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Integrating climate change in ocean planning

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Supplementary Information

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Supplementary Methods

To analyse the global status of marine spatial planning (MSP) development in mid-2019, and develop Figure 1 of the manuscript, we used the most recent data available from three main references: Frazão Santos et al.[1], the UNESCO Marine Spatial Planning Programme webpage[2], and the European Union MSP Platform webpage[3]. Webpages were last accessed in August 31, 2019.

For each country with ongoing MSP initiatives (Supplementary Table 1), we identified the development status and classified it according to five main categories. Although MSP development includes many steps and phases[1,4], for visualization purposes we considered the five mentioned categories only (Supplementary Table 2). The exclusive economic zone (EEZ) of each coastal country was then assigned a colour code, according to the corresponding category, as depicted in Figure 1 of the manuscript. When a country had more than one EEZ sub-area with MSP in different stages of development (e.g., in Ecuador, MSP is in a preplanning phase for the continental EEZ, but for the Galapagos EEZ it is already implemented) the EEZ sub-areas were differently coloured.

To develop the literature review on MSP and anthropogenic climate change upon which the manuscript builds, we conducted a qualitative systematic review. We first used ISI Web of Knowledge, collecting data from all databases and for all years (1900-2019). Data was collected on August 10, 2019, thus encompassing results available by then. We first assembled three different trends in the number of scientific publications per year: (1) climate change literature; (2) MSP literature; and (3) literature that simultaneously addressed MSP and climate change. To accomplish this, we used the following topics, together with the year of publication:

1. Climate change trend: ("Climate change" *or* "environmental change" *or* "changing climate" *or* "climatic change" *or* "ocean warming" *or* "ocean acidification");
2. MSP trend: ("Marine spatial planning" *or* "marine planning" *or* "ocean planning" *or* "maritime planning" *or* "maritime spatial planning" *or* "ocean zoning" *or* "marine zoning");
3. MSP-climate change trend: topics 1 and 2, combined using the function "*and*".

Because the aim of this review was to investigate the nexus between MSP–climate change–ocean sustainability, the ISI Web of Knowledge search was complemented with a search in Google Scholar, using the same combination of topics as in "3". Additional studies were further identified by analysing references cited in publications assembled through both ISI Web of Knowledge and Google Scholar (Supplementary Figure 1).

Each study of the MSP-climate change trend was analysed for contents and consistency. Studies that did not include MSP and/or climate change in the main text (being mentioned only in the title, abstract, key words, or references) were excluded (Supplementary Table 3). Studies were also excluded when only the abstract was available, rather than the full text. Whenever a study was available in a language other than English, translation of the full text to English was performed with Google Translate, using the "*source language detection*" option. Studies that were not excluded were further classified according to the type of connection between MSP and climate change they encompassed (separate, indirect, brief statement, direct discussion) and the spatial scale of the study (global, regional, country, local). See Supplementary Table 4 for a summary of each study included in the MSP-climate change subset.

Whenever both topics were addressed separately, i.e. without any type of connection, the study was considered as "separate" (SEP). "Indirect" (IND) references related to cases where the link between both topics was not straightforward – e.g. a paper that establishes the link between climate change and the ecosystem approach, and then establishes MSP as a way to implement such approach. Direct connections pertained to two types of studies: the ones that included brief statements (BS), i.e. one or two short sentences relating MSP and climate change; studies that actually discussed (DIS) the connection between MSP and climate change (to varying lengths).

As for the spatial scale, if a study did not focus in any particular area it was considered as "Global". "Regional" (or supra-country) studies corresponded to the ones that focused in specific international marine areas, i.e., areas beyond national jurisdiction, and/or areas that encompassed the marine space of more than one country (e.g., Baltic Sea, Arctic, Northeast Atlantic, Coral Triangle). When studies pertained to a coastal country alone, they were considered as "National". Finally, "Local" (or sub-country) studies were the ones that focussed only in a particular area within a country – e.g., Sumatra (in Indonesia), Gulf of California (in Mexico), the Azores (in Portugal).

For the ISI Web of Knowledge search, a total of 288,553 references were found for the climate change trend, 1,232 for the MSP trend, and 133 for the MSP-climate change trend. 45 additional studies were gathered from both Google Scholar and other studies' references. Two studies were available in a language other than English, namely in Korean[5] and in Russian[6]. After being analysed for consistency, 24 studies were excluded (Supplementary Table 3) from the MSP-climate change subset. A total of 153 studies were kept (see Supplementary Table 4), 73 corresponding to studies that separately discussed both topics, 22 that established an indirect connection between MSP and climate change, and 58 that directly related them – either through brief statements (n=29) or full discussions (n=29). Results were used to develop Figure 2 panels *b* and *c* of the manuscript. For visualization purposes, in Figure 2

panel *b* data is presented only for the 1988-2018 interval. This is because of the relatively low number of publications prior to the 1990s, and because 2019 values do not correspond to the entire year (as data was collected in August) therefore resulting in a false decreasing trend. In panel *b*, the left axis corresponds to the climate change trend, while the right axis pertains to both the MSP and MSP-climate change trends. Again for visualization purposes only, United Nations Sustainable Development Goals icons[7] are used to differentiate the three different publication trends.

Finally, to characterize the geographic patterns in research effort on studies that address both MSP and climate change, we assembled the number of existing studies by Marine Ecoregion – as in Spalding et al.[8]. We accomplished this by analysing and establishing a correspondence between the spatial context of each regional, national and local study (n=96) and the marine ecoregions with which they overlap (see Supplementary Table 5). Every time a study overlapped with a particular marine ecoregion, such ecoregion was attributed the value of 1 (independently from the spatial scale of the study). Values were them summed to obtain the total number of studies per ecoregion (see Supplementary Figure 2). Global studies (n=57) were not included in this analysis, as they would apply to all ecoregions equally, thus not providing any new information on spatial patterns. The same argument was applied to regional studies pertaining to the Southern Hemisphere (n=1) and Tropical Coastal Seas (n=1). Results are summarized in Figure 2, panel *a*, of the manuscript.

Supplementary Tables

Supplementary Table 1 | Countries with ongoing MSP initiatives by mid 2019. Based on data from Frazão Santos et al.[1], UNESCO Marine Spatial Planning Programme[2], and European Union MSP Platform[3]. Countries and overseas territories are presented alphabetically. (*) Overseas territory of United Kingdom. (**) Overseas territory of the Netherlands. Colour codes according to Figure 1 of the manuscript.

Country/territory	Phase of plan development	Country/territory	Phase of plan development
1. Angola	Under development	36. Madagascar	Under development
2. Antigua and Barbuda	Implemented for Barbuda waters	37. Malta	Approved
3. Australia	Revised for Great Barrier Reef Marine Park. Completed for remaining area	38. Mauritania	Under development
4. Bangladesh	Under development	39. Mauritius	Under development
5. Belgium	Revised	40. Mexico	Approved for Gulf of California and Gulf of Mexico. Completed for Northern Pacific. Under development for Central Southern Pacific
6. Belize	Implemented	41. Montserrat*	Under development
7. Bermuda*	Under development	42. Morocco	Under development
8. Bonaire**	Implemented	43. Myanmar	Under development
9. Bulgaria	Under development	44. Namibia	Under development
10. Cambodia	Completed	45. Netherlands	Revised
11. Canada	Implemented for Pacific North Coast. Completed for Nnunavut	46. New Zealand	Approved for Hauraki Gulf
12. China	Revised	47. Norway	Revised for Barents Sea. Implemented for remaining area
13. Colombia	Under development	48. Panama	Under development
14. Costa Rica	Under development	49. Philippines	Implemented for Bataan Province
15. Croatia	Implemented for Zadar county. Under development for remaining area	50. Poland	Under development
16. Curaçao**	Under development	51. Portugal	Under development for Azores. Approved for remaining area
17. Denmark	Under development	52. Romania	Under development
18. Dominica	Under development	53. Russia	Under development
19. Ecuador	Implemented for Galapagos. Under development for continental EEZ	54. Saint Kitts and Nevis	Under development
20. Estonia	Approved for Hiiumaa Island and Pärnu Bay. Under development for remaining area	55. Saint Lucia	Under development
21. Falkland Islands*	Under development	56. Seychelles	Under development
22. Fiji	Under development	57. Slovenia	Under development
23. Finland	Approved for Kymenlaakso Region. Under development for remaining area	58. Solomon Islands	Under development
24. France	Under development	59. South Africa	Under development
25. Germany	Revised for Mecklenburg-Vorpommern and Lower Saxony. Implemented for remaining area	60. Spain	Under development
26. Greece	Under development	61. St Vincent and the Grenadines	Under development
27. Grenada	Under development	62. Sweden	Completed
28. Iceland	Under development	63. Thailand	Under development
29. Indonesia	Under development	64. Tonga	Under development
30. Ireland	Under development	65. Trinidad & Tobago	Under development
31. Israel	Under development	66. United Arab Emirates	Approved for Abu Dhabi
32. Italy	Under development	67. United Kingdom	Approved for East/South Inshore and Offshore areas, and Scotland. Under development for remaining area
33. Kiribati	Implemented for Phoenix Islands	68. United States	Revised for Massachusetts and Rhode Island. Implemented for Oregon. Approved for Northeast and Mid-Atlantic regions, and Washington state. Under development for remaining area
34. Latvia	Approved	69. Vanuatu	Under development
35. Lithuania	Approved	70. Vietnam	Implemented for Danang Municipality

Supplementary Table 2 | Main stages of marine spatial planning development. Correspondence among main categories of marine spatial planning (MSP) development used in the present study, MSP main phases as in Frazão Santos et al.[1] and MSP key steps as in Ehler and Douvere[4]. Colour codes according to Figure 1 of the manuscript.

