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What evidence exists on how changes in marine ecosystem structure and functioning affect ecosystem services delivery? A systematic map protocol

C. Sylvie Sylvie Campagne, Joseph Langridge, Joachim Claudet, Rémi Mongruel, Eric Thiébaud

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1 ***How changes in marine ecosystem structure and functioning***
2 ***affect ecosystem services delivery? A systematic map protocol***

3
4
5 ***Authors' contacts***

6 **C. Sylvie Campagne^{1,2}, Joseph Langridge² Joachim Claudet³, Rémi Mongruel⁴, Eric Thiébaud¹**

7 ¹ Sorbonne Université, CNRS, Station Biologique de Roscoff, UMR7144, Adaptation et Diversité en
8 Milieu Marin, Place Georges Teissier, F-29680 Roscoff, France

9 ² Fondation pour la Recherche sur la Biodiversité, Centre de Synthèse et d'Analyse sur la Biodiversité
10 (FRB-Cesab), 5 rue de l'école de médecine 34000 Montpellier, France

11 ³ National Center for Scientific Research, PSL Université Paris, CRIOBE, CNRS-EPHE-UPVD, Maison des
12 Océans, 195 rue Saint-Jacques, 75005 Paris, France

13 ⁴ Ifremer, Univ Brest, CNRS, UMR 6308, AMURE, Unité d'Economie Maritime, IUEM, F-29280, Plouzane,
14 France

15
16 ***Abstract***

17 **Background:** The current biodiversity crisis calls for an urgent need to sustainably manage human
18 uses of nature. The Ecosystem Services (ES) concept defined as « the benefits humans obtain
19 from nature » support decisions aimed at promoting nature conservation. However, marine
20 ecosystems, in particular, endure numerous direct pressures (e.g., habitat loss and degradation,
21 overexploitation, pollution, climate change, and the introduction of non-indigenous species) all of
22 which threaten ecosystem structure, functioning, and the very provision of ES. While marine
23 ecosystems often receive less attention than terrestrial ecosystems in ES literature, it would also
24 appear that there is a heterogeneity of knowledge within marine ecosystems and within the
25 different ES provided. Hence, a systematic map on the existing literature will aim to highlight
26 knowledge clusters and knowledge gaps on how changes in marine ecosystems influence the
27 provision of marine ecosystem services. This will provide an evidence base for possible future
28 reviews, and may help to inform eventual management and policy decision-making.

29
30 **Method:** We will search for all evidence documenting how changes in structure and functioning
31 of marine ecosystems affect the delivery of ES, across scientific and grey literature sources. Two
32 bibliographic databases, Scopus and Web of Science Core Collection, will be used with a
33 supplementary search undertaken in Google scholar. Multiple organisational websites related to
34 intergovernmental agencies, supra-national or national structures, and NGOs will also be
35 searched. Searches will be performed with English terms only without any geographic or
36 temporal limitations. Literature screening, against predefined inclusion criteria, will be
37 undertaken on title, abstract, and then full texts. All qualifying literature will be subjected to
38 coding and meta-data extraction. No formal validity appraisal will be undertaken. Indeed, the

39 map will highlight how marine ecosystem changes impact the ES provided. Knowledge gaps will
40 be identified in terms of which ecosystem types, biodiversity components, or ES types are most
41 or least studied and how these categories are correlated. Finally, a database will be provided, we
42 will narratively describe this evidence base with summary figures and tables of pertinent study
43 characteristics.

44
45 **Keywords:** Ecosystem disservices; Coastal; Marine; Biodiversity; Nature's contribution to people;
46 Spatio-temporal dynamics

48 **Background**

49 In the context of the current biodiversity erosion crisis, there is an increasingly urgent need to
50 manage nature's contribution to people in a sustainable way and at a sustainable rate, thereby
51 maintaining its potential to meet the needs of the present and future human generations [1].
52 Nature's Contribution to People (NCP) and Ecosystem Services (ES) concepts have gained interest
53 in their ability to highlight our dependency on nature and all the services we extract from it [2–4].
54 The concept of ES is relatively recent—being introduced in the late 1970s—and has its roots in
55 the recognition that ecosystems provide irreplaceable goods and services [5]. It has since been
56 largely popularized by the Millennium Ecosystem Assessment as a way of thinking about the
57 relationships between humans and nature [6]. Defined as « *the benefits humans obtain from*
58 *nature* » [6], the ES concept helps in producing knowledge to support decisions aimed at
59 promoting nature conservation. The related concept of NCP, popularized first by
60 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
61 regional assessments, goes beyond ES by integrating a wider range of values (e.g., rational values)
62 and the consideration of negative contributions of nature (also called disservices [7,8]). NCP are
63 defined as « *all the contributions, both positive and negative, of living nature to people's quality*
64 *of life* » [1,2].

