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## **Mediterranean Temporary Lagoon: Proposal for a definition of this endangered habitat to improve its conservation**

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1 **Mediterranean Temporary Lagoon: proposal for a definition of this**  
2 **endangered habitat to improve its conservation**

3  
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## 37 **Abstract**

38

39 Coastal lagoons have been recognised as a priority habitat for conservation and have benefited  
40 from several conservation plans. Under the Mediterranean climate, some of these lagoons might  
41 dry out during summer due to drought events. We propose the term Mediterranean Temporary  
42 Lagoons (MTLs) for these ephemeral water bodies and discuss their definition and  
43 characteristics. This term emerged in France among its coastal zone managers, who now  
44 commonly use it for conservation purposes. It is used in both natural systems as well as most  
45 artificial salt ponds in abandoned saltworks.

46 In Europe, two directives have integrated lagoons as key targets to be preserved. Nonetheless,  
47 a certain discrepancy in the different definitions of lagoons has constrained joint actions.  
48 Indeed, while institutional definitions were originally derived from the scientific concept, their  
49 legislative and managerial meanings have been gradually modified and nowadays often differ  
50 from the original concept to create difficulties in the field. In addition, while it has been  
51 recommended to consider MTLs as a coastal lagoon habitat in the European Habitat Directive,  
52 its interpretation among EU member states is unsettled. Thus, clarifying lagoon habitats'  
53 terminology is required to ensure better management, monitoring and planning, and coordinate  
54 conservation actions.

55 We discuss the inclusion of MTLs in habitat 1150 by confronting scientific and institutional  
56 literature and propose a new framework to better delimitate lagoon habitat around the  
57 Mediterranean basin, integrating MTLs. MTLs represent a specific habitat that hosts a pool of  
58 stenoeious macrophytes of conservation interest like *Althenia filiformis*, *Riella helicophylla* or  
59 *Tolypella salina*.

60

61

62 **Keywords:** conservation, wetland, Habitat Directive, Water Framework Directive, salt pan,  
63 coastal lagoon

## 64 1. Introduction

65 The integration of habitat-based approaches within conservation planning has  
66 progressed over the last decades, as it is now widely accepted that the maintenance of  
67 ecologically suitable areas is the primary step to ensure the persistence of living communities  
68 (Bunce *et al.*, 2013; Brooks *et al.*, 2019; Mace, 2020). This is exemplified by the Habitats  
69 Directive that combines the species-based with the habitat-based approach, defining a list of  
70 231 habitats of high importance for nature conservation in Europe. Hence, member states are  
71 prompted to implement strategies to maintain these habitats' surface and ecological  
72 functionality and limit their exposure to human pressures (European Union, 1992).  
73 Nevertheless, different scientific concepts have been adopted to define habitats (Mitchell,  
74 2005), blurring its understanding among scientists. Habitats are based on human interpretation  
75 of the interplay between the local physical world (*i.e.* the biotope) and its associated living  
76 communities (*i.e.*, biocenosis). The conceptual delimitation of these entities induces issues to  
77 define its boundaries, as delimitations are arbitrary by essence (Hall *et al.*, 1997; Mitchell,  
78 2005). Therefore, this fuzziness can cause additional operational hindrances in the delimitation  
79 of study objects on the field (Mücher *et al.*, 2009).

80 In Europe, two directives define conservation objectives for the coastal lagoons, *i.e.*, the  
81 Habitats Directive (HD; European Union, 1992) and the Water Framework Directive (WFD;  
82 European Union, 2000); in many cases, the Birds Directive also applies. The WFD aims at  
83 "conserving all water bodies in a good ecological state" to improve the management of  
84 hydrologic resources (Acreman & Ferguson, 2010). The HD states that "habitat identified as  
85 conservation priorities needs to be conserved", with a particular focus on living communities  
86 (Bunce *et al.*, 2013; Valentini *et al.*, 2015). The European Union has identified coastal lagoons  
87 as highly important habitats through those directives, setting up targets for their conservation.  
88 The difference between the purpose of the two directives has led to two different definitions  
89 that, although they make sense within the scope of the two original directives, do not allow for  
90 uniformity in defining the "coastal lagoon" habitat. Such variability between definitions of the  
91 same ecological entity can create divergent interpretations in the field, resulting in different  
92 indicators being used to assess their ecological status, and eventually lead to contradictory  
93 conservation actions and impede joint efforts (Janauer *et al.*, 2015; Pérez-Ruzafa *et al.*, 2020).  
94 Thus, the entities' definition to be protected must be clarified and standardised to align

95 conservation actions and ensure the persistence of those habitats (De Wit *et al.*, 2020; Beunen  
96 *et al.*, 2009).

97         The definition of coastal lagoons is complex as they are transition zones between marine  
98 and continental systems, mostly structured by large spatial gradients and temporal variability  
99 of salinity and water inputs (Perthuisot & Guelorget, 1992; De Pascalis *et al.* 2012; Mahanty *et*  
100 *al.* 2016), and can be found across various biomes. The most commonly used definition has  
101 been proposed by Kjerfve (1994), who characterised them as "inland water bodies, usually  
102 oriented parallel to the coast, separated from the ocean by a barrier, connected to the ocean by  
103 one or more restricted inlets, and having depths which seldom exceed a couple of meters. A  
104 lagoon may or may not be subject to tidal mixing, and salinity can vary from that of a coastal  
105 freshwater lake to a hypersaline lagoon, depending on the water balance". Due to their  
106 worldwide distribution, scientists used the wording "coastal lagoon" to name different  
107 ecological systems, such as the Venice lagoon in Italy (vast permanent water body connected  
108 to the Mediterranean Sea; Sfriso, 1995; Sfriso *et al.*, 1987), the Greifswalder Bodden lagoon in  
109 Germany (permanent oligohaline water body connected to the Baltic Sea; Müller & Mathesius,  
110 1999), the Baix Ter lagoons complex in Spain (small inland temporary lagoons of variable  
111 salinity; Badosa *et al.*, 2007) or the Hourtin lake in France (permanent freshwater lake located  
112 close to the sea, Buquet *et al.*, 2017), to name a few. This heterogeneity has incited several  
113 authors to split coastal lagoons into subcategories based on the local ecological context  
114 regarding sedimentary dynamic, water input and tides (Kjerfve, 1994, Lucena-Moya *et al.*,  
115 2009).