Categories considered in the present study	Main phases as in ref.[1]	Key steps as in ref.[4]
No official MSP initiatives underway	Not applicable	Not applicable
MSP under development	1. Preplanning	Steps 1–4
	2. Analysis for planning	Steps 5,6
	3. Plan development	Step 7
Marine spatial plans fully developed but not yet approved	4. Plan completion	Not applicable
MSP approved, implemented or revised only for a specific area within the nation marine space (e.g., province, municipality, state, marine reserve)	5. Approval	Step 7
	6. Implementation	Steps 8,9
	7. Revision	Step 10
MSP approved, implemented or revised for the entire marine space of a nation	5. Approval	Step 7
	6. Implementation	Steps 8,9
	7. Revision	Step 10

Supplementary Table 3 | Studies excluded from the MSP and climate change subset.

Year	Reference	Topic	Reason for exclusion
2012	Rengstorf et al.[9]	Addresses high-resolution habitat suitability modelling of vulnerable marine ecosystems in the deep-sea.	MSP only in abstract – Plus one reference to conservation planning in main text; CC only in references.
2013	Berkström et al.[10]	Focuses on fish migrations and seascape ecology in a tropical embayment.	CC only in references
2013	Clarke and Harvey[11]	Addresses coastal management in Australia.	MSP absent – Main text pertains to coastal planning
2013	Hattab et al.[12]	Focuses on the use of a predictive habitat model and a fuzzy logic approach for marine management and planning.	MSP absent – Main text pertains to conservation planning
2013	Rengstorf et al.[13]	Discusses how habitat suitability modelling can improve conservation and planning of vulnerable marine ecosystems.	CC – ocean acidification – only in references
2014	Torre-Castro et al. [14]	Addresses the importance of seagrass for small-scale fisheries in the tropics and the need for seascape management.	MSP only in keywords
2014	Walton et al.[15]	Focuses on the development of a functional region-wide marine protected area system in the Coral Triangle.	MSP only in keywords – Main text pertains to conservation planning
2014	White et al.[16]	Analyses the progress, issues, and options of marine protected areas in the Coral Triangle.	MSP only in keywords – Main text pertains to conservation planning
2015	Magris et al.[17]	Focuses on conservation planning of coral reefs under warming disturbances.	MSP absent – Main text pertains to conservation planning
2015	Needles et al.[18]	Focuses on the management of estuarine ecosystems for multiple services.	MSP only in keywords and references
2016	Alexandrov et al.[19]	Analyses the current stage of maritime spatial planning implementation in Romania. Mentions the need to deal with future CC impacts and to define adaptive responses as an issue to coastal areas in Romania.	Main text not available – Abstract only
2017	Hidalgo et al.[20]	Addresses the link between ocean connectivity, ecological function and management challenges.	MSP only in keywords
2017	Keyl[21]	Addresses the variability in distribution and spatial abundance of sprat, Norway pout and small herring in the North Sea.	CC only in references
2017	McClanahan and Jador[22]	Focuses on coral reef fish community management and biodiversity conservation in Madagascar.	MSP only in keywords – Plus one reference to conservation planning in main text
2017	Smolinski and Radtk[23]	Spatial prediction of demersal fish diversity in the Baltic Sea: comparison of machine learning and regression-based techniques.	CC only in references
2017	von der Heyden[24]	Making evolutionary history count: biodiversity planning for coral reef fishes and the conservation of evolutionary processes	MSP only in abstract – Plus one reference to conservation planning in main text
2018	Villnas et al.[25]	Template for using biological trait groupings when exploring large-scale variation in seafloor multifunctionality.	CC absent – Main text mentions environmental change but not CC
2018	Domínguez-Tejo and Metternicht[26]	Poorly designed goals and objectives in resource management plans: Assessing their impact for an ecosystem-based approach to marine spatial planning	CC absent – Main text mentions environmental change but not CC
2018	Lacharité and Metaxas[27]	Environmental drivers of epibenthic megafauna on a deep temperate continental shelf: A multiscale approach.	CC absent – Main text mentions environmental change but not CC
2018	Levin et al.[28]	Discusses the inclusion of a third dimension to marine conservation.	MSP only in keywords – Main text pertains to conservation planning
2018	Patrizzi and Dobrovolski[29]	Addresses the integration of climate change and human impacts into marine conservation planning of starfish species in Brazil.	MSP only in title – Main text pertains to conservation planning
2018	Morzaria-Luna et al.[30]	Evaluates how conservation areas selected through systematic conservation planning exercises preserve biodiversity hotspots in the Gulf of California, Mexico	MSP only in keywords – Main text pertains to conservation planning
2019	Chung et al.[31]	Addresses building coral reef resilience through spatial herbivore management using the main Hawaiian Islands case study.	MSP only in abstract – Main text pertains to conservation planning
2019	Loredo et al.[32]	Addresses the spatial-temporal diving behaviour of non-breeding common murres during contrasting ocean conditions in the northern California Current System.	MSP only in abstract – Main text pertains to conservation planning
2019	Friesen et al.[33]	Presents an approach to incorporating inferred connectivity of adult movement into marine protected area design in the Northern Shelf Bioregion in British Columbia, Canada.	MSP only in keywords – Main text pertains to conservation planning

Supplementary Table 4 | Studies that establish a link between MSP and climate change.
A total of 153 studies published since 2008 simultaneously include MSP and climate change. Each study is identified bellow, and a brief description of its content is provided. Studies are organized according to the type of connection established between MSP and climate change (Discussion, Brief statement, Indirect reference, Separate reference), then by date and alphabetic order. EU, European Union. EEZ, exclusive economic zone. MPA, marine protected area. EBM, ecosystem-based management. GBRMP, Great Barrier Reef Marine Park. US, United States of America. CC, climate change.

Year	Reference	Brief description	Spatial scale
1. Discussion—Studies that provide a discussion relating both topics			
2008	Sivas and Caldwell [34]	This study addresses comprehensive ecosystem-based marine zoning in California as a new vision for California ocean governance. It mentions that if properly developed marine zoning can provide the flexibility needed to respond to ecological changes, such as those from global warming (changing uses and circumstances over time). States that management systems must be flexible enough to adjust management practices over time, and account for variability of natural systems and potential regime shifts from global climate change. Addresses the need for more prospective spatial planning and management for compatible uses.	Local – California, US
2009	Ehler and Douvere [4]	This UNESCO report provides guidance on the steps and tasks of setting up a successful marine spatial planning initiative that can help achieving ecosystem-based management. One of the main steps of MSP is examining how distributions of marine uses/resources might change due to CC and other long-term pressures. Refers to how climate change will drive change both in the marine environment and the way in which people use it. Adaptive management is another of the main steps addressed.	Global
2010	Agardy [35]	This book comprehensively addresses ocean zoning, considering MSP as large scale ocean zoning. It discusses the need for adaptation of zoning plans to changing circumstances, including CC, as well as the importance of adaptive management. States that dynamic marine ecosystems may change so rapidly that dynamic, truly adaptive zoning tools are needed. Refers the role of zoning in fostering sustainable management of marine ecosystems, that is needed to increase resilience of natural systems to changing environmental conditions.	Global
2011	Schaefer and Barale [36]	This study addresses the opportunities and challenges of MSP in the framework of the EU integrated maritime policy. It states that the effects of CC are likely to induce changes in marine ecosystems and activities, and that MSP plays an important role in the mitigation of such effects. MSP provides a proper framework to meet challenges that require cross-sectoral and cross-border management approaches, such as CC and the need to adapt to its effects. Discusses the importance of MSP to be adaptive.	Regional – Europe
2012	Craig [37]	This long piece focusses on how to make marine zoning climate change adaptable. It suggests and discusses ways in which MSP can adapt to CC adaptation, such as anticipatory zoning in the Arctic, dynamic zoning, and anticipatory bidding for future use rights.	Global
2012	Hoel and Olsen[38]	This study addresses the Norwegian experience in developing ecosystem-based, integrated management ocean plans (some of the first regional scale MSP plans that have been implemented), namely the Barents Sea Plan.The study provides a detailed discussion on how climate change is addressed in the plan and how this concern evolves over time.	National – Norway
2013	Ehler [39]	This report explores how MSP can be used to implement ecosystem-based management in the Coral Triangle. It explains how MSP can support the planning and implementation of climate change adaptation actions. It mentions that MSP provides an opportunity to take planned, coordinated action today to adapt to future climate, and that spatial and temporal CC adaptation actions should be included in MSP management plans.	Regional – Coral Triangle
2014	Ehler [40]	This UNESCO document provides guidance to evaluating marine spatial plans. It discusses the fact that an adaptive approach to MSP is essential to deal with uncertainty about the future and to incorporate various types of change, including CC.	Global