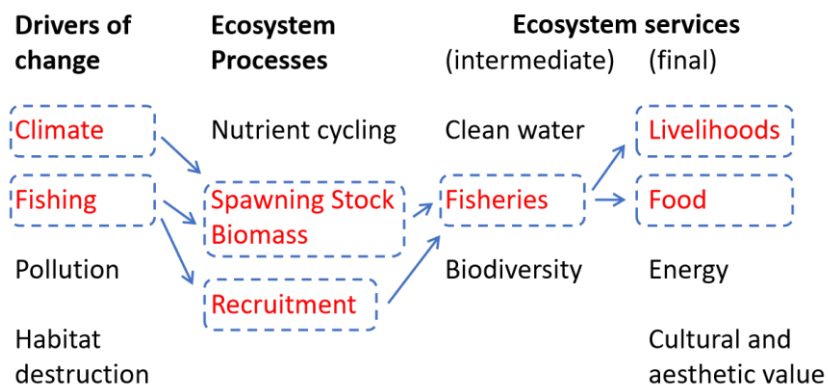
65
66 These concepts allow the studying of socio-ecological systems by proposing to analyse the
67 interactions between living components (humans and non-humans), which concerns rigorous
68 approaches across different scientific disciplines - ecology (e.g. [9,10]), economics (e.g. [11]),
69 anthropology (e.g. [12,13]), philosophy (e.g.[14]) or geography (e.g. [15]) - in order to describe
70 the numerous interactions and to understand their scope. ES concept allows for improving
71 interactions between disciplines but also among scientists, managers, stakeholders and
72 politicians by redefining the debates that exist around the conflicts between development and
73 conservation [16]. The different ES can be divided into three main categories: (1) provisioning
74 services which are products obtained from ecosystems (e.g., foods, raw materials for industry); (2)
75 regulation and maintenance services which are benefits obtained from ecosystems (e.g., climate
76 regulation, coastal protection) and (3) cultural services which are non-material benefits obtained
77 from ecosystems (e.g., Recreation activities) [17–19].

78
79 Marine ecosystems provide a wide range of ES. Several lists of marine ES are available in the
80 literature such as Bordt and Sander [20], Kermagoret *et al.* [21], Barbier [22] or Mongruel *et al.*
81 [13], generally inspired by the classification proposed in Liqueste *et al.* [19] and Beaumont *et al.*

82 [23]. For instance, based on the Common International Classification for Ecosystem Services
83 (CICES) [24] and Liquele *et al.* [19], the French platform for the evaluation of ecosystems and
84 ecosystem services listed the ES provided by marine ecosystems [13] as follows: food provision,
85 raw materials from aquaculture, macro-algae production, molecules production, coastal
86 protection, climate regulation, nutrient regulation, pest and disease control, symbolic,
87 emblematic and aesthetic values, recreation and tourism, landscape amenity and knowledge
88 production. They also considered “nursery function” and “maintenance of food webs” in their
89 assessment even if these are sometime considered as functions [13] or as regulating services [19].
90 We also decided to include them. However, ecological functions like primary and secondary
91 production provided by marine ecosystems and sometimes defined as support services were not
92 included in this review [21,25].

93
94 Marine ecosystems endure numerous direct drivers of change: mainly habitat loss and
95 degradation, overexploitation, pollution, introduction of non-indigenous species, and climate
96 change. All of which threaten the future sustainability of marine and coastal areas [26]. The
97 magnitude of these direct drivers may also depend on indirect drivers such as demographic
98 pressure, socio-cultural context, economy, technological development, institutions and
99 governance, and conflicts and epidemics. In 2008, Halpern *et al.* [27] showed in a multi-driver
100 analysis that no area of the global ocean is unaffected by human influence and that more than
101 40 % of the ocean, mainly in coastal areas (e.g., NE of USA, NW Europe, East Asia, Eastern
102 Caribbean) are strongly affected. From 2008 to 2013, « *sixty-six per cent of the ocean experienced*
103 *increases in cumulative human impact [...], especially in tropical, subtropical and coastal regions,*
104 *while only 13% experienced decreases in response to management measures* » [28]. Indeed,
105 threats and pressures endured by marine ecosystems induce changes which have impacted
106 marine ecosystem services and have negatively impacted human health and well-being, more
107 specifically for Indigenous peoples and local communities dependant on fisheries [26]. For
108 example Selim *et al.* (2016) highlighted pathways linking fishing and climate (drivers) to
109 Spawning Stock Biomass and recruitment of three demersal fish species (ecosystem
110 processes) and the consequences for delivery of the Fisheries and ultimately on food
111 provision and economic livelihoods (ecosystem services) (Figure 1).

112 While marine ecosystems are increasingly included in new international legislation, the need to
113 develop effective conservation and protection strategies remains. For instance, marine protected
114 areas concern only 7% of the marine realm, only partly cover important sites for biodiversity and
115 are not fully ecologically representative, well-connected, and effectively managed [29]. It is
116 therefore crucial to apply rigorous sustainable management practices in order to help guarantee
117 the delivery of ES and conserve the multiple benefits provided by marine ecosystems, that so
118 many people rely on [29,30]. Hence, it first is particularly necessary to better understand such
119 ecosystems and to highlight the related socio-ecological aspects.