116         In this context, Mediterranean lagoons share common features due to the Mediterranean  
117 climate and the peculiarities of the Mediterranean Sea. Hence, most lagoons are little affected  
118 by tides, although marine currents might condition water flows. In parallel, their hydrological  
119 cycle is largely driven by the yearly distribution of freshwater input characterised by the  
120 summer drought that precedes autumn and winter rainfalls (Blondel *et al.*, 2010; Acquavita *et*  
121 *al.*, 2015; Caroppo *et al.*, 2018). This seasonality induces important variations in abiotic  
122 conditions, ultimately imprinting consequent abiotic stress on living communities (Blondel *et*  
123 *al.*, 2010; Caroppo *et al.*, 2018). In this study, we introduce the term Mediterranean Temporary  
124 Lagoons (MTLs) to designate a specific type of waterbody that constitutes a part of  
125 Mediterranean coastal wetlands. This habitat can be described as brackish to hypersaline water  
126 bodies in deltas and other coastal sedimentary areas that dry out annually. It usually corresponds  
127 to former permanent lagoons, which have been subjected to sediment deposition (filling-in) and  
128 disconnection from the sea due to geomorphological processes. Because of their shallow depth

129 and climatic summer drought, these habitats experience large water level and salinity  
130 fluctuations (see Geertz-Hansen *et al.*, 2011, for example, in Donana National Park in Spain,  
131 and Verhoeven, 1975 in Camargue, France). Such habitats have a long history of human uses,  
132 as many have been transformed to extract salt in the past (De Wit *et al.*, 2019). Their vegetation  
133 is composed of macrophytes and *Characeae* with narrow ecological niches (Cook & Guo, 1990;  
134 Verhoeven, 1975), including several species of high conservation issues, mainly associated  
135 with this habitat. This is notably the case for *Althenia filiformis* Petit, *Riella helicophylla* (Bory  
136 & Mont.) Mont., or the rare *Tolypella salina* Corillon (Becker, 2019; Cook & Guo, 1990;  
137 Comelles, 1986; Marín Velázquez, 1982).

138

139         This paper aims to assess the pertinence of the Mediterranean Temporary Lagoons'  
140 concept in scientific studies and the normative approaches used in public policies related to EU  
141 directives. The objective is to better include these particular ephemeral water bodies in  
142 conservation policies within the Mediterranean ecoregion. Therefore, we examined the  
143 definitions of coastal lagoons most commonly used by the scientific community and public  
144 institutions, following two lines of inquiry. First, we identified mismatches, gaps, and  
145 similarities between its use by the scientific community and the public institutions. To do so,  
146 we critically assessed the definitions of coastal lagoons given by the scientific case studies. We  
147 then built a list of criteria based on terminologies invoked to describe a coastal lagoon and  
148 compared this list with terminologies employed in institutional definitions to describe coastal  
149 lagoons. Second, we searched for scientific articles that studied temporary coastal bodies of  
150 brackish to hypersaline water across the Mediterranean basin. We then analysed the  
151 terminology used so far to describe such habitats, identified which of these ephemeral water  
152 bodies classify as MTLs and if these have been included in the coastal lagoon habitat according  
153 to the scientific and institutional approaches. Then we built a conceptual framework that best  
154 summarises the definition of the different types of coastal lagoons in the Mediterranean context  
155 integrating the MTL concept.

156



## 157 2. Material and method

### 158 2.1. Building three corpus of definitions

159 To review scientific definitions of coastal lagoons, we conducted bibliographic research  
160 on Google Scholar using "coastal lagoon" as keywords, requiring their occurrence in the title.  
161 We only retained scientific articles and academic books written in English. We selected the first  
162 300 articles sorted by their number of citations and added 300 others randomly sampled to  
163 collect an unbiased representation of the literature. We excluded references from this initial list  
164 whose study site was located outside the Western Palearctic (following Cramp *et al.*, 1983).  
165 This list constitutes the "*coastal lagoon corpus*" and includes 281 articles.

166 We built a second corpus with definitions quoted from the interpretation manual of the  
167 HD (European Commission DG Environment, 2013) and its transposition into national laws of  
168 the member states and practical implementation in France (Bensettiti *et al.*, 2004), Spain (Soria  
169 & Sahuquillo, 2009) and Italy (Biondi *et al.*, 2009), and with WFD (European Union, 2000)  
170 definition and its French adaptation (Witkowski *et al.*, 2016). This list forms the "*institutional*  
171 *definition corpus*".

172 In parallel, we sought to gather a corpus of scientific articles studying temporary  
173 brackish to hyper-saline coastal water bodies across the Mediterranean basin (*i.e.* considered  
174 potential Mediterranean Temporary Lagoons). Preliminary searches have highlighted the  
175 heterogeneity in naming such systems; thus, we used the following keywords: "temporary  
176 lagoon", "temporary marsh", "temporary lake" and "*Althenia*", the latter being the genus of the  
177 most frequent plant species among the representative ones of this habitat. Given the limited  
178 amount of scientific literature available, we searched for those keywords in the title and the  
179 main text. We also added references known by us, which resulted in a list of 71 articles. Then,  
180 we restrained this list to studies located in the Mediterranean basin and excluded artefacts  
181 regarding the habitat concerned (*e.g.* freshwater habitat). We also eliminated purely taxonomic  
182 works as little to no ecological information was provided. This constitutes the "*Mediterranean*  
183 *Temporary Lagoon corpus*", which holds 31 articles. We provide a complete list of analysed  
184 articles in appendix A.

185

## 186 **2.2 Analysis of definitions of *coastal lagoon corpus***

187 To analyse arguments used to characterise coastal lagoons, we searched, through the  
188 “*coastal lagoon corpus*”, definitions of the habitat that follow few rules: (1) the definition must  
189 be written in the introduction section; (2) lagoon should be the subject of the sentence or the  
190 paragraph; (3) at least one stating verb whose subject is "lagoon" should be employed. We  
191 excluded descriptions of particular study sites.

192 After a first read, we divided each definition by topics referring to lexical fields of words  
193 employed and thematics used by authors to characterise lagoons: water salinity, hydrology flow,  
194 flooding temporality (*i.e.* whether lagoons dry partly/totally during the year), geographic range,  
195 landscape geography (*i.e.* where the water body is located in the landscape, and its spatial  
196 configuration), area, depth, sea connection, tide influence, sediment origin, nutrients,  
197 productivity, flora communities, fauna communities, past and present human activities and  
198 impacts. We then segmented each definition according to these topics (Appendix B) and  
199 computed each topic's frequency.

200 In parallel, we created a word cloud based on the *coastal lagoon corpus*. We converted  
201 the corpus into a vector representation, known as the "bag-of-words" model (Salton, 1971). We  
202 removed uncommon words to reduce the dimensionality of natural language text to be  
203 processed (Lucas *et al.*, 2015). We implemented a pre-processing protocol based on (1)  
204 removing number and stop-word, (2) lowercasing the text, (3) stripping corpus from  
205 punctuation and additional white spaces. Finally, we extracted the study site(s) from every  
206 article in the corpus and mapped them over the Palearctic.

207 To discuss this analytical perspective on the definition of coastal lagoons, we applied  
208 the same text segmentation to the “*institutional definition corpus*”.

209

## 210 **2.3. Analysis of definitions for *Mediterranean Temporary Lagoon corpus***

211 In the second part, we searched for definitions of MTLs throughout the “*Mediterranean*  
212 *Temporary Lagoon corpus*”. Due to the scarcity of scientific articles, this corpus was inherently  
213 biased, which prevented us from running quantitative analysis. Nonetheless, we searched for  
214 definitions following a similar protocol as detailed above and classified them in the same  
215 analysis grid. Additionally, we extracted the terminology used by authors to name their study  
216 habitat. We represent the wording of definitions thanks to a similar word cloud.

