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Threats to marine biodiversity in European protected areas

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2 Threats to marine biodiversity in the European Seas protected system
3 Threats to marine biodiversity in the European Seas marine protected areas
4

5 **Short Title:** Threats to marine biodiversity
6

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29

30

31 **Abstract:**

32 Marine protected areas (MPAs) represent the main tool towards halting the loss of marine
33 biodiversity. However, there is increasing evidence on their limited capacity to eliminate or

34 even reduce some threats even within their boundaries. Here, we analyzed a European wide
35 database comprising 31579 threats recorded in 2230 MPAs . Focusing explicitly on threats
36 related to marine species and habitats, we found that fishing and outdoor activities were the
37 most widespread within MPA boundaries, although some spatial heterogeneity in the threats
38 distribution was evidenced. Our results clearly demonstrate the need to reconsider current
39 management plans, and measures within and beyond MPAs, while any such planning should
40 avoid a centralized decision processes, and thus properly account for the heterogeneity that is
41 inherent in conservation networks.

42

43 INTRODUCTION

44 Marine protected areas (MPAs) represent a core strategy for conservation of marine
45 biodiversity, and, when properly planned and well managed, they reduce habitat loss and are
46 effective in maintaining species populations (Claudet et al. 2008; Fenberg et al. 2012).
47 Nevertheless, global studies highlight that many existing MPAs lack efficiency, failing to
48 both achieve their conservation objectives (**Leverington et al. 2010; Edgar et al. 2014; Gill
49 et al. 2017**). and secure the flow of ecosystem services (**Allison et al., 1998; Agardy et al.,
50 2011**). Systematic spatial prioritization of conservation needs together with effective
51 management and mitigation actions both within and beyond MPAs is required to overcome
52 shortcomings and maximize conservation efficiency (**Margules and Pressey, 2000**). This
53 however requires a sound database on spatial-temporal patterns of biodiversity measures and
54 risks in relation to current and future threats (**Halpern et al. 2008; Levin et al. 2014**). Still,
55 scarcity of information about the presence, extent and magnitude of the threats that
56 biodiversity faces may lead to biased and ineffective management decisions (**Coll et al.,
57 2012; Schulze et al., 2018**).

58 Acknowledging the need to develop comprehensive risk assessments for the marine
59 environment, a common practice is to assemble various layers of information on the most
60 acknowledged threats (**Micheli et al. 2013**). Such data are often accumulated through remote
61 sensing, satellite imaging or extensive field surveys (**Depellegrin et al., 2017; Ouellette and
62 Getinet, 2016**). These approaches are often guided by the application of future conservation
63 priorities at broad spatial areas, which bears the risk of failing to track threats either operating
64 at finer scales (e.g. recreational fishing) or being difficult to extrapolate to broad spatial maps
65 (e.g. contamination). As an alternative of improving our understating on the actual threats that
66 are present in the marine realm, questionnaire surveys and expert contributions have also been
67 placed in the front line of research (**Halpern et al., 2006; Donlan et al. 2010**). Such methods
68 could offer critical insights on the identification of basic threats and their ranking based on the
69 vulnerability of marine biodiversity, and thus could be used for directing conservation
70 investments (**Ban and Klein, 2009; Klein et al. 2017**) and for recognizing the scales at which
71 management actions should be taken (**Stelzenmüller et al., 2013**). Still, biases due to
72 background (i.e. education, scientific, professional, regional) and actual interest of responders
73 (e.g. expertise and interest in a given ecosystem type or species) could affect the generated
74 outputs (**Spruijt et al., 2014; Rudd, 2015; Gissi et al. 2017**).

75 Site-specific data on threats might exist for some MPAs, often used towards directing
76 management actions and understanding conservation conflicts and local threats for
77 biodiversity (**Zupan et al. 2018a**). At the same time, key management directives, are often

78 centralized, with decisions being taken at higher administrative levels largely ignoring local
79 knowledge, conditions and needs (Helvey, 2004; Christie and White, 2007). Under this
80 context, the identification of main threats and the assessment of patterns in their spatial
81 distribution could inform more effective management by directing fewer, focused, and
82 realistic measures (Knight et al., 2013).