120

121 **Figure 1** Examples of how drivers of change can affect ecosystem services (adapted from
 122 Selim et al. 2016)

124 In the ES literature, marine ecosystems receive less attention than terrestrial ecosystems; less
 125 than 9% of the ES literature [31]. In the numerous ES provided by marine ecosystems, food
 126 provision (i.e., fisheries and offshore aquaculture) seems to be by far the most intensively studied
 127 marine ES [17,19]. It can be related to the fact that some marine species groups are more
 128 assessed and studied like commercial species and top predator fish stocks [29]. In addition,
 129 another focus seems to be on specific ecosystems such as coral reefs, mudflats, and seagrass
 130 beds [13]. Also, knowledge on marine ecosystems seems to decrease with distance from the
 131 coastline [13]. Only a few studies have explored ES in deep-sea ecosystems [31]. Also, the
 132 literature seems to focus on snapshot assessments instead on multi-time assessments in relation
 133 to the ecological dynamics.

134

135 The heterogeneity of knowledge in marine and coastal ecosystems and their services is a major
 136 obstacle to the effective use of scientific results by decision-makers. Thus, in order to structure
 137 existing knowledge and produce results that are useful for decision-making, a systematic map
 138 seems particularly relevant. A systematic map on the existing literature will highlight knowledge
 139 gaps and knowledge clusters on how changes in marine ecosystems influence the provision of
 140 marine ES. This will provide an evidence base for possible future reviews, and should help to
 141 inform eventual management and stakeholder decisions.

142 **Stakeholder engagement**

143 This systematic map is part of the InDySEM project - Influence of ecological Dynamics on
 144 production and demand for marine Ecosystem Services, submitted to a call for research projects
 145 launched by The French Foundation for Research on Biodiversity - Center for Biodiversity
 146 Synthesis and Analysis –(FRB-CESAB-) and is supervised by a scientific team and a methodological
 147 team. The scientific team is composed of researchers with expertise from ecology, economy, and
 148 sociology, with expertise on the different main marine ecosystems. The scientific team developed
 149 and built the project for the call and follow the project leader and the project officer during

Commenté [s1]: Note pour Sylvie : à ajouter et à reprendre dans la biblio:
 Selim, S.A., Blanchard, J.L., Bedford, J., Webb, T.J. (2016) Direct and indirect effects of climate change and fishing on changes in coastal ecosystem services: a historical perspective from the North Sea. *Regional Environmental Change*, 16, 341-351

150 recurring meetings. Also, they validated the adjustment of the research question, the PECO
 151 elements, the search strings as well as all the ROSES elements. The methodological team is
 152 composed of systematic review and data analysis experts and follow all CEE methodological steps
 153 for systematic maps. The FRB's CESAB is a research structure with an international scope whose
 154 objective is to implement innovative work on the synthesis and analysis of existing data sets in
 155 the field of biodiversity.
 156

157 **Objective of the review**

158 The principal objective of this review is firstly to record and synthesise all evidence on how
 159 spatio-temporal changes in marine biodiversity impact ES provided by these ecological systems.
 160 We will focus on changes in biodiversity from species level to ecosystems, including functional
 161 and structural diversity, and how these changes influence the services provided (i.e., provisioning,
 162 regulation and cultural). The associated disservices—negative benefits from nature perceived by
 163 Human—will also be taken into account where it is studied.
 164

165 Indeed, the proposed mapping exercise differs from the 'traditional' ES literature, which often
 166 relies heavily on expert scientific knowledge and judgement for interpretation. This often results
 167 in a process that is rather subjective. By systematically mapping the existing literature, and by
 168 using recognised ES classification methods [19], our current strategy is expected to overcome
 169 previous biases and provide an objective and transparent overview.
 170

171 Thus, in order to highlight knowledge gaps on how changes in marine ecosystems influence
 172 marine ES, a systematic map is chosen following specific PECO components (Table 1). The main
 173 goal is to collate existing literature and configure a map on the resulting evidence base
 174 concerning our primary question: **what are the impacts of spatio-temporal dynamics of marine
 175 biodiversity such as changes in species abundance, and of ecosystems structure and
 176 functioning on the ecosystem services they provide?**

177 In addition, the systematic map will summarise the evidence base in terms of the following
 178 secondary questions:

- 179 - How do the spatio-temporal dynamics of marine biodiversity affect ecosystem disservices?
- 180 - How are marine ecosystem services and disservices linked to natural or anthropogenic drivers?