2014	Mendez et al [41]	This short article discusses the use of genetic data and satellites to support to conserve seascape dynamics. It discusses the importance of integrating of information on ecological boundaries, and their sensitivity to CC in MSP.	Global
2015	Agostini et al [42]	This study focuses on marine zoning and MSP in St. Kitts and Nevis. It discusses the challenge of developing tools to identify spatial and quantitative representation of future climate scenarios and future uses to support MSP.	National – St. Kitts and Nevis
2015	Khan and Amelie [43]	This study addresses the assessment of climate change adaptation readiness in Seychelles, and its implications for ecosystem-based adaptation and MSP.	National – Seychelles
2016	Frazão Santos et al [44]	This short article is focused on ocean planning under climate change. It addresses how MSP is affected by CC, and suggests how MSP can adapt to CC.	Global
2016	Queiros et al. [45]	This study explores solutions for ecosystem-level protection of ocean systems under climate change. It compares distribution of hotspots of change with spatial planning actions (wind farms and MPAs), and discusses that such approach can be part of a climate-ready solution for marine conservation that improves MSP in face of CC. It states that co-mapping of human uses and hotspots of ecosystem vulnerability to CC can support effective and well-informed MSP.	Regional – North-East Atlantic continental shelf
2016	Tobena [46]	This paper focuses on modelling potential distribution and richness of cetaceans in the Azores. It argues that there is a need to integrating dynamic ocean management with more traditional MSP approaches to effectively protect species with very dynamic distributions, especially in face of CC. It also states that high-resolution species distribution data for marine taxa are scarce but essential to implement ecosystem-based MSP. It presents SDMs for 16 cetacean taxa in the Azores archipelago at fine spatial resolution, and cetacean richness maps that can inform MSP.	Local – Azores archipelago, Portugal
2017	Edwards and Evans [47]	This article discusses the challenges of MSP in the Arctic. It argues that MSP offers a way to address and manage potential conflicts in advance, predicting how these may change due to CC. It states that a MSP plan for the Arctic must be adaptive and anticipatory, focused on the long term, and that MSP needs to be an iterative process that learns and adapts over time. It also identifies climate-induced changes in ocean use in the Arctic, and describes the MSP tool developed during the EU-funded ACCESS programme.	Regional – Arctic
2017	Pinarbasi et al. [48]	This study reviews present applications, gaps and future perspectives of using decision support tools (DSTs) in MSP. It states that DSTs should be able to run scenarios in which CC and human ocean uses will influence marine ecosystems. It also states that DSTs can help planners foresee possible impacts from CC, and be useful to help society adapt to these changes, with more sustainable MSP.	Global
2017	UNESCO [49]	This conference report summarizes messages from the 2nd International Conference on MSP by IOC-UNESCO and EC-DGMare. It identifies the main results from session 7, where the importance of strengthening the links between MSP and assessments on impacts of CC, as well as CC adaptation were established.	Global
2018	Frazão Santos et al. [50]	This short article summarizes major global challenges in developing MSP. It identifies CC as one of such challenges, stating that increasingly flexible and adaptive MSP approaches will be needed, but that incorporating CC into MSP will allow for better preparedness, improved response capacity and reduced vulnerability of marine socio-ecological systems.	Global
2018	Retzlaff and LeBleu [51]	This paper analyses MSP literature to explore how planners can contribute to MSP research and practice. States that some MSP processes include long-term data that goes beyond the plan's time span, identifying the case of MSP in Portugal that included risk parameters for up to 50 years for potentially serious impacts, such as CC. Mentions CC in the Arctic region and the potential role of anticipatory zoning. Finally states that some zoning solutions developed by MSP may be useful for planners to transfer to terrestrial zoning in a CC era (e.g. the use of "floating zones" to accommodate the dynamic nature of the environment).	Global
2019	Andersson et al. [52]	This paper addresses ecological and socioeconomic strategies to sustain Caribbean coral reefs under ocean acidification. It identifies MSP as one of the recommended solutions with ecological benefits to sustain coral reefs, highlighting the role of MSP in promoting coral reef resilience if proper information is available. It states that e.g. information on water quality and carbonate chemistry at local and regional scales can indicate refugia from ocean acidification.	Regional – Caribbean region

2019	Frazão Santos et al. [1]	This book chapter provides an overview on the status of MSP around the world. It identifies and analyses seven key challenges faced in MSP development, one of them being global CC.	Global
2019	Gissi et al. [53]	This review article depicts the current state of scientific knowledge on incorporating change and dynamics in MSP. It argues that long-term temporal scales are only seldom considered, and CC effects rarely incorporated in methods and tools to support MSP. It discusses the importance of overcoming this gap.	Global
2019	Hassan and Alam [54]	This article evaluates MSP and the Great Barrier Reef Marine Park Act 1975 (that incorporates MSP). It states that the Park is, and will continue to be, at high risk from CC effects, and that one of the shortcomings of the Act is the inadequacy to address risk from CC, among other factors. It also states that one of the loopholes in planning and management of the Park is the less focus on adaptation and improving resilience for CC. Finally, it argues that a strategic action plan should incorporate provisions to mitigate CC within the Park, particularly ocean acidification, and relevant stakeholders and NGOs working with CC should be engaged; and that geospatial analysis, remote sensing, molecular techniques, telemetry and modelling should be included in MSP to understand the spatial and temporal dynamics of marine organisms and ecosystems.	Local – Great Barrier Reef Marine Park, Australia
2019	Johnson et al. [55]	This paper addresses marine governance problems in the High Seas of the Northeast Atlantic Ocean, describes current research and stakeholder engagement efforts, and analyses the contribution of the ATLAS project. Addresses CC a major future driver of environmental change. Mentions the attempts to develop a MSP plan for the Rockall Bank in the context of ATLAS project. States that area-based planning should be responsive and adaptable, and that future planning for a sustainable blue economy should evaluate synergies/tensions between commercial interests such as oil and gas and offshore renewable energy provision due to emission cuts related to CC. Also states that an increasingly important element for consideration is the implication of CC, with an increased need for preservation of areas with resilience to predicted environmental changes.	Regional – Hatton-Rockall plateau, Northeast Atlantic Ocean
2019	Lombard et al. [56]	This study presents six multidisciplinary research projects that support ecosystem-based approaches to MSP in South Africa, by addressing several knowledge gaps and key challenges. One of the later is the need to develop models to understand potential CC impacts on food webs and fisheries. States that considering future impacts of ocean acidification and warming is essential to better inform resource management and planning in South Africa, especially in the emerging MSP processes, which need to remain adaptive to the spatial uncertainties resulting from CC.	National – South Africa
2019	Sanders et al. [57]	This paper reviews the role of integration in MSP, presenting an analytical framework to understand challenges in diverse settings. It addresses the temporal integration dimension as how MSP seeks to consolidate the now with the future. It states that the Rhode Island case shows the importance of continuity of an institutional approach supported by different types of knowledge to adapt to changing social and environmental conditions; this allowed the introduction of a new user into existing MSP (offshore wind energy, OSWE, which was largely promoted as an adaption to CC). It also states that the GBRMP case highlights the importance of review processes (in this case, use zoning) in order to adapt to changing conditions, e.g. CC or societal responses, and that these are integral to effective MSP.	Global
2019	Westmeijer et al. [58]	This article uses niche modelling to identify favourable growth sites of temperate microalgae. It quantifies habitat suitability of microalgae at a European scale by means of mechanistic species distribution modelling (SDM), using its physiological response to environmental conditions. States that the model can support the process of aquaculture optimal site selection. It also highlights that the tool can support dynamic MSP by including CC to allow selection of sites with favourable sea-weed growth conditions in the long term. Uses species distribution according to four CC scenarios.	Regional – Europe