83 Here, we focus on three key issues related to the diversity and distribution of threats within
84 MPAs: (1) We provide an overview of threats identified in 2230 MPAs located in the
85 European Seas, (2) investigate regional patterns among the reported threats, and (3) identify
86 groups of threats appealing the most for immediate management actions.

87

88 **METHODS**

89 *Datasets for the European conservation network*

90 The Natura2000 conservation network of the European Union (EU) represents the largest
91 network of protected areas in the world, which was established on the basis of two EU
92 legislative instruments, the Habitats and Birds Directives. The network currently consists of
93 more than 27,700 sites. These sites have been selected according to the occurrence of habitat
94 types and species of community interest for the EU (Annexes I and II of Habitats and Annex I
95 of Birds Directives).

96 For the purpose of this study, data on the spatial distribution of the sites of the Natura2000
97 network were derived from the database compiled and made available by the European
98 Environment Agency (EEA; <http://www.eea.europa.eu/data-and-maps>). As no *a priori*
99 distinction is made between marine, coastal or terrestrial Natura2000 sites, we selected sites
100 that host at least one marine habitat listed in the Habitats Directive. Following this process,
101 we selected a total of 2230 sites of the Natura2000 network.

102 To support and direct conservation and management initiatives, each EU Member State has
103 the obligation to compile related data for each Natura2000 site. These data are gathered by
104 experts following standardized protocols (EU 2011), and submitted within Standard Data
105 Forms, that actually represent the official documentation for justifying the importance of each
106 site. Once validated, this information becomes publicly available through the ‘Natura2000
107 Database’ (EEA; <http://www.eea.europa.eu/data-and-maps>). A key piece of information
108 archived in this database refers to a list of processes that could directly or indirectly affect
109 biodiversity. These records are listed under a section of the database named ‘*activities, threats*
110 *and pressures*’, which offers a classification scheme according to a predetermined list of 397
111 different categories (Supplementary Table 1). No distinction is made between natural or
112 anthropogenic processes. For each record of any process, the experts have to report its
113 perceived impact (i.e. positive or negative) on the conservation and management of the site
114 (EU 2011). Here, we maintained only the records that were assigned as having negative
115 impacts; we hereafter collectively refer to these records as *threats*.

116

117 *Threats classification*

118 In the Natura 2000 database the classification of threats follows a hierarchical structure with
119 four levels of information, starting from a broad description of 11 types (e.g. pollution). At
120 the second hierarchical level, each group is divided into more informative categories (e.g.
121 pollution to surface waters). Some of these threats are further divided into an additional level
122 providing a more detailed description of the reported activity (e.g. pollution to surface waters
123 by industrial plants). For a few of these sub-categories, a further lower hierarchal level exists.

124 With a few exceptions (e.g. marine water pollution, fishing and harvesting aquatic resources),
125 the majority of threat types found in the Natura2000 database refer to processes originating in
126 the terrestrial environment. At a site level, no reference is made if a reported threat is having a
127 potential effect on the marine or terrestrial part of the site. Therefore, in order to focus our
128 analyses on those threats that are likely to cause harm to marine species or habitats, we
129 selected only those types that impact marine biodiversity. This was achieved by analyzing
130 information from national reports on the conservation status of protected marine habitats and
131 species. These reports are compiled by each Member State every six years, as an obligation to
132 the Article 17 of the Habitats directive, and include aggregated information on threats for
133 each of the protected species and habitats at a national level (**Tsiripidis et al., 2018**). After
134 filtering out non-marine threats, we ended up with a list of 5094 reported threats for marine
135 biodiversity (see **Supplementary Methods**). These reported threats were classified into 71
136 different threats types belonging to the second hierarchical level of the threat classification.
137 To exclude threat types that explicitly reflected only extreme and rare conditions (e.g.
138 restructuring agricultural land holding was reported in only one case), we removed rare
139 threats that accounted for less than 1% of the records. This resulted in a selection of 25 threat
140 types of the second hierarchical level (**Fig. 1**).