181

182 **Table 1:** The different components of the systematic map

	PECO elements	Definition(s)
Population	Marine biodiversity (ecosystems and species)	This will include all types of marine ecosystems and the species that they contain.
Exposure	Types of changes in marine biodiversity	All changes at all levels, from species to the ecosystems, functional and structural.
Comparator	Spatial difference - temporal difference	Spatial difference or difference in time
Outcomes	Marine ecosystem services (and disservices)	All qualitative or quantitative values of marine ecosystem services and disservices

183

184 **Methods**

185 This systematic map follows the methodological guidelines in accordance with the Collaboration
 186 for Environmental Evidence Guidelines and Standards for Evidence Synthesis [32] and conforms
 187 to the 'RepORting standards for Systematic Evidence Syntheses' (ROSES) for Systematic Map
 188 Protocols presented by Haddaway *et al.* [33] (See Supplementary Information 1 for the ROSES
 189 systematic map template of this study).

190 **Searching for articles**

191 **Search string**

192 The research sub-strings are composed in accordance to the key elements of the question
 193 representing the Population, the Exposure, and the Outcomes (Table 2). The search terms used
 194 for the sub-string on ES types includes different synonyms for each ES in order to be as inclusive
 195 as possible and comes from the different lists of marine ES based on Mongruel *et al.* [13]; Global
 196 Ocean Accounts Partnership [18] and Liqueste *et al.*[19]. The search terms for the sub-string on
 197 Exposure, which concerns changes in biodiversity (from species to marine ecosystems and
 198 ecosystems) are composed of key words synonymous to "change".
 199

200 The search string was tested and constructed in Web of Science Core collection in order to have
 201 the highest efficiency and the best comprehensiveness related to the test list (See more in
 202 Supplementary Information 2 for information of the building process of the search string).
 203

203

204 **Table 2: Full search string grouped by sub-strings in relation to our concept categories**

Sub-string	Search terms
Term 1 POPULATION Ecosystem	(marine OR coast* OR ocean OR sea OR littoral OR maritime) AND (species OR biodiversity OR ecosystem OR ecological)
Term 2 OUTCOMES Ecosystem service	("ecosystem service\$" OR "contribution to people" OR "ecosystem function\$" OR "ecosystem process" OR "landscape service\$" OR disservice\$ OR "provisioning service\$" OR ((provision OR production OR exploitation) AND (food OR fisher* OR macro-algae\$ OR molecules)) OR "biomass for nutrition" OR "biomass for materials" OR "genetic materials" OR "raw materials" OR "maintain* food webs" OR "life cycle maintenance and habitat protection" OR "habitat provision" OR "nursery function" OR "regulation service\$" OR "climate regulation" OR "carbon sequestration" OR "weather regulation" OR "atmospheric composition and conditions" OR "air quality regulation" OR "coastal protection" OR "water retention" OR "nutrient regulation" OR "nutrient cycling" OR "pathogen regulation" OR "pest and disease control" OR "mediation of waste" OR "mediation of mass" OR "cultural service\$" OR "intellectual interaction" OR "physical interaction" OR "experiential interaction\$" OR tourism OR recreation OR amenity OR aesthetic OR heritage OR symbolic OR "cognitive effect\$" OR "knowledge production" OR education)
Term 3 EXPOSURE Dynamic	(dynamic\$ OR impact\$ OR effect\$ OR variation\$ OR interaction\$ OR evolution OR change\$)

205 The asterisk (*) at the end of a search term/word is used to accept any variant of a base term.
 206 The dollar (\$) is used to accept single or no added characters; useful for acquiring plural and
 207 singular forms. Quotation marks were used to search the exact word order (or phrase).

208 Search language

209 Searches will be performed using English terms only. All relevant international literature
 210 published in English will be included in this systematic map. Indeed, this will include diverse
 211 bibliographic documents (e.g., books, journal articles, theses and technical reports).

212

213 **Table 3: Databases and search engines used**

Platform	Databases and search engines	Years	Platform or Provider
Scopus	Scopus	1788–2020	Elsevier
Web of Science Core Collection	Arts & Humanities Citation Index	1975 -present	Clarivate Analytics
	Conference Proceedings Citation Index: - Science	1998-present	
	- Social Science & Humanities	1998-present	
	Current Chemical Reactions	1985-present	
	Emerging Sources Citation Index	2015-present	
	Index Chemicus	1993-present	
Science Citation Index Expanded	1900-present		
Social Sciences Citation Index	1956-present		
Google scholar	Google scholar	N/A	Google

214

215 Bibliographic databases

216 The 3 sub-strings of the search equation will be combined with “AND” and searched in title,
 217 abstract and keywords of the Scopus and WOS databases using the search tags “TITLE-ABS-KEY”
 218 and “TS”, respectively. In Web of science core collection, we will use exact search mode. All
 219 databases will be accessed with the subscription of the CNRS (Table 3).