217

218 We ran analyses using the R software version 3.6.2 and *tidyverse*, *dplyr*, *tidytext*,  
219 *stopwords*, *stringr*, *scales* and *ggplot2* packages. Code for *word-cloud* graphics and data are  
220 available in appendix A, B and C.

221

## 222 **3. Results**

### 223 **3.1. The definitions of coastal lagoons in the scientific literature**

224 We analysed a total of 281 references in the *coastal lagoon corpus* (Appendix A). Study  
225 sites are heterogeneously scattered along the Western Palearctic coast, the Mediterranean basin  
226 being the most studied (Figure 1). In particular, the French, Spanish and Italian shores have  
227 been extensively sampled, the most studied lagoons being *Mar Menor* (Spain, 40 articles),  
228 *Sacca di Goro* (Italy, 22 articles), and *Thau* (France, 21 articles).

229

230 [Insert Figure 1]

231

232 Among the 281 references, 31% (87 references) provided a clear definition of coastal  
233 lagoons (Figure 2a). Indeed, the majority of studies simply describe their study lagoon. Among  
234 those, the most used topics are "sea connection" (68%), "depth" (63%) and "landscape  
235 geography" (62%). Thus, a common approach is to consider lagoons as shallow water bodies  
236 located parallel to the shore, with one or several sea connections allowing potential exchanges  
237 with the seawater. However, nearly half of definitions (47%) characterised the "water salinity"  
238 as brackish or similar to the adjacent sea (sometimes even hypersaline, e.g. Marcos *et al.*, 2015),  
239 which distinguish lagoons from freshwater coastal lakes (see Lake Vrana in Croatia for  
240 example; Schmidt *et al.*, 2000). The item "human activities and impacts" (33%) pinpoints the  
241 importance of productive and recreational activities on such habitats, including aquaculture or  
242 nautical leisures. "Hydrology flow" topic (32%) showed the water cycle's origin in lagoons and  
243 balance between seawater and freshwater inputs. All the other topics were rarely employed  
244 (<22%). "Nutrients" input is often considered important are lagoons might be "naturally  
245 eutrophic" (Guyoneaud *et al.*, 1998) (22%). "Sedimentary origin" is most of the time recent due  
246 to quaternary deposits (21%). "Productivity" is usually high (16%), and "tide influence" varies  
247 according to the study site (13%). Lastly, "area", "flora communities", "geographic range" and  
248 "fauna communities" are anecdotally employed (9%, 8%, 6% and 6% respectively). This

249 highlights the importance of geomorphological and hydrological over biological criterion to  
250 define this habitat. It is also interesting to note that no word related to flooding temporality is  
251 employed in all of the 87 definitions analysed.

252  
253

[Insert Figure 2]

254  
255

256 The text mining analysis of the 87 definitions gives similar results. We detected seven  
257 vocabulary groups (VG) in scientific habitat definitions (Figure 3a). The first vocabulary group  
258 relates to "sea connection": "sea" and "water" constituted the most frequently used words,  
259 "barrier", together with "open", "separated", "ocean", "connected", "exchange" and  
260 "influenced". The second VG deals with geographic themes: "terrestrial", "land", "adjacent",  
261 "location", "continental". The third VG refers to "human activities and impacts": "human",  
262 "activities", "anthropogenic", "aquaculture". Fourth, fifth and sixth VG refers to salinity, soil  
263 composition and depth, respectively with "salt" and "salinity", "sediment" and "sand" and  
264 "shallow" and "shallowness". The last VG gathers words linked to the lexical field of variation  
265 and/or stress: "fluctuations", "gradients", "dynamic", and "stressed". Bigram analysis showed  
266 that this last group's items were connected with generic words attached to the lexical field of  
267 habitat or emphasising words like "highly" or "strong".

268  
269

[Insert Figure 3]

270

### 271 **3.2. The institutional definitions of coastal lagoon**

#### 272 *Habitats Directive*

273 In the Habitats Directive, coastal lagoons are considered a priority habitat and listed as  
274 habitat type 1150\*. The Interpretation Manual (European Commission DG Environment, 2013)  
275 provided an operational definition for the 1150 lagoon habitat type as "*expanses of shallow*  
276 *coastal saltwater, of varying salinity and water volume, wholly or partially separated from the*  
277 *sea by sandbanks or shingle, or, less frequently, by rocks. Salinity may vary from brackish*  
278 *water to hypersalinity depending on rainfall, evaporation and through the addition of fresh*  
279 *seawater from storms, temporary flooding of the sea in winter or tidal exchange. With or*  
280 *without vegetation from *Ruppiaetea maritima*, *Potametea*, *Zosteretea*, or *Charetea* (CORINE*  
281 *91: 23.21 or 23.22).*" Hence, several aforementioned topics have been used for this institutional

282 definition, e.g., "sea connection", "depth", "water salinity", "hydrology flow", "human activities  
283 and impacts", "tide influence", "area", "flora communities", and "geographic range" (Figure  
284 2.b). Contrary to scientific literature, the Habitats Directive uses phytosociological vegetation  
285 units as an optional criterion for identifying subcategories of the water body as a coastal lagoon.  
286 This induces new criteria as these units include both typically marine species as well as species  
287 occurring in stagnant waters with higher or lower salinity. Such perspective echoes CORINE  
288 Biotopes (Moss & Wyatt, 1994), which added the possibility to refine the identification of  
289 coastal lagoons based on phytosociological units.

290 Additionally, the Interpretation Manual (European Commission DG Environment,  
291 2013) allows salt basins and ponds, including salt marshes, to be included in this habitat as long  
292 as *"they had their origin on a transformed natural old lagoon or a saltmarsh, and are  
293 characterised by a minor impact from exploitation"*. In the Mediterranean region, some of these  
294 ecosystems are inherently intermittent yearly. Thus, this definition includes non-permanent  
295 lagoons, which contrasts with the general agreement on lagoon definition in the scientific  
296 literature mentioned above.

297 The different Mediterranean EU member states did not systematically use all these  
298 topics to apply the HD definition of coastal lagoons, and different approaches were used among  
299 them (Figure 2.b). EU member states had the duty to interpret the HD to implement to their  
300 particular environmental context. Thus, while the Interpretation Manual recommended  
301 including salt basins and salt ponds as long as the human impact is minor, Spain and Italy did  
302 not explicitly include these habitats in their interpretation of EU definitions, nor used "Human  
303 activities and impacts" theme that linked to salines in the HD definition.