141 At a next step, we analyzed the site-specific Standard Data Forms of the 2230 Natura2000
142 protected areas that included a marine component, extracting all records of the 25 identified
143 threats. A total of 31579 site-specific records at the finest hierarchical level were identified.
144 Here, we performed our analyses on threats at the second hierarchical level, since experts
145 recorded more than 50% of the records at this level. By aggregating records of lowest levels
146 to the second hierarchical level, we ended up to 8861 distinct site-specific records of threats.

147 For a number of Natura2000 sites with a marine component, no record on marine related
148 threats, or even of any type of threat, were available. In an effort to investigate for the
149 potential factors that might have driven this gap on recording, we employed a Kruskal Wallis
150 test. We examined whether any difference among sites occurred in respect to a) their surface,
151 b) the relative percentage of marine surface covered. To estimate the percentage of marine
152 surface covered, we overlaid the spatial data on the Natura2000 sites against the digital
153 terrestrial terrain of Europe; both spatial datasets were derived by EEA
154 (<https://www.eea.europa.eu/data-and-maps/>).

155 *Spatial patterns of threats*

156 To explore the spatial patterns of the diversity of threats across European waters we assigned
157 each site to one of four marine regions (i.e. the Baltic Sea, the north-eastern Atlantic Ocean,
158 the Mediterranean Sea and the Black Sea) and used the Spearman rank coefficient to detect
159 any pairwise difference in the rank of the 25 marine related threats.

160 Analysis of similarities (ANOSIM; **Clarke 1993**) was used to compare threat composition
161 within and among regions. The level of similarity regarding reported threats was calculated
162 by using the Bray-Curtis similarity index. The degree of discrimination was determined based
163 on a test statistic (i.e. global R) which varies between -1 and 1, and is higher when records
164 within groups of sites (i.e. marine regions) are more similar than those from different groups.
165 In cases with many records, R could be significantly different from zero but attaining very
166 small values (**Clarke and Warwick, 2001**); the level of significance was determined after
167 999 permutations. To further delineate the contribution of individual threats to overall
168 dissimilarity of the four marine regions, we applied SIMPER analyses (**Clarke 1993**).
169 Analyses were conducted using the *vegan* package in R (**Oksanen et al., 2011**).

170

171 **RESULTS**

172 *Threats in MPAs of the European Union*

173 For about one fourth (24%, n =538) of the 2230 European Natura2000 sites that host marine
174 habitats, no record on threats related to marine biodiversity was reported (**Fig. 2**). Actually,
175 for 17% (n = 383) of the total sites, no record of any type of threat was reported, while for 7%
176 of these sites (n = 155) there were records only for threats to terrestrial biodiversity. The total
177 surface and the relative marine surface covered did not statistically differ between the sites for
178 which records on threats were or were not available (in both cases $p>0.05$).

179 The most frequently recorded threat was ‘outdoor sports and leisure activities, recreational
180 activities’, reported at 57% of the sites (n = 970) for which marine threats were reported. The
181 second and third most frequent threats were ‘fishing and harvesting aquatic resources’ and
182 ‘human induced changes in hydraulic conditions’ reported in 55% (n = 924) and 40% (n =
183 679) respectively of the sites for which marine threats were reported.

184 *Spatial patterns of threats*

185 Correlation analyses demonstrated significant positive associations between the ranking of the
186 different threats in the four marine regions (r_s ranged from 0.752 to 0.875, in all cases
187 $P<0.01$). Some threats (e.g. fishing, outdoor activities, urbanization) were highly ranked in all
188 regions but their relative importance varied (**Fig. 1, 2**). Threats listed under the category of
189 ‘fishing and harvesting of aquatic resources’ were most frequently reported in the marine
190 Natura2000 sites located in Atlantic and the Black Sea, while this group was ranked second in
191 Mediterranean sites and third in Baltic Sea sites. Similarly, ‘outdoor sports and leisure
192 activities, recreational activities’ was the most frequent threat in the Mediterranean and the
193 Baltic Sea, but ranked second in Atlantic sites and third in Black Sea sites. The group
194 enclosing threats related to ‘discharges’ was the second and fourth more frequently reported
195 in the Black Sea and Mediterranean MPAs respectively, but it was ranked 14th and 15th in
196 the Atlantic and Baltic Sea respectively.