220 Web-based search engines

221 Google Scholar, with the aid of the software Publish and Perish [34], will be used to retrieve
 222 scientific and grey literature (Table 3). Indeed, Google scholar’s use of Boolean characters differs
 223 from WOS and Scopus and is limited in terms of number of characters, and thus search terms [35].
 224 Therefore, we adapted the search string to correspond to what the review team deemed as the
 225 most important keywords (Table 4) and searched in the section “keywords” which searches in the
 226 title, abstract, and body text. We will export the first 300 search hits, in line with
 227 recommendations by Haddaway *et al.* [35].

228

229 **Table 4: Search strings and Search hits**

230

	Name	Section of search	Search string	Search hits	Date Search
LITERATURE DATABASES	Web of science	TS	-	17329	20/07/2021
	Scopus	TITLE-ABS-KEY	-	24051	20/07/2021

ONLINE SEARCH ENGINE	Google scholar	keywords	(marine OR coastal OR ocean) AND (species OR biodiversity OR ecosystem) AND "ecosystem services" AND change	300	22/07/2021
ORGANISATIONAL WEBSITES	FAO	language: "English"	fishery	50	27/08/2021
	UNESCO	Filter: language: "English" - source: "UNESCO" - AuthoCorporate-en-s: "Intergovernmental Oceanographic Commission" - nature of content: "guide" AND "manuals and handbooks"	marine ecosystem service	50	19/08/2021
	UNEP	Filters: "Reports and publications" AND "Publication" AND "Report", "Ecosystems and biodiversity" AND "oceans and seas"	marine ecosystem service	50	19/08/2021
	US NOAA		ecosystem service	15	19/08/2021
	EEA		marine ecosystem service	7	19/08/2021
	IUCN		ecosystem service	32	27/08/2021

231 Organisational websites

232 The following specialist organisations will be searched in order to collect reports with primary
233 data related to our question.

234 (1) Intergovernmental agencies under the aegis of the UN

- 235 - Food and Agriculture Organization of the United Nations (FAO)
- 236 - United Nations Educational, Scientific and Cultural Organization (UNESCO)
- 237 - United Nations Environment Programme (UNEP)

238 (2) National or supra-national structures:

- 239 - US National Oceanic and Atmospheric Administration (NOAA)
- 240 - European Environment Agency (EEA)

241 (3) Non-governmental organization and international associations:

- 242 - International Union for Conservation of Nature (IUCN)

243

244 For each organisation website, the search string is adapted with specific keywords with manual-
245 systematic hand-searches and vary between the websites (Table 4). The main keywords used will
246 be « marine ecosystem services » which contains the keywords of the population and the
247 outcomes. Adaptation of the keywords used depends on the main topic of the organisational
248 websites. For example, as the NOAA focuses on marine ecosystems, the search string will only be
249 « ecosystem services ». For the FAO, the main keywords did not lead to any results, so we will
250 focus on one ecosystem service : « fishery ». Again, the main keywords did not lead to any results
251 in the IUCN publication websites, so we will focus only on « ecosystem service ». Other websites
252 were tested such as the websites of the Intergovernmental Panel on Climate Change (IPCC) and of
253 the IPBES. Nevertheless, the main keywords of our search string did not lead to any results. These
254 Intergovernmental websites only proposed review reports and no records with primary results. A
255 maximum of 50 references will be considered in each organisational website.

256

257 Estimating comprehensiveness of the search

258 The search terms were tested in Web of Science Core Collection. The review team compiled a list

259 of 30 articles that we considered as important and relevant for our respected fields and the
260 research questions. These articles are listed in Supplementary Information 3. Search terms were
261 modified and refined several times until the benchmark publications were retrieved. Indeed,
262 words related to the population, the outcomes and the exposure were progressively added as
263 described in Supplementary Information 3. Concerning Web of Science Core Collection, 25 out
264 of the 30 articles in our test list were retrieved with the search terms while 3 out of the 30
265 articles were not found at all in Web of Science Core Collection. With all the results extracted
266 (Web of Science Core Collection, Scopus and Google Scholar) 29 out of the 30 articles in our test
267 list were retrieved, equating to a 96.7% comprehensiveness (Supplementary Information 3). The
268 only article we did not retrieve was Roessig et al. (2004). We tried different search string,
269 nevertheless the numbers of documents found with other search string retrieving Roessig et al
270 (2004) was either increased or other documents in the test list were not found. The current search
271 string at 96.7% is the best compromise.
272

273 **Organisation of search hits**

274 Once the extraction of records from each database and website is completed, we will first
275 reassemble all bibliographic information from all the different databases in one file using Excel
276 software and Mendeley. This will allow us to collate all records retrieved from each database.
277 Then we will remove clear and partial duplicates based on similar DOI and similar titles.
278

279 ***Article screening and study inclusion criteria***

280 **Screening strategy**

281 In order to select the relevant literature to be analysed, a three-stage filtering process will be
282 undertaken in accordance with pre-defined screening and study eligibility criteria. Firstly, title
283 screening will be performed followed by abstracts screening, then full-text screening. If we are
284 unable to retrieve/find the full-text of a record where its abstract was accepted during abstract
285 screening, then the article's full text will not be screened. The proportion of documents missing
286 relative to accepted records will be provided. The search for full texts will be undertaken for all
287 accepted abstracts with the use of journal subscriptions from the CNRS and the Sorbonne
288 University. If the articles cannot be found, request for texts may be made via ResearchGate
289 (www.researchgate.net) or the authors may be contacted through ResearchGate or directly by
290 email. Following a conservative approach, if articles are not clearly in the inclusion criteria or do
291 not clearly follow a reason for exclusion (details in the Eligibility criteria section), the articles will
292 be kept for screening at the next eligibility stage.