304 However, differences in approaches were not limited to a redefinition of lagoons, as  
305 some countries subdivided the coastal lagoons into subcategories. This was the case for French  
306 and Spanish interpretations. The French interpretation divided coastal lagoons into Atlantic  
307 lagoons (habitat: 1150-1) and Mediterranean lagoons (habitat: 1150-2), considering tides'  
308 influence. Spain's interpretation created three subcategories: "coastal lagoons and salt ponds",  
309 "Delta and floodplains", and "Salina". The significant difference between the first and second  
310 Spain subcategories was the hydrology and geomorphological origin: the first group was  
311 composed of lagoons dominated by the coastal dynamics while the river dynamics'  
312 predominance characterised the second group. Finally, if Spain did not use "human activities  
313 and impacts" in the first definition of lagoons, it created a specific group for these water bodies.  
314 Indeed, the last Spanish group, "saline", was characterised by anthropogenic modification and  
315 exploitation within lagoons. Italy did not create a sub-division in its definition of lagoons.

316

317 *Water Framework Directive*

318 According to the WFD, coastal lagoons can be either placed in the "Transitional waters"  
319 (article 2.6) or the "Coastal water" (article 2.7) category according to their freshwater inputs  
320 (Tagliapietra & Ghirardini, 2006). The WFD defines "transitional waters" as '*bodies of surface*  
321 *water in the vicinity of river mouths that are partly saline in character due to their proximity to*  
322 *coastal waters but which are substantially influenced by freshwater flows*'. "Coastal waters" are  
323 defined as "*surface water on the landward side of a line, every point of which is at a distance*  
324 *of one nautical mile on the seaward side from the nearest point of the baseline from which the*  
325 *breadth of territorial waters is measured, extending where appropriate up to the outer limit of*  
326 *transitional waters*". The main difference between these definitions was based on the  
327 geographical range. In addition to the geographical location topic, the first definition highlights  
328 the importance of sea contiguity in the salinity of lagoons and the greater influence of freshwater  
329 currents in these water bodies. The second definition includes water bodies located in a  
330 geographical range defined by a distance of 1 mile to the territorial waters' baseline.

331 The European definition of Transitional Waters in the WFD has also been defined with  
332 part of the topics presented above and used in scientific literature and the HD definition: "sea  
333 connection", "water salinity", "hydrology flow", and "geographic range". Similarly to the HD,  
334 EU member countries had the duty to interpret the WFD to stick to its environmental context.  
335 To this European definition, French interpretation added a limit regarding the minimum size of  
336 a lagoon: waters bodies smaller than 50 ha were excluded from the WFD application along the  
337 Mediterranean coast (Witkowski *et al.*, 2016).

338

339 **3.3 Definition of Mediterranean Temporary Lagoons**

340 A total of 31 references have been analysed (Appendix A). In the "*Mediterranean*  
341 *Temporary Lagoon corpus*", we found just five definitions of the habitat. Authors characterised  
342 those temporary saline coastal waters using eight themes: "depth" is low, "water salinity" varies  
343 from brackish to hypersaline, "hydrology flow" is influenced by freshwater inputs and less by  
344 winter's flow of seawater, "human activities and impacts" (*i.e.* salines, or aquaculture),  
345 "nutrients", "productivity" (*i.e.* fish nursery), "tide influence", "flora communities", "fauna  
346 communities", "geographic range" and "flooding temporality". "Water salinity" and "flooding  
347 temporality" were both the most-used themes (see Figure 2.c). Salinity can vary from brackish  
348 to hypersaline between water bodies and often shows a yearly dynamic of increase over time

349 due to spring and summer evaporation. The other topics were used just by one or two of five  
350 definitions.

351 We found five vocabulary groups (VG) through the word-cloud analysis of  
352 Mediterranean Temporary Lagoons definitions (Figure 3.b). The first one described the aquatic  
353 environment, with "Water", "aquatic", and "marine", while the second one grouped the different  
354 words used to name water bodies: "Lakes", "Lagoons", and "Wetlands". Three other VG  
355 described distinctive features of Mediterranean Temporary Lagoons. The "salinity" theme  
356 showed a gradient from "salt" or "saline" to "brackish" and "freshwater". These water bodies  
357 differ from the permanent coastal lagoons due to their temporality, which is reflected by words  
358 including "temporary" and "duration" in contrast to the word "permanent". The last VG had  
359 several words attached to biotic themes: "organisms", "Chara", "Arctodiaptomus", or  
360 "Daphnia". While authors do not precisely describe the common geomorphology of  
361 Mediterranean Temporary Lagoons, they use organisms that could live in temporary salt  
362 systems with annual drought. Thus, Mediterranean Temporary Lagoons were mostly defined  
363 by their biocenosis and large gradients of annual temporality, summer drought and salinity.

364 Many terms were used to name these habitats (*i.e.* shallow saline lake, salinas, salt lakes,  
365 brackish marsh, wetlands, coastal lagoons, temporary marsh, coastal aquatic ponds, coastal  
366 pool, temporary shallow lagoon). It was more difficult to build a corpus because papers that  
367 included a temporary lagoon complex did not share a common terminology. Often, the term  
368 used to name the habitat was linked to other words like "shallow", "temporary", or "brackish"  
369 (Appendix A).

## 370 **4. Discussion**

371 Integrating habitat-based conservation has been a cornerstone of modern conservation  
372 policies (Brooks *et al.*, 2019). However, the inherent difficulty of defining habitats and the  
373 multiplication of definitions between numerous scientific and institutional texts has led to  
374 difficulties to apply such policies (Bunce *et al.*, 2013; Beunen *et al.*, 2009; Janauer *et al.*, 2015;  
375 Bolpagni *et al.*, 2017). This problem was previously discussed for coastal lagoons (see  
376 Tagliapietra *et al.*, 2006 & 2009; Valentini *et al.*, 2015), but the water bodies that we describe  
377 as Mediterranean Temporary Lagoons were not addressed. These discrepancies between  
378 scientific and institutional definitions have blurred the conceptual delimitation of this habitat  
379 and impede joint conservation actions. Here we support the explicit inclusion of MTLs in the  
380 lagoon habitat, especially under the HD's 1150 code. We propose an integrated framework, at

381 the interface between institutional texts and scientific literature, to explain the ecological  
382 relationship among coastal water bodies and propose clarifying the definition of MTLs. This  
383 definition can be used both in a scientific context and in institutional texts for applied  
384 conservation.

385

#### 386 **4.1. Ambiguity around the habitat concept**

387 The concept of habitat and its use in scientific literature has been debated for many years  
388 (see Yapp, 1922). This ambiguity has resulted from blending two approaches to define what is  
389 a habitat. Thus, species-based approaches postulate that the habitat must be related to the home  
390 environment that a given species uses to grow and reproduce. In contrast, community-based  
391 approaches define habitat as a combination of taxa found in specific places that present specific  
392 environmental characteristics (Bunce *et al.*, 2013). The first approach can be related to the  
393 realised niche of a given taxon, whereas the second is thought to provide insights on particular  
394 biotope conditions that can be considered homogenous and suitable for an ensemble of species  
395 (following Daubenmire, 1976). This duality has run since the birth of modern ecology (Yapp  
396 1922), and the current use of the term is still under debate, as some authors consider that using  
397 a community-based approach to describe a habitat is misleading and should be avoided (Hall *et*  
398 *al.*, 1997; Miklos, 1959). However, community-based approaches have been used to describe  
399 habitat through standard institutional typologies like CORINE Biotope (Moss & Wyatt, 1994)  
400 or EUNIS (Gayet *et al.*, 2018), which has bolstered the use of the term habitat in this sense,  
401 particularly in Europe (Bunce *et al.*, 2013).

