic features of the system-to-be-planned with the planning actions aimed at orienting the system towards a desired future. The challenges of incorporating change in MSP include both the representation of the dynamic features, and the incorporation of cause-effect relations within the decision making process. The elaboration of planning actions linked to their potential effects can be supported by connecting and integrating multiple types of models and DST, moving from a silo model development to a truly interdisciplinary thinking in DST, where natural and social sciences mutually contribute. This nexus approach has been recently claimed in order to support the sustainable development goals globally (Liu et al., 2018). At present, our review shows that scientific research is still focused on elaborating tools to represent dynamics features (tools to represent reality, *sensu* Starfield, 1997), which is a first step towards supporting decision making. Some promising examples of the use of DST in MSP as problem solving tools have already been published. For instance, Gissi et al. (2018) addressed transboundary conservation challenges by explicitly considering trade-offs between maritime uses and between countries through systematic conservation planning under multiple scenarios.

Applying DST and models to explore potential consequences of planning actions under changing conditions is also essential to produce relevant knowledge for planning marine and coastal areas uses under climate change (CC). Despite the critical role of CC in marine and coastal social-ecological systems, this review found only 4 studies addressing this issue. This is likely due to the fact that modelling the effects of CC on social-ecological systems remains challenging. For instance, when modelling the impact of CC on fisheries productivity, Barange et al. (2014) found that the downscaling from global to regional or national scales highlights uncertainties and contradictions between models. Uncertainty is an integral component of decision making (Canessa et al., 2015; Knights et al., 2014; Walker et al., 2003) because of the evolving scientific evidence (Wardekker et al., 2008) and also because MSP is a future-oriented process (Ehler and Douvere, 2009). Global climate change is an additional, evolving challenge requiring flexible and adaptive planning for the oceans (Santos et al., 2016). Adopting scenario analysis is the most promising approach for informing adaptation to future evolving conditions. However, scenario analyses might fail to depict future threats to the marine environment, since CC is already producing ecological responses, and surprises, at multiple ecological levels (Walther et al., 2002), as well as social changes (Adger et al., 2009).

To overcome such limitations, and support adaptation to future changes, much emphasis in research should be put on adaptive MSP. Our review found that only 3 studies reflect on the need of monitoring and recording evolving conditions of marine and coastal social-ecological systems. Monitoring is essential not only to understand the conditions of the system to be managed (e.g. Shabtay et al., 2019), but also for adaptation to changing conditions. Major challenges relate to the capacity of accessing and organizing data representing temporal and spatial change and dynamics at multiple scales, and importantly, translating data into understanding of these dynamics and their drivers. Our review found that there is a growing interest in managing and analyzing data for MSP (e.g., Stamoulis and Delevaux, 2015; Tsilimigkas and Rempis, 2017). Of particular relevance is the management and use of real-time data, for example from remote sensing, which can be used to inform MSP of real-time changes and support dynamic ocean management (Maxwell et al., 2015).

As emerging from our review, incorporating long-term change is a critical gap in MSP research. We found that studies link changes in the drivers with the potential effects of these changes in marine systems within management scenarios at 15–20 years, by using modelling tools or DST such as Marxan or Invest. Long-term dynamics and change are included mainly mentioning the social dimension of MSP processes, on projections at 30–50 years. When entering in long-term projections of change, the social dimension more than the ecological one – through visioning – plays a major role in guiding MSP, both in the planning process and in the implementation phases. If the MSP implementation process has to be adaptive, the final scenario towards which the MSP process tends should be elaborated and envisioned not only through the participation of the stakeholders, but through a boarder process of transformation of the management system along with the changes of the *system-to-be-managed*. In this sense, Kelly et al. (2018) recently argued for transition management, which is a process of redirecting and steering a wide range of factors (markets, energy technologies infrastructure, governance, individual behaviour). Transition management is supported by transition research as an interdisciplinary field of study, in which innovation studies, history, ecology and modelling are combined with sociology, political and governance studies, and even psychology (Loorbach and Rotmans, 2010).