293 **Consistency checking**

294 To test the consistency of the screening process, a Cohen's Kappa test [36] will be performed
295 between two reviewers (C.S.C. and E.T.). Accordingly, 1000 titles, 10% of the abstracts selected,
296 then 10% of retained full texts will be pre-screened by the two reviewers separately to check for

297 consistency in the interpretation of eligibility criteria. Due to resource limitations and the
 298 considerable number of records within all databases used (more than 40 000 in total - see Table
 299 4), it will not be possible to do the Kappa test on 10% of the titles. If the Kappa score is less than
 300 0.6, (which would mean a lack of consistency), the sources of disagreement will be analysed and
 301 discussed in order to resolve the reasons for disagreement. Another set of articles will then be
 302 screened and the Kappa scores re-calculated. This will be repeated until statistical agreement is
 303 reached *i.e.* the Kappa score is greater than 0.6 [37]. After which, all (if any) remaining
 304 disagreements will be discussed before beginning the full screening process.
 305

306 Eligibility criteria

307 The selection of records will depend on the inclusion and exclusion criteria presented in Table 5.
 308 The inclusion/exclusion decisions at each screening stage will be documented. A list of records
 309 will be provided with reasons for exclusion during the full-text (see Supplementary Information 4).
 310 Concerning the title screening, only articles with a clear mention of “marine ecosystems” and
 311 “ecosystem services” with the wording of ES or ES-related concepts directly mentioning an ES will
 312 be accepted (see list Liqueste *et al.* [19], or Pr eat [17] for ES list of marine ecosystems). In the
 313 abstract screening process, we will consider in addition to the previous criteria, the Exposure and
 314 Comparator. If an article respects the inclusion criteria of population and outcome but not of
 315 exposure – (*i.e.*, article on marine ecosystem and ES but without consideration of spatial or
 316 temporal difference), the article will be excluded. As we are looking for ES values, we will not
 317 consider documents only focusing on methods or on policy analysis. The full-text screening will
 318 consider the previous criteria and will also consider a new criteria related to the outcomes with
 319 the need to contain ES values.

320 Each screening stage will be undertaken with a conservative approach in respect to our
 321 selection criteria. If qualifying information is unclear or unknown then records in question will be
 322 passed to the next eligible screening stage.
 323

324 **Table 5: Eligibility criteria**

Criteria	Screening Steps	Inclusion criteria	Exclusion criteria
<i>Population</i>	Title	titles on any marine biodiversity, marine species, habitats and ecosystems	OUT: any title referring to ecosystem services provided by terrestrial and/or fresh water ecosystems.
<i>Outcomes</i>	Title	titles on any marine ecosystem service (as well as related terms of ES like “nature contributions to people” and all the relevant terms in the search string) no matter the types of values. titles on ecosystem service of food supply in terms of indicators of stock or population size of commercial species.	OUT: titles that address commercial species criteria with indicators other than the stock or the population size of the species. .
<i>Exposure</i>	Abstract	abstracts have to present a change (spatial or temporal change) in marine biodiversity, marine species, habitats and ecosystems or in ecosystem services	OUT: abstracts presenting an assessment - a one-time state - of the population or of the outcomes.
<i>Comparator</i>	Abstract	abstracts presenting temporal and spatial differences.	OUT: abstracts only assessing ES.
<i>Temporal period</i>	Abstract	abstract analysing data covering period at least part of the Twentieth century and/or the twenty-first century	OUT: full-texts analysing data covering period ended before 1900 (e.g., Palaeoecology analysis).

<i>Outcomes</i>	Full-text	full-texts have to contain qualitative or quantitative values of marine ecosystem services and disservices	OUT: full-texts without qualitative or quantitative values of marine ecosystem services and disservices
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325

326 **Data coding strategy**

327 A thorough metadata extraction for the map will be performed by the same two members of the
328 mapping team. The metadata form will be tested on 20 articles in order to test its applicability.
329 Each selected article will be double coded. If, due to resource limitations, true double coding is
330 not possible, an *a posteriori* cross-check will be carried out and potential disagreements will be
331 discussed until a consensus is reached. Any missing information will be highlighted with an
332 'unknown'. For each retained article after the screening process, the following metadata will be
333 extracted and coded (Supplementary Information 4):

334

335 *Bibliographic information*

336 Authors, Article Title, Keywords, Journal, Abstract, Affiliation first author, Country affiliation, DOI,
337 Type of document (peer-reviewed article, book, book chapter, conference object, PhD thesis,
338 technical report, or other), Sources of funding, Year of publication

339

340 *Information to be coded*

341 All items which will be coded in the selected articles are presented in Table 6. Each option of each
342 item will be coded « yes » or « no ». If several items are present options as well as a free space
343 for the text present in the article.