2019	Zaucha and Gee [59]	This book comprehensively addresses a number of key issues regarding MSP processes. For example, it acknowledges that CC is likely to pose challenges to MSP, not only related to MSP adaptiveness but also to geostrategic issues, such as the exploitation of the Arctic. It also highlights the role of visioning in allowing MSP to incorporate CC, as well as to link desired futures to present conditions and related spatial planning needs.	Global
2020	Rilov et al. [60]	This study addresses adaptive marine conservation planning in face of CC. It highlights that most MSP plans give little attention to CC mitigation and adaptation in their planning goals or objectives and discusses ways forward.	Global
2. Brief statement—Studies that establish a direct connection between MSP-CC through limited, concise sentences			
2008	Gilliland and Laffoley [61]	This study addresses key elements and steps in the process of developing ecosystem-based MSP. It states that attempts should be made to "future-proof" ocean plans by considering long periods of time in preparing and reviewing them (e.g. 50-100 years), particularly in respect of CC.	Global
2008	Maes [62]	This study addresses the international legal framework for MSP. It states that ocean plans need to be flexible to allow for adaptation as a consequence of new scientific insights about the effects of certain activities or CC effects.	Global
2010	Foley et al. [63]	This study identifies guiding ecological principles for MSP. It argues that MSP management plans need to be updated periodically to assess and address changes associated to CC, and that because of uncertainty, monitoring of a changing climate must be a central component of MSP.	Global
2012	Halpern et al. [64]	This study identifies near-term priorities for the science, policy and practice of Coastal and Marine Spatial Planning (CMSP). Among the top-20 near-term priorities for advancing CMSP processes, the need to develop proactive management methods in particular with respect to CC is identified. Recognizes that the changing ocean climate among the large changes CMSP will face in the near-term.	National – USA
2012	SCBD [65]	This report reviews large- and small-scale MSP practices examining them in the context of the Convention on Biological Diversity. It recognizes that MSP is a dynamic process, and that MSP that builds on monitoring/evaluation mechanisms allows for true adaptive management, which promotes maximum resilience (ecological and social) in light of CC. Mentions the use of scenarios to assess uncertainty due to future changes in human uses of the sea.	Global
2013	Hazen et al. [66]	This study focuses on predicted habitat shifts of Pacific top predators in a changing climate. It states that maps of changes in ecosystem services, habitat preferences and trophic interactions (due to CC) could serve as the foundation for reserve design and MSP in a changing ocean.	Regional – North Pacific
2013	Kim and Choi [67]	This study analysis and evaluates the 2nd Korean Ocean and Fishery Development Plan (OK21 2011-2020), a comprehensive, integrated national plan encompassing the EEZ and coastal areas in Korea. Climate change is considered in the plan through sector plans.	National – Korea
2014	Ehler [68]	This book chapter addresses the need for Pan-Arctic MSP. It argues that Arctic ecosystems and people are facing substantial change due to the effects of CC, and that examining potential changes in distributions of marine activities and resources due to CC is an important step of MSP.	Regional – Arctic
2014	Long [69]	This study addresses the legal and policy challenges in the EU regarding harnessing offshore wind energy. It states that the MSP Directive aims to improve resilience to CC impacts. Addresses the link between MSP and the development of offshore renewable energy. CC policies contribute to growth of offshore renewable energy.	Regional – Europe
2014	Malek et al [70]	This study addresses the fine-scale spatial patterns in the demersal fish and invertebrate community in a northwest Atlantic ecosystem. It states that the spatial planning process for Rhode Island and Block Island Sounds is being conducted against a background of CC.	Local – Rhode Island Sound and Block Island Sound, USA
2014	Okey et al. [71]	This article reviews the effects of climate change on Canada's Pacific marine ecosystems. It states that CC considerations could be routinely included into coastal and marine planning, and stresses the importance of assessing social-ecological vulnerabilities to CC and modelling CC impacts.	Local – British Columbia, Canada
2014	Sale et al. [72]	This article addresses how management of tropical coastal seas must be transformed to cope with challenges of the 21st century. It states that MSP may facilitate revisions to zoning needed to accommodate changes in environmental	Regional – Tropical coastal seas

		conditions, such as distribution of species and habitats, due to CC. It identifies management actions to support adaptation to CC for a set of human activities, such as shipping, aquaculture, small-scale fisheries, tourism, and biodiversity conservation.	
2015	Cormier et al. [73]	This report provides a generic structure on how to set up spatial planning processes in marine areas, pointing to sub-processes and types of information that need to be included from the perspective of Quality Management Programs. It identifies that the MSP Directive sets the objectives of MSP within the context of environmental, economic and social aspects, including resilience to CC.	Global
2015	Frazão Santos et al. [74]	This study analyses the Portuguese regulations on MSP (framework law and complementary legislation). It states that according to the EU MSP Directive national MSP must fulfil a set of minimum requirements including resilience to CC impacts, and that resilience to CC impacts is only briefly mentioned in the Portuguese legislation.	National – Portugal
2015	Gormley et al. [75]	This study focuses on adaptive management, international co-operation and planning for marine conservation hotspots in a changing climate. It states that MSP development needs to include a horizon that enables CC management; it aimed to consider implications of climate induced losses/gains of Priority Marine Habitats in light of MSP policy (national/international).	Regional – North-East Atlantic
2015	von Storch et al. [76]	This study addresses how to make coastal research useful by examining a number of case studies. It identifies CC as an overarching issue in all planning exercises.	National – Germany
2016	Davies et al. [77]	This article focuses on integrating climate change resilience features into the design process of an existing marine protected area. It states that the method presented can be developed to provide insights into future MSP practices globally.	Local – Ningaloo Marine Park, Western Australia
2016	Papageorgiou [78]	This study argues over the significant role of MSP in organizing and planning coastal and marine tourism activities. It argues that MSP has a significant role ensuring/achieving adaptation to climate change, so that coastal tourism activities and infrastructures become resilient to its effects. It states that tourism activities contribute to accelerating climate change (energy consumption).	Global
2017	Bethoney et al. [79]	This article analyses benthic animal assemblages in areas with different temperature patterns and discusses the level of resiliency to temperature changes. It states that findings on differences in climate change resiliency provide information on a scale that correlates with MSP, and argues that maps with multiple elements can support regional MSP. It addresses the Northeast Ocean Plan research priorities for future data pertaining to “characterize changing conditions and resulting impacts to existing resources and uses”.	Local – US Northeast Shelf
2017	Buhl-Mortensen et al. [80]	This study discusses lessons learned from the application of a generic framework for monitoring and evaluation of spatially managed areas in Europe, namely in the context of the MESMA project. Mentions the Barents Sea (Norway) case study, which is experiencing additional pressure from the effects of CC. States that MSP is by nature a future oriented process which requires a dynamic analysis process to assess its success in fulfilling the pre-established operational objectives.	Regional – Europe
2017	McHenry et al. [81]	This study addresses the use of abiotic proxies to characterize marine benthic assemblages along the Maine coastal shelf, and its implications for MSP. It states that as the trajectory of species under increasingly warming conditions is still largely unknown, it will be critical to consider climate-induced effects when developing foundational ecological principles and priorities for MSP.	Local – Maine coastal shelf, US
2017	United Nations and World Bank [82]	This report by the United Nations and the World Bank analyses the potential of the blue economy to increasing the benefits of sustainable ocean use for Small Island Developing States and Coastal Least Developed Countries. Addresses CC as a stressor to marine and coastal socio-ecological systems, and MSP as an important spatial management tool. States that debt for coastal/marine nature swaps allow a country to redirect a portion of its current debt payments to fund nature-based solutions to CC, including MSP and networks of MPAs. When analysing the relevance of blue economy sectors to Sustainable Development Goal 14 targets, also states that integrating CC considerations into (coastal) planning and development can enhance economic, social, and environmental resilience.	Global
2017	Veidemane et al. [83]	Discusses the use of the marine ecosystem services approach in the development of MSP in Latvia. States that the distribution of fish populations is	National – Latvia