402 The use of phytosociological typologies as a classification for community-based  
403 habitats brings a different perspective for the definition of coastal lagoons compared to the  
404 classic geomorphological/hydrological approach. In several cases, the delimitation of the  
405 coastal lagoon habitat according to these two perspectives introduces incoherences as it often  
406 results in different spatial entities. Hence, a single geomorphological/hydrological habitat can  
407 contain several vegetation types, while each of these vegetation types can be found in different  
408 geomorphological habitats. For example, a single lagoon can include both non-vegetated sandy  
409 bottoms and *Zostera* meadows, while such *Zostera* meadows can also be found in the open sea  
410 (Röhr *et al.*, 2016). This situation is not anecdotal, and such incoherences directly impact the  
411 way habitats are mapped. Hence, it can create problems in our actual identification of those  
412 entities in the field and ultimately impedes the use of vegetation alone to classify lagoons. In



413 this paper, we follow the position of Bunce *et al.* 2008 that define habitat as "an element of the  
414 land surface that can be consistently defined spatially in the field in order to define the principal  
415 environments in which organisms live". We use the term *habitat* to describe geomorphological  
416 units characterised by their hydrological systems and consider that living communities (mainly  
417 plants) bring additional insights into each waterbody's ecological functioning.

418

#### 419 **4.2. Confusion around the limits of lagoon habitat in EU institutional texts**

420 Defining coastal lagoons as habitat is inherently complex, as exemplified by the most  
421 recent European habitat typology, i.e., the EUNIS classification, which considers lagoons as a  
422 complex of habitats (EUNIS code X02-X03). This scientific complexity surrounding coastal  
423 lagoons' definition represents an additional challenge when it comes to including the MTLs.

424 The Interpretation Manual (European Commission DG Environment, 2013) of the HD  
425 defines coastal lagoons based on hydrologic features, geographic location and sea connection,  
426 but also adds vegetation as an optional criterion ("with or without vegetation from *Ruppiaetea*  
427 *maritima*, *Potametea*, *Zosteretea* or *Charetea*", European Commission DG Environment,  
428 2013). The vegetation class *Ruppiaetea maritima* (J. Tüxen *ex* Den Hartog & Segal 1964) can  
429 be found both in permanent and temporarily flooded lagoons. Hence, adding this  
430 phytosociological unit as an optional feature the Interpretation Manual has probably broadened  
431 the conceptual limit of the habitat 1150\* *Coastal lagoons*. Although implicitly, the HD  
432 interpretation manual has considered lagoons operationally as a habitat complex, including  
433 large permanent water bodies and smaller, sometimes temporary water bodies.

434 Then, EU member states must interpret and adapt European definitions of habitats from  
435 the WFD and the HD to their national ecological context. According to the subsidiarity  
436 principle, these member states have a high degree of freedom for interpretation and adapting to  
437 the local conditions, although coordination between countries sharing the same coastline has  
438 been encouraged. Nevertheless, differences have arisen among Mediterranean member states  
439 when interpreting the anthropogenic impact on these systems in the HD and implementing a  
440 minimal area threshold in the WFD. First, the HD definition of lagoons states that the human  
441 impact should be "limited", which is too vague to be interpreted. This has led to the integration  
442 of active Salinas inside the Spanish typology (Soria & Sahuquillo, 2009), while France has  
443 excluded the part of such habitat complexes that are used to harvest salt (*i.e.* "tables saunantes").  
444 Second, the French Mediterranean application of the WFD restrains water bodies' classification

445 as water bodies larger than 50 ha (De Wit *et al.*, 2020), as applied in Polish Lakes (Kolada *et*  
446 *al.*, 2005). The area of most permanent coastal lagoon complexes in the south of France exceeds  
447 that threshold, but some permanent coastal lagoons are excluded from this institutional  
448 definition, such as "l'étang du Dou" (37 ha) and in Corsica "l'étang du Terenzana" (36 ha) and  
449 "l'étang de Balistra" (30 ha) (De Wit *et al.*, 2021). In contrast, temporary water bodies rarely  
450 reach such an area. Past anthropogenic uses have often fragmented those water bodies, in  
451 particular during salt extraction. Even the largest temporary system in the south of France (*i.e.*  
452 the *Salin du Caban*) does not reach that areal threshold, which impedes its classification as a  
453 coastal lagoon regarding the WFD. Therefore, in scientific literature and institutional texts, it  
454 appears that much confusion around the different perspectives on lagoons is related to the  
455 inclusion of temporary systems.

456

### 457 **4.3. What are Mediterranean Temporary Lagoons?**

458 Over the last 40 years, several authors have studied temporary saline coastal water  
459 bodies throughout the Mediterranean basin. While the earliest work defined such systems as  
460 "coastal lagoons" (Koumpli-Sovantzi, 1995; Cook & Guo, 1990; Onnis, 1974), the wording  
461 employed to name those habitats has remained diverse and vague, using indifferently *marsh*,  
462 *lagoon*, *lake*, *pond*, *wetland*, *pool* or *Salinas* to name a few. This has probably increased the  
463 misunderstanding of this habitat classification.

464 We propose to define Mediterranean Temporary Lagoons (MTLs) as coastal water  
465 bodies, temporally filled with brackish to hypersaline water, which dries out yearly (Lopez-  
466 Gonzalez *et al.*, 1998; Onnis, 1974). Such drying up is usually induced by the climatic summer  
467 water deficit typical of the Mediterranean climate and their disconnection from permanent water  
468 sources (sea and/or streams). Under the Mediterranean climate, the hydrological year includes  
469 two major periods, *i.e.* (i) high freshwater input during autumn and winter seasons and (ii) dry  
470 periods during spring and summer. This bimodal behaviour results in flooding with reducing  
471 salinities in autumn/winter and in strong evaporation with increasing salinities while finally  
472 drying out in spring/summer. Nonetheless, sea surges during periods of high sea levels and the  
473 lowering of the groundwater table might also cause flooding and drying, respectively. Like  
474 other coastal lagoons, MTLs are mostly shallow and do not exceed a few decimeters depth.  
475 These temporal water bodies may contain submerged vegetation, often belonging to the