344 For the services classification, we used an adaptation of Pr at [17] and leave the option to right
345 the name of the ES if it is not in the list of ES proposed.

346

347 *Complementary information to be coded*

348 In addition, on the bibliographic information and information related to the PECO elements,
349 information on the type of documents, the type of bibliographic content and if it is primary data
350 made in the document will be coded. Also, we will code information about the types of pressures
351 and management in order to know more about the origin of the change of marine ecosystems.

352

353 **Table 6: Meta-data to be extracted from the selected articles**

354

Item	Description	References
Population		
<i>Ecosystem type</i>	A1 - Intertidal rock and other hard substrates; A2 - Intertidal sediment; A3 - Subtidal rock and other hard substrates; A4 - Circalittoral rock and other hard substrates; A5 - Subtidal sediment; A6 - Deep-sea habitats; A7 - Pelagic habitats; A8 - Ice-associated marine habitats (sub-categories of EUNIS would be classified in its higher categories) + free space for others ecosystem types	Classification EUNIS Niveau 2 - European Commission
<i>Specific ecosystem</i>	Tidal marsh; Seagrass; Coral reefs; Mangroves; Kelp forests + free space for others specific ecosystem types	
<i>Level of biological organisation</i>	Species; population; community	Lausch <i>et al.</i> [38]; Bruford <i>et al.</i> [39]
<i>Characteristics of biodiversity</i>	Taxonomic; structural; functional	
Outcomes		
<i>Number of ES per</i>	Number of ES for the following ES categories: Provisioning services; Regulating services; Cultural services; Disservices	

<i>Categories</i>		
<i>ES</i>	Food provision; Raw materials; Genetic materials; Water provision; Water purification; Air quality regulation; Coastal protection; Climate regulation; Weather regulation; Nutrients cycling; Habitat provision; Pest and disease control; Symbolic and aesthetic values; Recreation and tourism; Cognitive effects; Educational opportunities (related ES terms would be considered in each ES type) <i>+ free space for other ES</i>	Préat [17]
<i>EDS</i>	<i>Free space to record all EDS assessed (e.g. release of greenhouse gases, wild animal attacks)</i>	
<i>ES-EDS components</i>	Potential; capacity; use/flow; demand; preferences; desires	
<i>ES-EDS values</i>	Economic; social; biophysical	
<i>Exposure / Comparator</i>		
<i>Scale of study area</i>	L: local; N-: subnational; N: national; N+: supranational; C: continental; G: global; N: no case study	Liquete <i>et al.</i> [19]
<i>Location of analysis</i>	List of country names; no application; global	
<i>Specific location</i>	<i>Free space</i>	
<i>Temporal scale of analysis</i>	Interval (time elapsed between successive temporal replicates): <i>free space</i> Duration (time elapsed between first and last temporal replicates): <i>free space</i>	
<i>Time frame</i>	Past; present; future	
<i>Spatial scale of analysis</i>	<i>Free space (e.g., « between a MPA and a no-MPA area»)</i>	
<i>Type of data</i>	Observation; prediction	
<i>Complementary information</i>		
<i>Bibliographic document type</i>	Journal article; book; book chapter; conference object; PhD thesis; technical documentation	Following Langridge <i>et al.</i> , [40]
<i>Bibliographic content</i>	Study; review; modelling; meta-analysis; other	
<i>Primary data</i>	Yes; No	
<i>Pressure type</i>	Land/sea use change; Direct exploitation; Climate change; Pollution; Invasive alien species <i>+ free space for other pressures</i>	IPBES [41]
<i>Management type</i>	Status of protection; conservation; specific management <i>+ free space for other type of management</i>	

355

356 **Study validity assessment**

357 The validity of evidence will not be assessed within this systematic map but we will code study
358 design elements that may provide some preliminary indication of internal validity. Thus, two
359 additional types of information will be coded. The 'bibliographic content' i.e., study, review,
360 modelling, meta-analysis. In addition, the 'type of data' will be reported with an « yes » if the
361 record produces primary data (Table 6).

362

363 **Study Mapping and Presentation**

364 The results will be synthesized using a narrative approach, graphs and summary tables to
365 highlight the state of the evidence related to our primary and secondary questions. We will first
366 depict the increase in the number of papers addressing the links between the changes of marine
367 biodiversity and ecosystems and their provision of ES.