In our review, the social dynamics are the least represented in the literature, and environmental dynamics dominate the scientific basis for MSP. Several studies mentioned stakeholder engagement as key to the MSP process (e.g., Flannery and Cinnéide, 2008; Pomeroy and Douvere, 2008). However, only few studies (e.g., Craig, 2012; Milerienė et al., 2014; Olsen et al., 2014a, b) embrace dynamics and change from a joint perspective of incorporating spatial, temporal, and social dynamics at once, including institutional changes. From a social perspective, studies analyzed here reflect mainly on groups of stakeholders, such as maritime sectors and their economic interests. The community level, the societies intended as “people [that] can understand, relate to, and care about” the ocean (Ehler and Douvere, 2009) are not represented, remaining a "missing layer" (sensu St. Martin and Hall-Arber, 2008) in studies that incorporate change in MSP. Communities are not only the final end-users of the marine resources, but also the beneficiaries of multiple and diverse marine ecosystem services (e.g., Drakou et al., 2017; Gissi et al., 2015). The social dimension of change has been recently defined by Olsson and Galaz (2011) as social-ecological innovation that is ecologically literate and able to deliver sustained provision of a bundle of desirable ecosystem services while maintaining ecosystem structure and function. Social-ecological innovation is essential for the emergence and spread of innovative ideas for stewardship of marine and coastal social–ecological systems, such as MSP (Merrie and Olsson, 2014). With MSP we can only manage human uses and not ecosystems (Ehler and Douvere, 2009). Since ecosystems are mainly impacted by anthropogenic drivers of change (Halpern et al., 2008), social learning and social-ecological innovation are essential in order to move towards the sustainable use of marine resources. A challenge for scientific research emerging from our review is, indeed, to incorporate social learning in order to promote institutional transitions in MSP.

6. Conclusions

Ocean management is facing growing challenges due to the unexpected changes and dynamics from multiple drivers, not least climate change effects. Scientists can support MSP in incorporating change and dynamics, which entail multiple dimensions – environmental change, social-ecological dynamics over time, and planning scenarios towards evolving futures. In this review, we show that existing studies have tried to address change and dynamics through, firstly, considering single response variables in order to detect evidence of changes, and to model cause-effect dynamics while modelling drivers of changes with the potential effects. Connecting socio-economic, governance and environmental aspects within cause-effect dynamics is still a challenge, and limited guidance emerged from our analysis in scientific literature. In order to answer to the multiple dimension of change and dynamics entailed in MSP, a promising approach consists in adopting a tier-approach able to connect the response variables and the modelling approaches within a general transdisciplinary framework that integrates socio-economic, governance and environmental dynamics in space and time. In order to build such integrated framework, this review highlighted several gaps in current MSP science. Future research efforts should:

1 Overcome present barriers in modelling approaches towards incorporating social, ecological and temporal changes at once. Interdisciplinary research provides a path for addressing the challenge of incorporating multiple change in MSP. Models and DST for MSP should be considered as problem solving tools, e.g. to give evidence on potential consequences of planning and management actions to decision makers.
2 Address social-ecological innovation as a major driver of change to adapt to climate change and to uncertain future conditions. Social sciences should be better integrated into modelling approaches supporting MSP processes, even if social learning and social-ecological innovation are at stake in order to guide change towards sustainable management and use of ocean resources.
3 Incorporate both the short- and long-term temporal scales of change and dynamics in methods and tools to support MSP, to address the multi-level dimensions of change towards an envisioned common future. Incorporating the temporal dimension in data stocktake and management to support recording and monitoring change for adaptive MSP is a key research need.
4 Acknowledge the limits and potential sources of uncertainty that are entailed in the methods used to represent change and dynamics for MSP.

Finally, this review draws on studies carried out in specific areas of the world. When targeting change and dynamics, research should address the peculiarities of the multiple change and dynamics of the oceans worldwide. No solution fits all. Potential mechanisms of incorporating change and dynamics in MSP should reflect the specificities of the marine social-ecological system of study, besides existing practices reported in this review.

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Appendix A. Supplementary data

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