197 Pollution-related threats, i.e. threats listed as ‘pollution to surface waters’ and ‘marine water
198 pollution’ were recorded relatively often (ranked 4th and 5th respectively) in the Baltic Sea
199 but none of them was listed within the 7 more frequently reported groups of threats in the
200 other regions. The threat of ‘biological invasions’ was frequently reported in the Atlantic
201 (41% of sites with records on marine threats) but in only 28%, 26% and 21% of the sites in

202 the Mediterranean, Black, and Baltic Sea, respectively. Threats that are related to climate
203 change, and have been reported to have a potential impact upon biotic conditions, were only
204 listed within the last 4 reported threats at all regions. Similarly, ‘climate change driven
205 alteration of abiotic conditions’ was the least reported threat in the Baltic Sea, while also
206 ranked very low in the other regions. These examples are indicative of the significant
207 differences detected among the four marine regions (ANOSIM $R=0.08$; $p<0.001$), despite that
208 the overall pattern in the frequency of threats was similar among regions for most of the
209 threats (**Figs 1 & 2**).

210 ‘Discharges’ was recognized as the main driver of differences between the Black Sea and the
211 other three marine regions (contributing from 8.0% to 10.5%). The distribution of ‘outdoor
212 recreational activities’ contributed the most to group similarity between Mediterranean and
213 the Atlantic or the Baltic Sea (8.0% and 9.3% respectively), while ‘fishing and harvesting of
214 aquatic resources’ was the threat that mainly reflected differences between the Atlantic and
215 Baltic Sea. Other threats that were recognized to contribute the most to regional differences
216 were ‘urbanization, human intrusions and disturbances’, ‘pollution to surface waters’, and
217 ‘marine infrastructure (i.e. shipping lanes, ports)’.

218

219 **DISCUSSION**

220 The network of Natura2000 marine sites in European seas is subjected to a suit of diverse
221 threats. Importantly, the most common threats can be directly controlled through targeted
222 management actions at the scale of the protected areas, i.e. in their management plans,
223 because they mainly concern human activities of local impact (e.g. fishing, recreational
224 activities, intrusions and disturbances) (but see Zupan et al. 2018a).

225 Although the assessment, reporting and prioritization of threats are key steps for the
226 establishment of efficient conservation measures, we show that many sites of the European
227 conservation network lack records on any marine related threats. Recently, concerns on
228 irregular and insufficient reporting were raised for the Mediterranean sites of the Natura2000
229 network, regarding the threat of biological invasions (**Mazaris and Katsanevakis, 2018**).
230 Such information gaps accompany the limited number of Natura2000 sites with an
231 implemented management plan (**Mazaris et al., 2017**), but also the lack of systematic
232 procedures for the network site selection (**Giakoumi et al., 2012**). Even though there is now
233 a scientific consensus that fully protected areas could maximize conservation outputs
234 (**Fraschetti et al., 2018**), Natura2000 sites are not meant to be exclusively fully protected
235 areas but rather areas where human activities are regulated and biological resources are used
236 sustainably, using the range partially protected area classes (Horta e Costa et al. 2016).
237 However, care should be given when assigning protection levels in the system of Natura2000
238 sites as not all classes of partially protected areas can confer ecological benefits and some
239 moderately protected areas, where some fishing activities are still allowed can be effective
240 only when adjacent to a fully protected area (Zupan et al. 2018b)

241 Targeted management actions for threat mitigation should be prioritized regionally (**Pascual**
242 **et al., 2016; Gissi et al. 2018**). For example, while fishing remains the largest threat and a
243 huge conservation challenge, the fishing types threatening marine biodiversity vary between
244 regions and the respective socio-cultural context. When looking at the more detailed

245 classification of threats in the Natura2000 dataset, professional active fishing (i.e. benthic,
246 demersal or pelagic trawling, demersal and purse seining, benthic dredging) is identified as
247 the most common fishing-related threat in the Atlantic MPAs, while leisure fishing (e.g. bait
248 digging, pole and spear fishing) dominates in MPAs in the other three regions. Although it is
249 well recognized that the design and establishment of conservation networks should consider a
250 coarser scale to ensure representativity, connectivity and replication of ecological conditions
251 (**Rees et al. 2018**), the importance of a given threat, its perceived and actual impact and the
252 potential solutions vary across spatial and administrative scales (**Stelzenmüller et al. 2010**).