368

369 Summary tables and/or graphs will be created to identify the types of ecosystems, the
370 biodiversity metrics, the ES category, and the temporal and spatial scale of each study. The types
371 of ecosystems will be determined following the EUNIS (European Union Nature Information
372 System) habitat classification which is a hierarchical comprehensive pan-European system for
373 habitat classification. According to this typology at level 2, eight main categories of marine
374 habitats will be considered: one category for pelagic habitats, one category for ice-associated

375 marine habitats and 6 categories for benthic habitats depending on depth and substrate type.
376 Although this typology has been developed for European waters, its application to the world's
377 oceans does not raise any major concerns. This list of eight habitats will be completed by specific
378 charismatic habitats such as tidal marshes or seagrass meadows. To describe which facet of
379 marine biodiversity is monitored to depict changes in marine populations or ecosystems, we will
380 consider 3 classes of Essential Biodiversity Variables [42]: species populations, community
381 composition, and ecosystem structure. For each class which corresponds to 3 different levels of
382 biological organization (i.e., population, community, ecosystem), three essential characteristics of
383 diversity will be used: (i) the taxonomic diversity, which is the number of different biotic entities;
384 (ii) the structural biodiversity, which is the distribution of biological entities; and (iii) the
385 functional diversity, which is the diversity of functions or functional traits [38]. The ES will be
386 classified following the classification framework of Mongruel *et al.* [13] adapted from Liqueste *et*
387 *al.* [19] and Barbier [22]. This classification relies on the CICES which includes 3 groups of ES
388 subdivided into different categories: provisioning services, regulation services and cultural
389 services. In comparison with the framework proposed by the Millennium Ecosystem Assessment
390 [43], this classification framework excludes the supporting services. As there is no classification of
391 disservices commonly used the disservices would be reported as written in the records and then
392 an analysis of the main concept or words used would be made.

393
394 In addition, to depict the source of impact on marine biodiversity and the provision of ES, we will
395 consider the 5 main direct drivers of change as identified by the IPBES [41]: (i) sea use change
396 leading to habitat degradation, (ii) exploitation of marine resources, (iii) climate change, (iv)
397 pollution, and (v) introduction of non-indigenous species. As management measures can
398 counteract the negative effects of human stressors on marine biodiversity, we will also take into
399 account the implementation of marine protected areas as a human intervention that may
400 influence the ecosystem health and the provision of marine ES.

401 Heat maps will be used to identify knowledge clusters and knowledge gaps. A particular
402 attention will be given to the links between habitat categories and ES types, and between
403 biodiversity classes and levels of biological organization and ES. The results of the map will
404 contribute to identifying the variability of the state of knowledge according to the ecosystems
405 and their distance from the coast and the diversity of interactions between marine biodiversity
406 and ecosystem services. We hypothesize a decrease in knowledge in offshore waters and deep-
407 sea habitats, a focus on the most emblematic or charismatic habitats as opposed to ordinary
408 nature, while offshore habitats will be associated with global and common goods issues such as
409 climate change.

410 The results will be used to identify key meta-data variables for a meta-analysis planned
411 after the map review.

412

413 **Declarations**

- 414 • **Ethics approval and consent to participate**

415 Not applicable

416 • **Consent for publication**

417 Not applicable

418 • **Availability of data and materials**

419 Data sharing is not applicable to the systematic map protocol in that no datasets were generated
420 for this article. Datasets produced by the systematic map will be shared in open access.

421 • **Competing interests**

422 Authors declare having no competing interests.

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426 • **Authors' contributions**

427 All authors contributed to the conception and the design of the protocol. CSC was the major
428 contributor in writing the manuscript. ET contributed in writing the manuscript. JL contributed
429 more specifically to all elements of the methods and CEE guidelines. JC and RM provided
430 comments on the manuscript. All authors read and approved the final manuscript.

431 • **Authors' information**

432 ¹ Sorbonne Université, CNRS, Station Biologique de Roscoff, UMR7144, Adaptation et Diversité en
433 Milieu Marin, Place Georges Teissier, F-29680 Roscoff, France

434 ² Fondation pour la Recherche sur la Biodiversité, Centre de Synthèse et d'Analyse sur la Biodiversité
435 (FRB-Cesab), 5 rue de l'école de médecine 34000 Montpellier, France

436 ³ National Center for Scientific Research, PSL Université Paris, CRIOBE, CNRS-EPHE-UPVD, Maison des
437 Océans, 195 rue Saint-Jacques, 75005 Paris, France

438 ⁴ Ifremer, Univ Brest, CNRS, UMR 6308, AMURE, Unité d'Economie Maritime, IUEM, F-29280, Plouzane,
439 France

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444

445

446 Supplementary information

447

448 • **Supplementary Information 1: Excel files ROSES protocol filed**

449

450 • **Supplementary Information 2: Search string evolution and estimating**
451 **comprehensiveness of the search**

452

453

454 • **Supplementary Information 3 : Test list of articles for assessing comprehensiveness**

455

456

457 • **Supplementary Information 4: Codebook outlining the meta-data extraction**
458 **methods**

459

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