		influenced by several factors including CC. Also states that healthy marine ecosystems and their services, if integrated in planning decisions can deliver substantial benefits in terms of CC mitigation and adaptation, among others.	
2018	Bennett [84]	This discussion paper addresses critical issues regarding social justice and inclusion in ocean science, management, governance and funding. It states that there is a need to increase attention to justice and inclusion in the blue economy, MSP and climate adaptation at all scales from local to global.	Global
2018	Harvey et al. [85]	This study focusses on management of coral reefs under CC. It identifies MSP as a management strategy, together with climate-ready MPAs, that can be used to maximise coral reef resilience under CC.	Global
2018	Janßem et al [86]	This article reviews the integration of fisheries into MSP. It states that MSP must understand changes in fish species/fisheries (due to CC) in order to develop reliable spatial management regimes; and that long-term changes such as CC impacts may further complicate the integration of fisheries into MSP. It also raises the question of revision periods in MSP plans (at most 10 years) and suggests the early identification of areas of relevant fish/fisheries dynamics.	Global
2018	Visbeck[87]	This article advocates that ocean science research is key for a sustainable future. CC is addressed as a threat to healty ocean systems. It states that the UN system and coastal states have a unique chance to collaborate in multi-stakeholder processes to advance MSP and effective ocean governance. It also argues that spatial planning procedures that take the global ocean system into account (among other factors) can help find more sustainable and equitable regimes of ocean use and access, and that science can help in this effort by reflecting on a range of human development scenarios and evaluating how best to sustain ocean prosperity while respecting planetary and ocean boundaries.	Global
2019	Mallory et al. [88]	This study focuses on the identification of key marine habitat sites for seabirds and sea ducks in the Canadian Arctic. Updates key marine sites for migratory birds in Arctic Canada (principally Nunavut and the Northwest Territories) identifying that they are used for spatial planning. Addresses CC as a driver of change in the Arctic. States that for future conservation planning and MSP, a continued assessment of key marine habitats for migratory birds is essential as CC is altering sea ice conditions.	Local – Canadian Arctic
2019	Morgunov et al. [8]	This article evaluates transboundary risks and global effects of CC and economic activities in the basis of Arctic Seas. It states that among the main obstacles to mitigating CC impact on the state of Arctic seas, is the absence of unified cross-country tools for MSP.	Regional – Arctic
3. Indirect reference—Studies that indirectly relate both topics			
2008	Halpern et al. [89]	Addresses managing for cumulative impacts through ocean zoning. CC as one of the multiple stressors considered. States that comprehensive ocean zoning is one management tool that can explicitly deal with the reality of the cumulative and interactive effects of multiple stressors.	Global
2009	Douvere and Ehler [90]	Addresses Agenda 21 as an international legal and policy framework relevant for MSP development. Chapter 17 of Agenda 21 sets a framework program of action that includes addressing critical uncertainties for marine management and CC.	Regional – Europe
2010	Lester et al [91]	Assess whether the necessary science exists to support EBM. Addresses the implications of cumulative impacts for MSP. CC as one of the main sorces of change in marine systems. States that long-term ocean health requires planning for the future using forecasting and management scenario analyses; and that the latter have been done for e.g. single human activities, and climate change impacts.	Local – USA West Coast
2011	Katsanevakis et al. [92]	MSP as a way to support ecosystem based marine spatial management (EBMSM). Addresses the CC-EBMSM link.	Global
2013	Liquete et al. [93]	Addresses the assessment of coastal protection as an ecosystem service in Europe. CC as an important factor for coastal protection. States that in face of future CC, protective role of coastal ecosystems must be included in MSP through an adaptive strategy.	Regional – Europe
2013	Underwood et al. [94]	Addresses MSP as spatial planning of MPAs, and CC as a stressor to marine ecosystems. MPAs planning as a way to mitigate CC impacts (currently constrained by lack of scientific knowledge on population connectivity).	Local – North-West Australia
2014	Gerber et al. [95]	Addresses CC impacts on connectivity of marine organisms, and its implications for MSP. MSP addressed as an approach to marine conservation.	Local – Gulf of California, Mexico

2014	Le Cornu et al. [96]	Addresses current practice and future prospects for using social data in coastal and MSP. CC is an indicator for social-ecological interactions within the Social Data Index (which is used to evaluate the incorporation of social data in coastal and ocean plans).	Global
2014	Milligan [97]	Addresses offshore CO2 storage as a potential mitigation response to CC. Addresses the link between the MSP framework and offshore CO2 storage.	Regional – United Kingdom
2015	Maxwell et al. [98]	Discusses that management approaches such as MSP are relatively static. Dynamic ocean management (DOM) provides needed flexibility and can be used together with MSP. DOM can be useful to track marine environment shifts due to climate change.	Global
2017	Borges et al. [99]	Addresses conservation planning and ecosystem-based management of mangroves in Brazil. States that including models and values of ecosystem services and vulnerability in MSP can help achieve multiple benefits for nature and people. It also states that it is important to consider different spatial scales when valuation of ecosystem services is applied to support development of spatial plans. CC as a driver of change, and threat to mangroves. States that to support systematic conservation analyses and policy-making, mangrove ecosystems can be grouped into planning units according to expected effects of CC, among other factors.	National – Brazil
2017	Fonseca et al. [100]	Discusses identification of fish diversity hot-spots in data-poor situations. CC as an anthropogenic threat included in the study. Argues that assessment of richness and hot-spot abundance in areas with limited information is an important first step towards developing effective MSP.	Local – Northern Shelft of Rio Grande do Norte, Brazil
2017	Wyatt et al. [101]	Assesses cumulative risk of human activities to coastal/marine habitats in two ocean planning regions. CC (increasing sea surface temperatures) is one of the main stressors considered in the analysis. Addresses MSP in U.S. Northeast and Mid-Atlantic areas. States that risk assessment can be repeated over time to respond to changes in climate and other stressors.	Local – US Northeast and Mid-Atlantic
2018	Kelly et al. [102]	This article discusses the potential of Transition Management in promoting change and transformation in marine governance. It states that current marine governance arrangements are too fragmented to deal with dynamic ecosystems and cross-scale drivers of change, including CC. MSP and ecosystem-based management are addressed as integrated governance mechanisms that will involve transformative change of institutions, values and practice to be successful.	Global
2018	Lovvorn et al. [103]	This article explores the utility of sediment organic carbon as a predictor of benthic assemblage in the Bering Sea. Addresses CC as a driver of change in the marine environment. States that MSP requires the mapping of habitats and projections of future trends to ensure conservation of marine ecosystems in the long-term. Refers that recent efforts to model and map benthic assemblages based on measured proxy variables have allowed important advances in MSP at much reduced cost.	Regional – Northern Bering Sea
2018	Sangiuliano and Davies [104]	Focuses on a quality management review (QMR) of Scotland's sectoral marine plan for tidal energy. Uses key MSP documents to guide the QMR. Both MSP and CC are among the key drivers for the sector plan development. States that the criteria set out in QMR can be adopted to inform broader international MSP collaborations in order to set in motion governance structures, and associated regulatory frameworks, that account for CC factors.	National – Scotland
2019	Balbar and Metaxas [105]	This paper reviews the current application of ecological connectivity in the design of MPAs, namely in select countries with advanced MSP. States that there is a gap between increasing research on connectivity and its integration into MSP. Highlights the importance of evaluating connectivity of MPAs under CC, and the need for adaptive management.	Global
2019	deCastro et al. [106]	This study provides an overview of offshore wind energy resources in Europe under present and future climate. It identifies renewable energy as key to achieve international/national commitments to fight CC. It highlights that MSP (and the MSP Directive) can prevent conflicts between offshore wind farms and other uses, offering greater certainty and security to investors and helping to reduce processing time.	Regional – Europe

2019	Furlan et al. [107]	This paper proposes a new Cumulative Impact Index for the Adriatic Sea, accounting for interactions among climate and anthropogenic pressures. CC scenarios are integrated into the index. Discusses the importance of cumulative impact maps, vulnerability and risk maps to support MSP. Discusses the importance of including future CC scenarios in risk maps to support the development and implementation of management measures.	Regional – Adriatic Sea
2019	Kirkman et al. [108]	This study focuses on using systematic conservation planning to support MSP and achieve marine protection targets in the transboundary Benguela Current Large Marine Ecosystem (CLME). It states that the BCLME is under pressure from CC, and that area-based tools such as MPAs are vital to reduce risks from CC. Addresses how systematic conservation planning tools can support a multi-national MSP process, by identifying priority areas to be included in MSP and informing MPAs designation and management.	Regional – Benguela Current Large Marine Ecosystem
2019	Stephenson et al. [109]	This paper addresses practical framework for implementing and evaluating Integrated Management (IM) of marine activities. It discusses the need for flexibility to adapt to changing conditions, stating that management of ocean uses will face deep transition in coming decades due to ecosystem change and increased use. It highlights that IM is essential for managing impending CC and emerging economy interests. Considers MSP as a type of IM.	Global
2019	Willaert et al. [110]	This article focuses on promoting EBM, using a case study to demonstrate how the InVEST model tool and associated methods can be applied to calculate benthic habitats cumulative risk and to create a vulnerability index of the potential of these habitats to deliver ecosystem services. A CC scenario for the end of the century was analysed. Discusses how results can support MSP in Portugal, and adaptation to CC risks.	Local – Western-Atlantic coast of Portugal
4. Separate reference — Include MSP and CC in their contents, but do not establish a connection between both			
2008	Boersma [111]	Discusses the use of penguin species as marine sentinels for southern oceans. Addresses the impacts of CC on Antarctic and sub-Antarctic penguins. Identifies ocean zoning as a tool to exclude conflicts between fishers and penguins.	Regional – Southern Ocean
2008	Halpern et al. [112]	The analytical framework provides flexible tools for regional and global efforts to inform MSP. CC considered as an anthropogenic driver.	Global
2009	Crain et al. [113]	Addresses the management of human threats in the ocean. CC as a top human threat to coastal and marine ecosystems. States that comprehensive MSP or ocean zoning is the most promising example of area-based, multi-objective management, and that cumulative impact maps can be important tools for informing ocean zoning plans.	Global
2009	Halpern et al. [114]	Addresses the mapping of cumulative human impacts. CC as a top threat in the California Current. Mentions that the quantitative assessment of spatial patterns of all ocean uses and their cumulative effects i(cumulative impacts maps) is needed for the development of ocean zoning.	Regional – California Current
2009	Kloser et al. [115]	Acoustic methods for characterizing micronekton biomass can provide valuable inputs to monitoring CC effects, and to marine planning. Brief reference.	Regional – Tasman Sea
2009	Portman et al. [116]	Development of offshore wind energy (OWE) as an effort to combat CC. Addresses the link between offshore wind energy and MSP.	National – Germany and US
2010	Dolman and Simmonds [117]	Offshore wind, wave and tidal energy as a way to reduce greenhouse gas emissions responsible for CC. MSP as a way to reduce negative environmental impacts from marine renewable energy.	Regional – United Kingdom
2010	Lubchenco and Petes [118]	CC as a progressive stressor that induces changes in ecosystems. Mismatch of scales between CC scenarios (global) and CC impacts (local) hinders managers to incorporate climate information into planning. MSP identified as a way to minimize user conflicts and ecosystem impacts.	Global
2010	Lubchenco and Sutley [119]	Analyses U.S. policy for ocean and coastal stewardship. CC as a stressor. U.S. regional planning bodies would implement coordinated, ecosystem-based approaches to coastal and MSP.	National – US
2011	Briggs [120]	Discusses marine extinctions and conservation. CC as a stressor to marine species. States that MPAs and extensive ocean zoning can avoid species extinction.	Global