253 Through multiple ecosystem services delivery, MPAs can attract tourism and recreation (e.g.
254 **Rodriguez et al. 2017**), but if not appropriately managed conceal a risk of impairing
255 conservation efficiency (Zupan et al. 2018b). Outdoor activities inside MPAs are often
256 proposed to raise awareness of citizens to conservation issues. Still, in partially protected
257 areas such activities may lead to unexpected impacts (**Refs**). If we further consider that MPAs
258 often attract masses of tourists (**Dimitriadis et al., 2018; Ref**), the pressures from such
259 activities is often higher in such partially protected areas compared to unprotected areas
260 (**Zupan et al. 2018a**). At the same time, given that outdoor and leisure activities often lead to
261 high economic benefits, restrictions upon such activities could raise obstacles in the
262 expansion, management, and acceptance of MPAs (**Ruiz-Frau et al. 2013, Refs**). Our results
263 showed for the first time that outdoor activities are among the most extensive threats in
264 European Natura2000 MPAs offering priorities for setting key management directions for this
265 highly heterogeneous European conservation network. However, the large range of potential
266 impacts of these threats is often difficult to assess (**Refs**), and therefore their consideration in
267 systematic spatial planning and risk assessment remains challenging.. Acknowledging that
268 outdoor and recreation activities could also embed many benefits for conservation, with
269 regional agreements setting a pillar for sustainable development (e.g. the European Strategy
270 for the Adriatic and Ionian region), the tradeoffs between benefits and threats should be made
271 clear along the management process.

272 Climate change is often cited as a major threat for marine protected areas (**Bruno et al., 2018**)
273 but seems rather underestimated in the European conservation network. Plausible
274 explanations could be a gap between scientific evidence on climate change and the perception
275 at local scale, a gap already detected in MPAs outside EU (e.g. **Cvitanovic et al., 2014;**
276 **Hopkins et al. 2016**). For example, there is ample evidence that the Mediterranean Sea is
277 very sensitive to climate change, with mounting evidence on adverse effects reported
278 throughout the region (e.g., **Sara et al. 2014; Rilov 2016; Almpanidou et al., 2018**).
279 However, most scientific advice spans over less than a decade, thus a short time lag for
280 reporting on the Natura2000 threats. Also a possible explanation may refer to the lack of
281 available information on physical and biochemical data at temporal and spatial scales relevant
282 to organisms' biology and behavior, which could serve as a main obstacle in our
283 understanding on how ocean variability could affect biodiversity (**Bates et al., 2018**). Even in
284 the context of global changes such as increase in sea water temperature or ocean acidification,
285 management of local threats is a key for effective conservation. Global threats interact with
286 local threats and conditions, thus leading to cumulative effects on marine ecosystem
287 components (**Stelzenmüller et al., 2018; Coll et al. 2008**). Mitigating local threats is often
288 the only feasible course of action to reduce negative synergies with global threats. Still,
289 further efforts are needed to comprehensively monitor threats on marine biodiversity and
290 manage human impacts (**Mazaris and Katsanevakis, 2018; Refs**). With the need to attain