476 *Ruppiaetea maritimae* (J. Tüxen ex Den Hartog & Segal 1964). This class of vegetation is  
477 composed of aquatic angiosperms, among which *Ruppia maritima* L. and *Althenia filiformis*  
478 Petit are often found (Cook & Guo, 1990; Verhoeven 1975 and 1979). Some species of  
479 Characeae can also occur, such as *Lamprothamnium papulosum* (K.Wallroth) J.Groves,  
480 *Tolypella salina* Corillon, *Tolypella hispanica*, different *Chara* spp. (Bracamonte *et al.*, 2013;  
481 Lambert *et al.*, 2013), as well as the rare bryophytes *Riella helicophylla* (Bory & Mont.) Mont.  
482 and *Riella notarisii* (Mont.) Mont. (Casas *et al.*, 1992; Sabovljević *et al.*, 2016). These species  
483 support significant salinity variations, and at least one stage of their life cycle can support  
484 periodic desiccation. Therefore, the main distinction with the other coastal lagoons is this drying  
485 up and often also a lack of direct connection with the sea. Intermittent connections with the sea  
486 may rely on natural inlets that open and close depending on coastal dynamics and sea surges  
487 related to the annual climatic variability; sometimes, it is achieved through man-controlled  
488 canals with sluice gates (Figueiredo da Silva *et al.*, 2004). However, at least in Mediterranean  
489 France, the vast majority of MTLs are isolated from the sea. Because of their origin, often due  
490 to the sedimentary infilling of old lagoons, MTLs can be found at the periphery of permanent  
491 coastal lagoons. Many of the human-built ponds used for salt extraction in the past are still  
492 separated from the sea and permanent lagoons by dikes and nowadays function as MTLs. These  
493 often occur in complexes as the former salt extraction works were often compartmentalised in  
494 pre-concentration and salt extraction ponds. Many exploitations have been abandoned during  
495 the past 70 years, resulting in rewilding (De Wit *et al.*, 2019). Hence, depending on their  
496 geographical location in lagoon-complexes and their historical formation, these MTLs are either  
497 endorheic or interconnected in a lagoon-complex during the flooding periods (hydroperiods)  
498 occurring from autumn to spring. The salinity of the water column in the endorheic systems  
499 mainly relies on the dissolution of the salt present in the soils that precipitates again during the  
500 following drying-out period. However, in some cases, additional input of salt may result from  
501 saline groundwater inputs.

502           Some MTLs thus correspond to systems defined as Intermittently Closed and Open  
503 Coastal Lakes and Lagoons (ICOLLS), a concept that has been introduced primarily in Australia  
504 for coastal lagoons with an intermittent connection with the sea (Haines *et al.*, 2006; see in  
505 Portugal the use of this term by Gamito *et al.*, 2019). Indeed, some of these ICOLLS may dry  
506 out entirely during the dry season and could thus correspond to what we consider as a temporary  
507 lagoon. The inlet is temporarily closed off during the dry season by longshore drift and re-  
508 opened during the wet season. Thus, the functioning of these ICOLLS follows a similar cycle

509 as MTLs, with flooding during the wet season and a variable dry period during summer.  
510 Examples in South France of natural MTLs that are also ICOLs with intermittent inlets are  
511 the Orpellières and Grande Maire lagoons close to Béziers. In North Africa, the term "Sebkha"  
512 or "Sabkha" is used to name thalassic evaporitic environments for temporarily flooded areas  
513 (Lakhdar *et al.*, 2006). Coastal "Sebkhas" were formed from the sedimentary infilling of coastal  
514 lagoons, and with partial or total separation to the sea, "Sebkha" dries up in summer similarly  
515 to MTLs. However, "Sebkha" can be used for continental water bodies because this name does  
516 not use a strict geographical range in its definition (Blondel *et al.*, 2010).

517         While different wordings have been used to qualify this habitat, they all seem to blur  
518 our understanding and mislead the reader toward other habitats. To clarify that, we chose to use  
519 the word "temporary" by analogy with "Mediterranean temporary ponds" (EUNIS habitat C1.6  
520 "Temporary lakes, ponds and pools"), a habitat whose hydrological system follows similar  
521 dynamics for freshwater waterbodies. While *marshes* or *saltmarshes* were often used for the  
522 MTLs, we consider them deceptive because these terms often refer to a variety of habitats  
523 classified in the HD Interpretation Manual under the codes 1310 "*Salicornia* and other annuals  
524 colonising mud and sand", 1410 "Mediterranean salt meadows (*Juncetalia maritimi*)", 1420  
525 "Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)", 1430  
526 "Halo-nitrophilous scrubs (*Pegano-Salsolatea*)" and 1510 "Mediterranean salt steppes  
527 (*Limonietalia*)" (European Union, 1992). These habitats were defined based on their floristic  
528 association and are composed of terrestrial plants excluding aquatic macrophytes, which require  
529 longer inundation. Other names like *ponds* or *lakes* have often been used to describe freshwater  
530 entities, so we considered their use inappropriate for brackish to hypersaline water bodies. The  
531 term *wetland* includes a wide variety of water bodies regardless of localisation (coastal or  
532 continental) and is not specific enough to define this habitat (Hu *et al.*, 2017; Keddy, 2010).  
533 Thus, we argue that *lagoon* is the most appropriate wording, based on the spatial proximity of  
534 those systems within coastal wetlands, the often shared geomorphological origin, their  
535 hydrological similarities based on brackish water, and their ecological function. Besides, it is  
536 the name used in European institutional directives which simplifies the nomenclature.

537

#### 538 **4.4. The limit of the habitat concept applied to lagoon complexes**

539 A key challenge to implement habitat-based conservation is to ensure a shared  
540 understanding of the conceptual entity to map this habitat similarly across its distribution range  
541 and build coherent conservation plans (Valentini *et al.*, 2015). One of the main issues to  
542 characterise habitats on the field relates to the spatial and temporal imbrication of different  
543 habitats that render the localisation of each habitat complex, *i.e.* the habitat mosaic (Stenzel *et*  
544 *al.*, 2014). It is often the case for lagoon complexes where MTLs can occur spatially  
545 intermingled with saltmarsh vegetations dominated by *Sarcocornia* and *Salicornia* shrubs to  
546 the point that it is often complex to distinguish both entities. However, this problem is typical  
547 of habitat mapping, *i.e.* creating limits for management purposes where gradients and  
548 continuum are the rules. This situation has been largely discussed for grassland encroachment  
549 when two vegetation (grassland and young forest) can mix (Bock *et al.*, 2005). Such an issue is  
550 artefactual and induced by the spatial grain to which the habitat is mapped. This way,  
551 practitioners should delimitate entities based on their map's spatial resolution and attribute  
552 percentage cover to the different habitats if they cannot individualise them under this resolution.  
553 Following Raunkiaer (1937), we support the distinction between saltmarshes and lagoons,  
554 considering that macrophytes attest to aquatic habitat while shrubs compose terrestrial  
555 vegetation.

556 Another issue is the extent to which humans have modified those systems. Humans have  
557 exploited resources (such as fishes) to a point where they have durably modified living  
558 communities (Marcos *et al.*, 2015). They have influenced the marine/freshwater balance by  
559 controlling exchanges with the sea and adding wastewater that decreases the salinity and  
560 increases nutrient level (Mahapatro *et al.*, 2013; Cañedo-Argüelles & Rieradevall, 2010); they  
561 have also fragmented the habitat to separate water bodies and manage ecological factors (De  
562 Wit *et al.*, 2019). These actions have durably influenced coastal lagoons' functioning: the  
563 important segmentation of MTLs using dams to enable salt extraction persists in the landscape  
564 and conditions the water balance of many water bodies (De Wit *et al.*, 2019; De Wit, 2011). In  
565 southern France, such practices have reached a point where it is currently nearly impossible to  
566 find MTLs free of any trace of past man-use (De Wit *et al.*, 2020). Similarly, it is complex to  
567 assess whether actual water bodies could have been gained on the surrounding *halophilous*  
568 *scrubs* by extracting sediment (De Wit *et al.*, 2019). In the end, the level of alteration might  
569 lead practitioners to declassify some water bodies from being lagoons. However, these

570 perturbations remain complex to characterise to fix a threshold that would ensure a shared  
571 understanding of the habitat.