2011	Francisco Carcamo et al. [121]	Installation of coal-fired power plants increases greenhouse gas emissions, opposing to international/regional recommendations in a CC context. MSP as a way to reduce user conflicts. CC only briefly referred.	National – Chile
2011	Gilman et al. [122]	CC as anthropogenic driver of change and loss in biodiversity. MSP, including conservation planning, identifies areas critical for biodiversity conservation and mandatory restrictions on incompatible human activities.	Global
2011	Hobday [123]	Climate-aware marine conservation planning should consider dynamic protected areas.	National – Australia
2011	Hutchings and Rangeley [124]	Climate-induced variability contributes to increases in cod mortality. Long-term benefits of cod recovery can be attained by expansion of MSP. Brief reference.	National – Canada
2011	Jessen [125]	Use of MSP in Eastern Scotian Shelf Integrated Management and in Pacific North Coast Integrated Management Area processes. CC as a stressor to ocean ecosystems. MPAs as a way to adapt to CC.	National – Canada
2011	Ostrander et al. [126]	Addresses how Integrated Ocean Observing Systems support resource management by providing key information on CC impacts and on conflicting uses needing MSP.	National – US
2011	Portman [127]	Addresses evaluating integration in MSP. CC as a threat to marine environment. CC only briefly referred.	Global
2012	Allnutt et al. [128]	MSP addressed as method for mapping conservation priorities and management actions (conservation planning). Exposure to CC (thermal stress) as one variable relevant to conservation decisions.	National – Madagascar
2012	Fluharty [129]	Adoption of MSP as an ocean policy initiative. Need for national policy on adaptation to CC for oceans.	National – US
2012	Frazão Santos et al. [130]	Addresses the EU Marine Strategy long-term adequacy in its link to MSP, and to CC.	National – Portugal
2012	Grech et al. [131]	Addresses the need for MSP to be coordinated with adjacent watershed planning. Addresses impacts from CC on global seagrass bioregions.	Global
2012	Guerry et al. [132]	Discusses the use of ecosystem services to inform coastal spatial planning and MSP. CC as an anthropogenic threat. States that model outputs are useful for understanding the risk of CC to habitats within a study region and among alternative future scenarios, and that the model can inform the design of marine spatial plans.	Local – West Coast of Vancouver Island, Canada
2012	Samhouri [133]	Provides a framework for evaluating ocean health and ecosystem services. States that such framework can advance components of ecosystem-based management, including MSP. CC as a stressor for oceans health.	National – US
2013	Alvarez-Romero [134]	Addresses systematic marine conservation planning, and CC significance in conservation planning.	Local – Gulf of California, Mexico
2013	Borja et al. [135]	Indentifies CC among the most frequent marine topics in papers by Spanish/Portuguese authors. MSP as a way to balance conservation and uses.	Regional – Iberian Peninsula
2013	Christensen et al. [136]	Addresses a forecasting system for fisheries, which is tested for typical scientific questions appearing in MSP. The approach allows for investigating propagation of changes in ocean climate.	Regional – North Sea
2013	Jordaan et al. [137]	Addresses the employment of ecological approaches (proxies of biodiversity) in MSP. CC as a stressor for fisheries.	Local – Gulf of Maine and Georges Bank, US
2013	Levy and Ban [138]	Addresses the inclusion of CC projections in marine conservation planning (identification of priority areas).	Regional – Indo-West Pacific
2013	Meiner [139]	Addresses the fact that both MSP and CC adaptation need to be informed effectively by marine/coastal spatial data.	Regional – Europe
2013	Stanford et al. [140]	Develops a methodology to map fisheries dependence and incidences of poverty amongst fishers, which is applicable to national MSP. CC as a stressor to marine fisheries.	Local – West Sumatra, Indonesia
2014	Börger et al. [141]	Analyses the use of ecosystem services valuation in MSP. CC as an anthropogenic stressor to marine ecosystem services, and a source of uncertainty.	Regional – United Kingdom and US

2014	Börger et al. [142]	Analyses the applicability of a discrete choice experiment to value benefits from conservation of an offshore MPA. States that the general public has limited knowledge of current MSP. CC causes species migrations northwards.	Regional – Dogger Bank
2014	Christie et al. [143]	Discusses how MSP will have to consider concurrent activities in time/space (co-location). Renewable energy with vital role in meeting growing energy demand and maintaining CC targets. CC only briefly referred.	Regional – British Isles
2014	Hays [144]	Addresses implications of CC to charismatic marine mega-fauna. Conservation issues have become integrated into marine planning and have resulted in extended networks of MPAs and large MPAs. MSP only briefly referred.	Global
2014	Kocur-Bera and Dudzinska [145]	Addresses information and database range used for MSP and ICZM. CC as anthropogenic stressor. MSP and ICZM objectives include coastal adaptation to CC. CC only briefly referred.	National – Poland
2014	Kononen et al. [146]	Addresses CC, and MSP as crosscutting issues in BONUS+ Projects.	Regional – Baltic Sea
2014	Lagabriell e et al. [147]	Addresses challenges of integrating ecosystems connectivity into MSP (MPA network planning and management). CC effects and uncertainty must be accounted in planning for future MPAs. CC only briefly referred.	Global
2014	Magris et al. [148]	Addresses how to effectively integrate connectivity and CC into marine conservation planning.	Global
2014	Robb [149]	Addresses the assessment of human activities' impact on estuaries. This will inform MSP. CC effects as a threat to estuaries. MSP only briefly referred.	Local – British Columbia, Canada
2014	Rodwell et al. [150]	Addresses challenges and opportunities in UK marine policy (and MSP). CC only briefly referred.	Regional – United Kingdom
2014	Rouse et al. [151]	Addresses baseline data on Scottish bryozoans (diversity and distribution patterns over space/time). States that such data is important to informing MSP and monitoring CC impacts.	National – Scotland
2015	Goela et al. [152]	Addresses the use of bio-optical parameters as a tool for detecting changes in phytoplankton. States they are important in selecting indicators/metrics for the implementation of the EU Marine Strategy and the EU MSP Directive. CC as a driver of change in the intensity/frequency of upwelling events.	Local – South-West Portugal
2015	Reiss et al. [153]	Addresses benefits of using Distribution Modelling in MSP, and in future scenarios of environmental change (such as CC).	Global
2015	Young [154]	Addresses the role of MSP in facilitating offshore renewable energy. States that in light of the reality of CC, the study seeks to explore the role of MSP in facilitating the development of offshore renewable energy.	Global
2016	Clark et al. [155]	States that MSP would benefit from quantitative, spatially explicit estimates of cumulative impact of human activities on marine ecosystems. CC as a human stressor, although not included in the study due to lack of information.	Local – Tauranga Harbour, New Zealand
2016	Di Sciara [156]	Addresses place-based approaches to marine mammal conservation, such as designation of Important Marine Mammal Areas (IMMAs). States that the presence of IMMAs can help identify valuable areas for biodiversity during MSP. CC as a human threat that does not follow physical boundaries.	Global
2016	Guerra [157]	Discusses governance challenges for Offshore Renewable Energy (ORE). Addresses ORE as a contributor to CC mitigation. Refers MSP as a mechanism to address the challenges of ORE.	Regional – Europe
2016	Lubchenco et al. [158]	Discusses how economic and social incentives can enable ocean sustainability. CC as a global-scale stressor. States that around the world positive changes are underway towards ocean sustainability, and that robust progress has been maid e.g. in MSP.	Global
2016	Pascal et al. [159]	Addresses the economic valuation of coral reef ecosystem services of protection against coastal floods. States that the method is not sufficiently detailed for MSP. CC included in the valuation method (hazard likelihood).	Global
2016	Wells et al. [160]	Discusses the importance of including MPAs in ICZM and MSP initiatives. Discusses the role of MPAs to building CC resilience.	Global
2016	Asjes et al. [161]	Addresses changes in haddock distribution and implications for spatial management. States that understanding fish distributions is becoming increasingly important for MSP, and that legislation such as the MSP Directive has been put in place to protect essential fish habitat. CC as a driver of change in habitat suitability.	Regional – North Sea