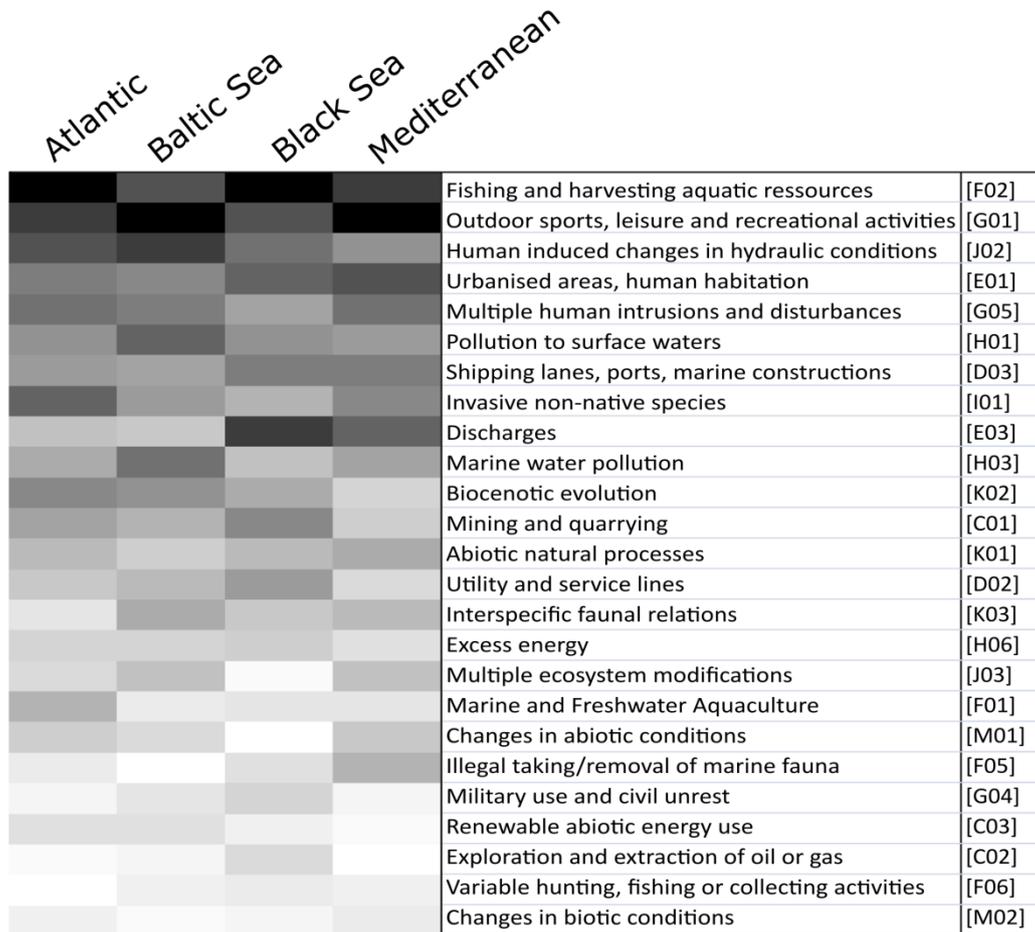
291 good environmental status in all marine areas, monitoring threats that would need other
292 regulatory measures beyond MPAs is also important. Still, the network of Natura2000 sites
293 could be used as a network to monitor both Essential Ocean Variables (Miloslavich et al.
294 2018) and marine human uses in wider regions (**Addison et al. 2018, Weatherdon et al.**
295 **2017**).

296 Threats to marine biodiversity are not only related to activities in the ocean but may originate
297 from land-based activities (**Tallis et al., 2008; Depellegrin et al. 2017**). For example,
298 pollution as the result of coastal or terrestrial inputs is widely recognized in European MPAs,
299 (**Refs**). Assessment frameworks should thus account for land based uses and land use changes
300 acknowledging land-sea interactions s. Still, in highly heterogeneous conservation networks
301 such as the Natura2000 where political, societal and economic factors are largely driving
302 criteria for prioritizing the site support (**Tsianou et al., 2013**) but also the type, intensity and
303 magnitude of threats (**Tsiafouli et al., 2014**), the centralization of prioritization actions might
304 be misleading.

305 Despite a remarkable expansion in the number of MPAs in European seas, it is clear that long
306 standing and well recognized threats such as fishing, recreational activities or pollution are
307 still persistent inside most MPAs. Of additional concern is the relatively high number of sites
308 (of the largest conservation network globally) that fail to provide information on the actual
309 threats present. Thus, our results put a spotlight on the need of standardized monitoring and
310 assessment approaches ensuring spatial coverage, consistency, and clarity. The banning of
311 highly impacting activities should gain more attention at the political level, in order to make
312 trade-offs explicit in conservation planning.

313

314 **Figure 1.** Ranking of 25 marine related types of threats reported at the sites of the European
 315 Natura2000 conservation network that host marine habitats of community interest, located
 316 within the four marine regions of the European seas. The ranking follows a grey gradient,
 317 with darker types of threats been more frequently identified.