572 This question has become even more central as the HD (alongside the Corine Biotope  
573 classification) uses such alteration to define what should be considered a lagoon. Indeed,  
574 lagoons should exhibit "limited impact" and be abandoned for a "long time" to be considered  
575 lagoons and legally protected. These terms are somewhat vague and leave an important part to  
576 states to interpret the text. In the case of MTLs, we advocate that modifying the hydrologic  
577 cycle and/or salinity regime is tantamount to disrupting the habitat's ecological functioning.  
578 This has significant consequences on the biocenosis, which should lead to the declassification  
579 of water bodies. Nevertheless, this position could induce conflicts among managed lagoon  
580 complexes, where conservationists add fresh and/or marine water to temporary systems to  
581 favour birds breeding, leading to similar disruption of the salinity dynamic (see Geslin *et al.*,  
582 2002, for example). It is then imperative to order conservation priorities.

583

#### 584 **4.5. An integrative approach of lagoon complexes in the Mediterranean**

585 Through this last section, we propose a simple framework to define the ecological  
586 determinants of Mediterranean Temporary Lagoons in regard to other coastal water bodies in  
587 the Mediterranean basin (Figure 4). Due to its peculiar climate, two ecological factors condition  
588 the expression of biodiversity within coastal water bodies: hydrological temporality (Keddy,  
589 2016) and salinity (Grillas, 1990). Therefore, in the Mediterranean basin, when a waterbody is  
590 (1) located within a coastal context, (2) with brackish to hypersaline water, (3) with shallow  
591 waters and (4) whose vegetation (if present) is dominated by macrophytes, we recommend the  
592 use of "coastal lagoon", regardless of its extent and whether it dries out or not. The dominance  
593 of aquatic macrophytes reflects the paramount importance of the submerged period on the  
594 habitat functioning and allows it to differentiate from other habitats that could be temporarily  
595 flooded, such as *halophilous scrubs* or *salt steppes*.

596

[Insert Figure 4]

597 For permanent coastal lagoons, we follow the classic terminology based on the Venice  
598 system (1958), where we can distinguish permanent euryhaline and polyhaline coastal lagoons,  
599 which are water bodies with salinity close to or higher than the sea ( $\sim 18$  to  $40 \text{ g.l}^{-1}$ ), from

600 permanent oligohaline (0.5 to 5 g.l<sup>-1</sup> of salt) to mesohaline (5 to 18 g.l<sup>-1</sup> of salt) coastal lagoons  
601 that have a relatively low and stable salinity during the year (Lucena-Moya *et al.* 2012). Waters  
602 most often come from a mixture of freshwater (*i.e.* runoff or river flow), rainwater and saltwater  
603 through a connection to the sea, which ranges from permanently open inlet to intermittent or  
604 rarely open inlet that leads to limited saltwater inputs (Christia *et al.*, 2018; De Wit *et al.*, 2020;  
605 Le Fur *et al.*, 2017; Pérez-Ruzafa *et al.*, 2011).

606 In addition to this classic typification, we propose a third class: Mediterranean  
607 Temporary Lagoon. They are differentiated from permanent lagoons as the latter do not dry up  
608 totally following annual cycles driven by climate and flooding events. This way, they show  
609 greater variations of their hydrologic features due to their drying and their local substrate  
610 composition. This drying up is not necessarily an annually-occurring event, depending on their  
611 physical features (surface, depth, connexion with lagoon complex), annual climatic conditions  
612 and annual fluctuation of hydrology's lagoon complex.

613

## 614 **Conclusion**

615

616 In this work we introduce Mediterranean Temporary Lagoons (MTLs) as particular  
617 habitats that show characteristic biotic communities and great intra-annual variations of their  
618 water compartment. While some of these MTLs are intermittently connected to the sea and  
619 could be considered as ICOLLs, many MTLs are endorheic systems with their hydrology  
620 shaped by the annual fluctuations of the Mediterranean climate. Most MTLs have been  
621 profoundly modelled by human use; nevertheless, rare biodiversity persists in these temporary  
622 water bodies that render MTLs essential habitats with high conservation stakes within coastal  
623 wetlands. To ensure their persistence, we advocate for their inclusion within the HD coastal  
624 lagoon habitat (1150\*), based on their geomorphological, hydrological and ecological  
625 proximities. Furthermore, their water quality and ecological conditions should also be  
626 addressed as transitional waters by the WFD.

627 Nevertheless, these habitats have been poorly studied over the past 40 years, and we  
628 still lack a global analysis of their ecological functioning and distribution. Such scientific  
629 knowledge constitutes the way forward to better account for this habitat within conservation

630 strategies, particularly regarding the expected fluctuation of hydrological systems induced by  
631 global changes.