2016	Kwak [7]	Discusses possibilities of co-existence of offshore wind farms and other uses. Addresses MSP as a way to overcome spatial conflicts among uses. States that demand for wind farms is increasing as a way of reducing CC impacts.	Global
2017	Hammar et al. [162]	Discusses ocean energy industries. Addresses marine renewable energy as a way to mitigate CC effects. MSP as a important management tool that accounts for cumulative impacts from different activities.	Global
2017	Miller et al. [163]	Addresses the spatial valuation of California marine fisheries. Mentions CC as a driver of species and fisheries range shifts. States that ecosystem service maps can improve MSP by identifying important fishing grounds.	Local – California, US
2017	Santora et al. [164]	Addresses trophic hotspots within na upwelling marine ecosystem. Discusses implications for trophic hotspots from changes in upwelling due to CC. States that trophic hotspots have potential applications to MSP and fisheries management.	Regional – California Current
2017	Sherley et al. [165]	Discusses the scale of MPAs for an endangered seabird. Discusses the implication of results for MSP and the relevance of no-take zones. Identifies CC as anthropogenic stressor for marine ecosystems.	Local – West Coast of South Africa
2018	Fredston-Hermann et al. [166]	Discusses biogeography and MPAs/conservation planning under CC. States that embracing biogeographic perspectives on MSP will lead to management recommendations more realistic to a dynamic ocean.	Global
2018	Jumin et al. [167]	This study describes the approach used to develop a zoning plan for the Tun Mustapha Park in Sabah, Malaysian Borneo, using the planning tool Marxan with Zones, together with stakeholder consultation. CC is mentioned as a key threat to marine ecosystems.	Local – Sabah, Malaysia
2018	Kraufvelin et al. [168]	Identifies CC as a major human-induced threat to essential fish habitats (EFH). Mentions the need for a successful implementation of international directives such as the MSP Directive; and the lack of information on coastal EFH to be used in MSP.	Regional – Baltic Sea
2018	Mikkola et al. [169]	This paper presents a utilization of a multi-use platform that combines wind energy and fish farming in the Gulf of Bothnia. Addresses MSP as a tool to identify suitable locations for multi-use of the ocean space. Mentions CC as a challenge to the use of the ocean space.	Regional – Gulf of Bothnia
2018	Rempis et al. [170]	This article discusses coastal use synergies and conflicts evaluation in the Heraklion area, Crete Island. It highlights the importance of ensuring coherence between terrestrial planning and MSP, namely for coastal areas. It also addressed the importance of preventing effects of CC in coastal areas.	Local – Heraklion area, Crete Island
2018	Sará et al. [171]	Addresses the integration of multiple stressors (including CC) in aquaculture. Addresses MSP as a crucial tool to develop ecosystem-based use and management strategies for the marine environment.	Global
2018	Soares and Lucas [172]	Discusses strategies for establishing large scale MPAs, and addresses challenges faced in managing them in a changing ocean. States that establishing large MPAs has enhanced the probability of achieving global protection targets, using large-scale MSP.	Local – St. Peter and St. Paul's Archipelago, and Vitória-Trindade Seamount Chain, Brazil
2018	Soares [173]	Discusses CC as a challenge for managing oceanic islands. Discusses the resilience of offshore MPAs in South Atlantic to CC stressors. Addresses the need for large scale MSP in South Atlantic islands and seamounts to deal with regional and global pressures.	Regional – South Atlantic
2018	Thiault et al. [174]	Addresses mapping of social-ecological vulnerability of a small-scale fisheries. States that vulnerability assessments and maps provide key information to optimize MSP. Mentions CC as a driver of change.	Local – Moorea, French Polynesia
2018	Thiault et al. [175]	Addresses an approach to integrate spatial and temporal dimensions into social-ecological vulnerability assessments. Mentions the MSP initiative in Moorea. CC as an indirect driver of change.	Local – Moorea, French Polynesia
2018	Visbeck [176]	Discusses ocean science research. Mentions MSP as a way to advance sustainable ocean governance, and CC as a major threat to the ocean.	Global
2018	Willsteed et al. [177]	Provides an evaluation of offshore wind farm cumulative impact assessments (including CC effects). States that results will be of interest to countries where marine renewable energy is emerging alongside MSP aspirations.	Regional – United Kingdom
2019	Bennett [178]	This perspective article argues that marine social sciences must inform the pursuit of sustainable oceans, and reviews the insights that social science can offer to guide ocean and coastal policy and management. States that decision-	Global

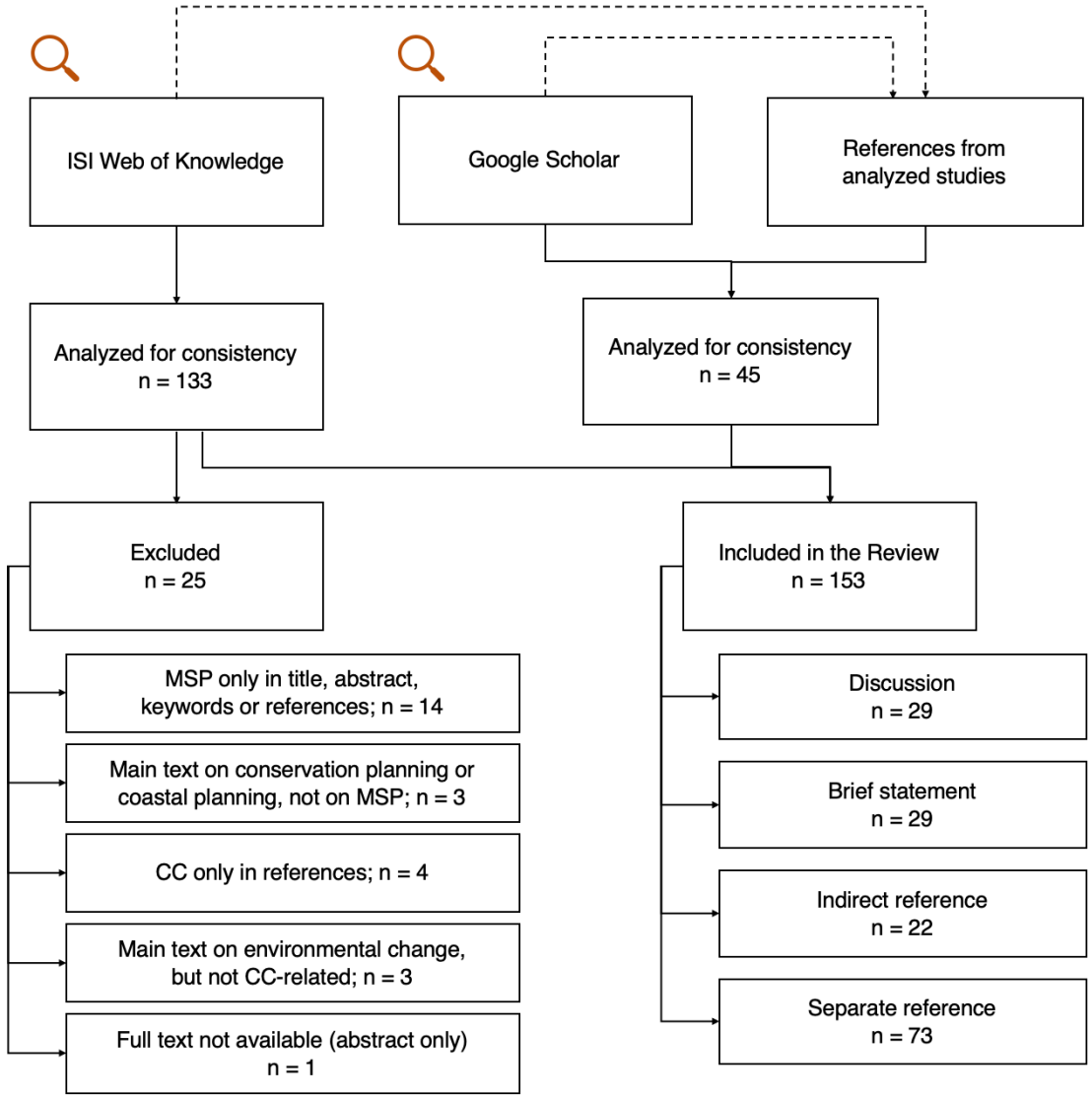
		making in different ocean policy realms should be guided by an understanding of human dimensions, and that this is true to both MSP and climate adaptation, among others.	
2019	de la Torre-Castro [179]	This study proposes inclusive management through gender considerations in small-scale fisheries as a new approach to address ocean degradation. Mentions MSP as one type of management plans, among others. CC as a human pressure to marine and coastal ecosystems.	Local – Zanzibar, Tanzania
2019	Holden et al. [180]	This study reviews the challenges facing shellfish aquaculture development on the central and north coast of British Columbia. Is addresses CC as a challenge to shellfish production in the area. It states that CC mitigation strategies are being incorporated into the design, construction, and restoration of shellfish facilities; and that all life stages, hatchery processes, and local oceanic conditions need to be considered when assessing the vulnerability of shellfish aquaculture operations to CC. It highlights the importance of including the shellfish aquaculture industry in marine planning.	Local – Central and north coast of British Columbia, Canada
2019	Pinheiro et al. [181]	This paper reviews Sustainable Development Goal 14 targets and indicators, highlighting challenges and flaws that are compromising their achievement. It states that after the 2017 UN Ocean Conference, where governments recommitted to SDG 14, nations worldwide presented intentions to develop MSP among other management tools. Identifies the link between CC and SDG 14.	Global
2020	Boersma et al. [182]	This article focuses on applying science to pressing conservation needs of penguins. It states that developing MSP is of highest priority for yellow-eyed penguins' distribution areas (i.e. South Island of New Zealand, and sub-Antarctic Campbell and Auckland Islands). It also states that safeguarding the future of penguins will require international collaboration on spatial planning, particularly in areas beyond national jurisdiction. CC as a stressor to penguin populations.	Regional – Southern hemisphere