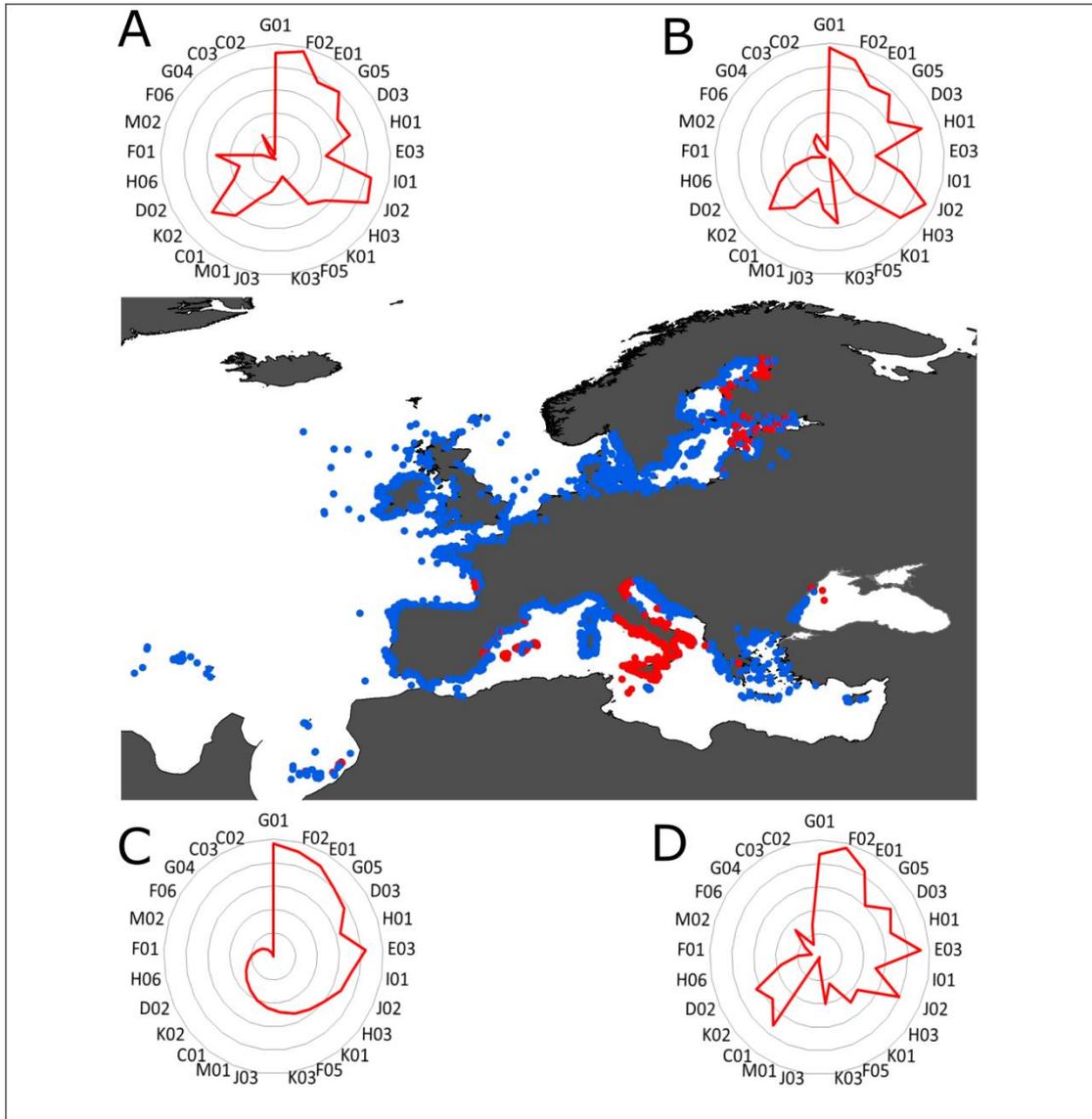


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321 **Figure 2.** The distribution of the Natura2000 marine sites. The centroid of each site is
 322 presented; sites for which no record on threats was reported are colored in red. In panels A to
 323 D, the relative ranking of the various threats in the Atlantic, the Baltic Sea, the Black sea and
 324 the Mediterranean, respectively, is depicted. The coding of threats if presented in Figure 1 and
 325 is in accordance to the classification provided by the European Environmental Agency.



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