Supplementary Table 5 | Correspondence between regional, national and local studies of the MSP and climate change subset, and Marine Ecoregions as in Spalding et al. (2007)[8]. Data on geographic context of each study (location and spatial scale), and total number of studies per location were assembled from Supplementary Table 4. Locations are presented by spatial scale of the study (regional, national, or local), and then by alphabetic order. For visual purposes, regional studies corresponding to the Southern Hemisphere[182] and Tropical Coastal Seas[72] are not included in the table, nor mapped in Figure 2 of the manuscript, because of the vast extension of both areas. US, United States of America.

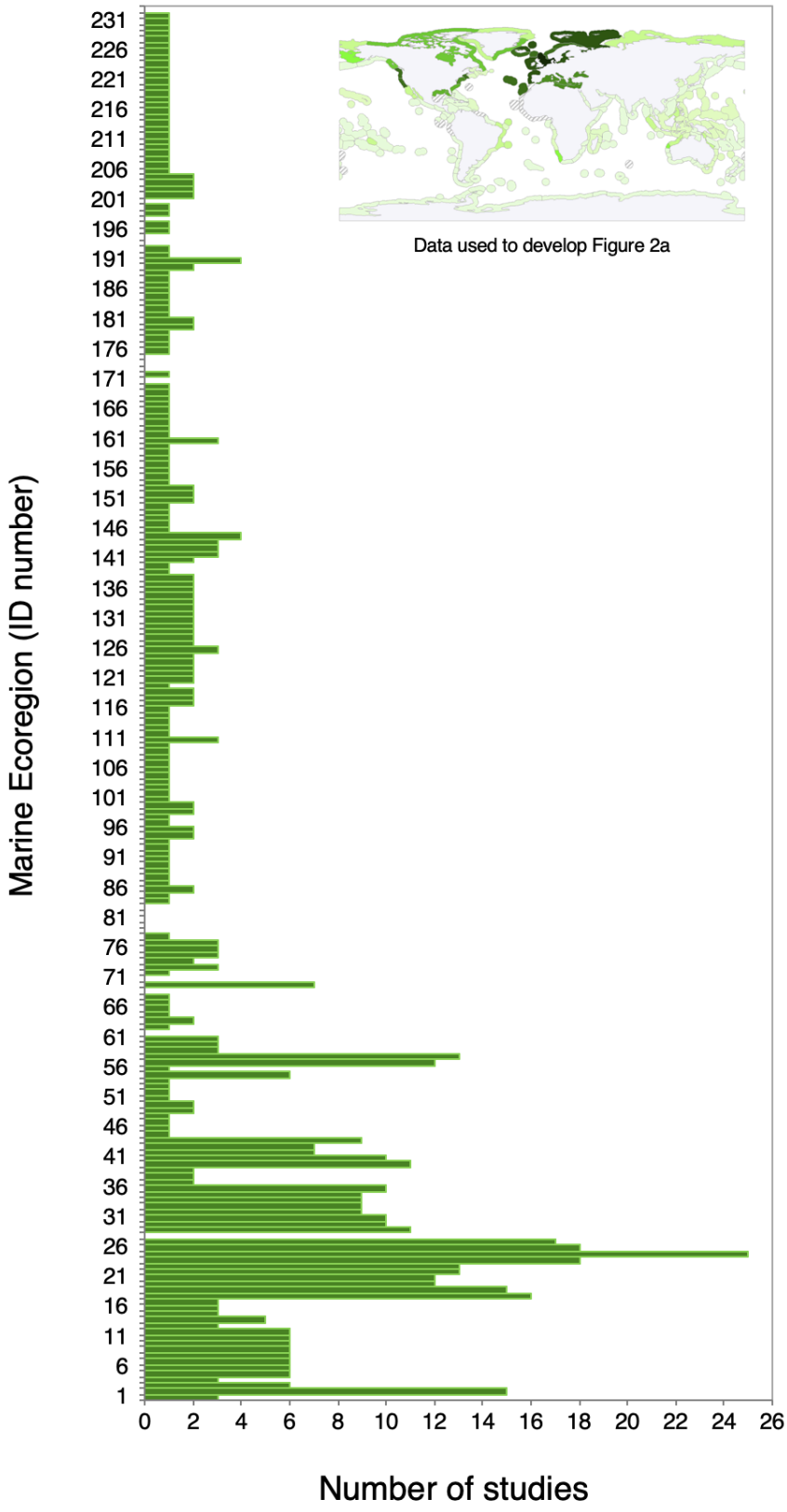
Location and spatial scale	Number of studies per location	Marine Ecoregion (ID number)
Regional		
Arctic	3	1-19
Adriatic Sea	1	30
Baltic Sea	2	24
Benguela Current Large Marine Ecosystem	1	86,190,191
British Isles	1	25,26
California Current	2	57-59,61
Caribbean region	1	63-68
Coral Triangle	1	111,117-119,126-138
Dogger Bank	1	25
Europe	9	2,18-27,29-36,44
Gulf of Bothnia	1	24
Iberia Peninsula	1	27,36
Indo-West Pacific	1	87-163
North-East Atlantic (one on Hatton-Rockall plateau, one on continental shelf)	3	2,3,18-23,25-27
North Pacific Ocean	1	14,45-61,121-125,152,153, 164-170,172
North Sea	2	25
Northern Bering Sea	1	14
South Atlantic Ocean	1	73-78,84-86,180-186,189-191
Southern Ocean	1	212-232
Tasman Sea	1	151,197,199,200,202-205
United Kingdom	5	25,26
National		
Australia	1	140-145,202-211
Brazil	1	72-77,180,181
Canada	2	5-12,37-39,55
Chile	1	176-179,187,188
Germany	2	24,25
Korea	1	49,50
Latvia	1	24
Madagascar	1	99,100
Norway	1	18,22,23
Poland	1	24
Portugal	2	27,29
Seychelles	1	96
Scotland	2	25,26
South Africa	1	191-193
St. Kitts and Nevis	1	64
United States	7	40-43,57,58,70

Local		
Azores, Portugal	1	29
British Columbia, Canada	3	55
California, US	2	58
Canadian Arctic, Canada	1	5-12
Great Barrier Reef Marine Park, Australia	1	142,143
Gulf of California, Mexico	2	60
Gulf of Maine and Georges Bank, US	1	40
Heraklion area, Crete Island, Greece	1	31
Maine coastal shelf, USA	1	40
Ningaloo Marine Park, Western Australia	1	145
North-West Australia	1	144,145
Northern Shelf of Rio Grande do Norte, Brazil	1	75
Moorea, French Polynesia	2	161
Rhode Island Sound and Block Island Sound, US	1	41
Sabah, Malaysia	1	126
South-West Portugal	1	27
St. Peter and St. Paul's Archipelago, and Vitória-Trindade Seamount Chain, Brazil	1	73,76,77
Tauranga Harbour, New Zealand	1	196
US Northeast Shelf	1	40,41
US Northeast and Mid-Atlantic	1	40,41
US West Coast	1	57,58
Western-Atlantic Coast of Portugal	1	27
West Coast of South Africa	1	191
West Coast of Vancouver Island, Canada	1	57
West Sumatra, Indonesia	1	111
Zanzibar, Tanzania	1	95

Supplementary Figures



Supplementary Figure 1 | Literature review approach. Overview of the methodological approach used to develop the literature review, number of included and excluded studies, reasons for exclusion, and distribution of included studies by type of connection established between climate change and marine spatial planning (MSP).



Supplementary Figure 2 | Number of studies included in the MSP and climate change subset, by Marine Ecoregion[8].

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