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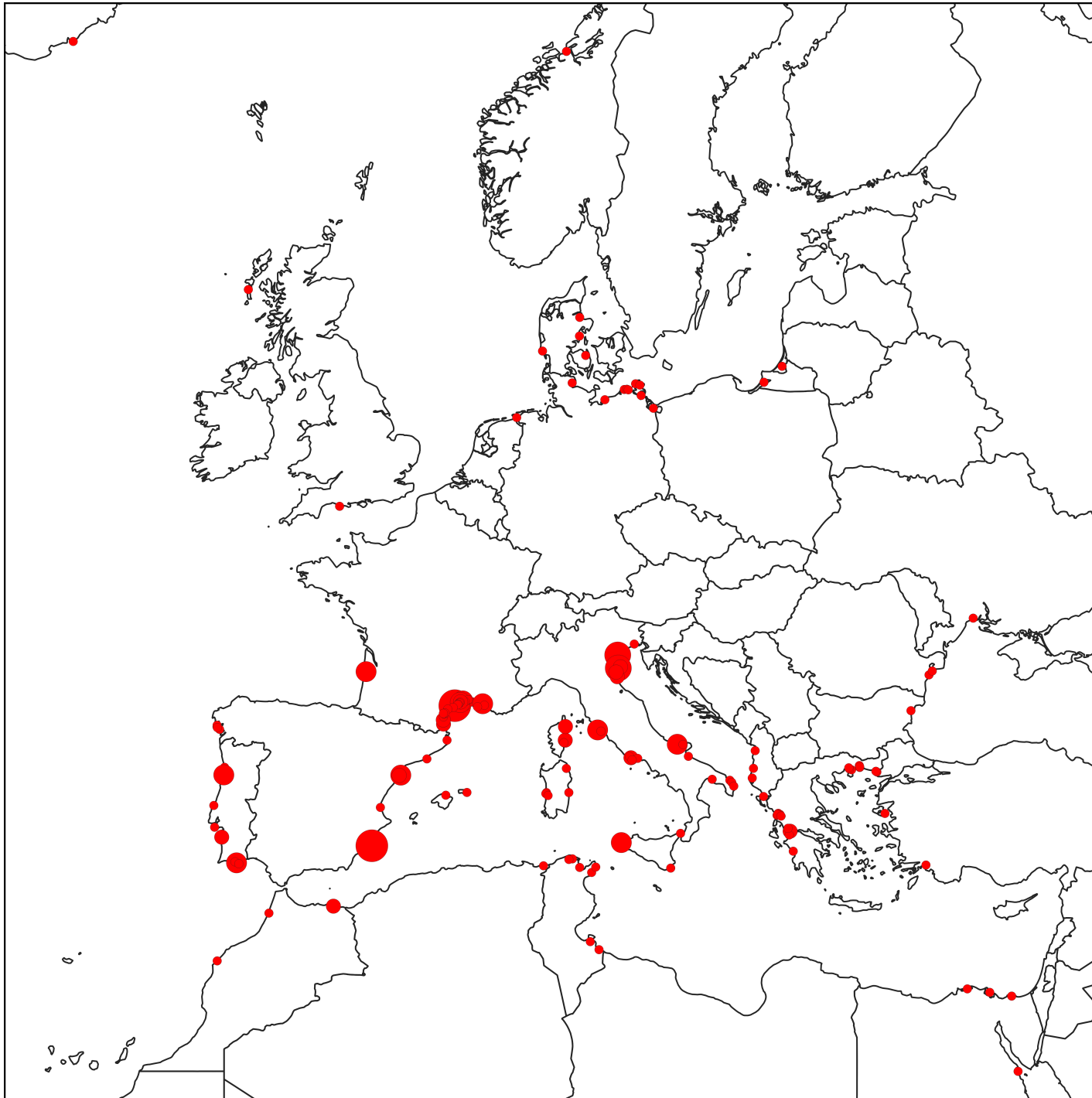
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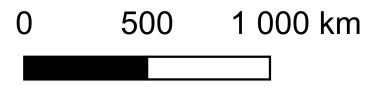
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**Number of citations**

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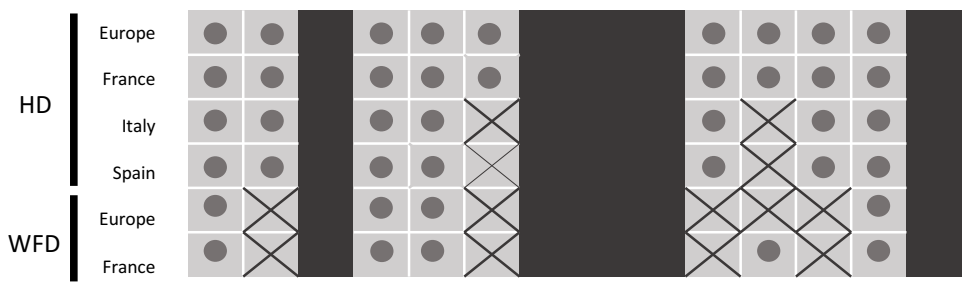
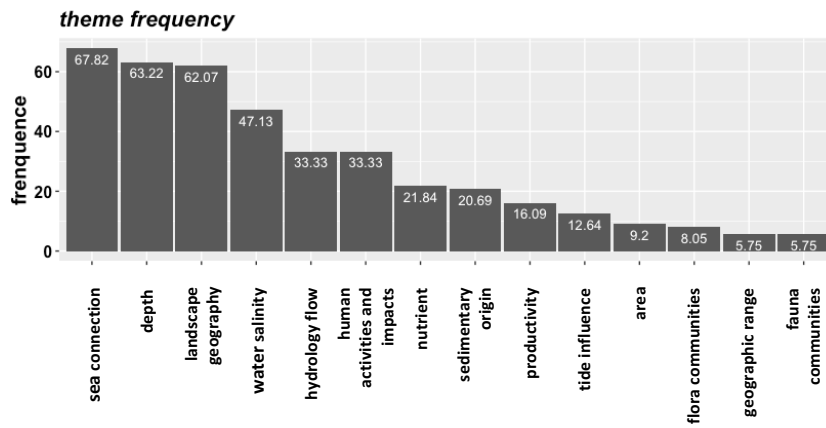
Scientific definitions

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Institutionnel definitions

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Temporary lagoon definitions



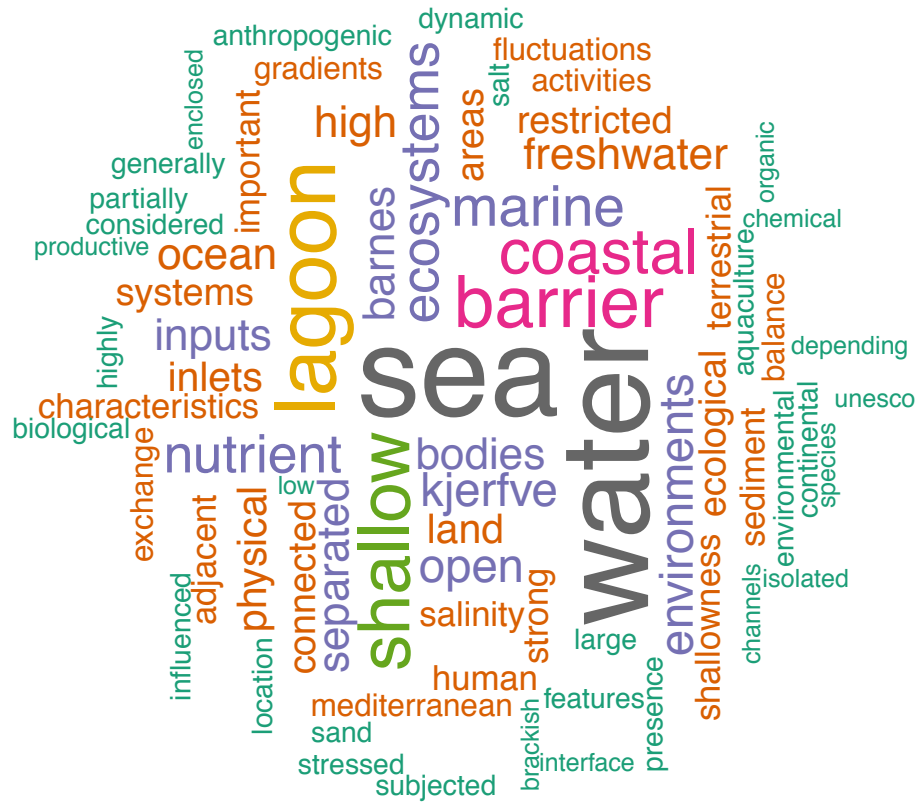
Themes frequency (percentage) :



Other theme used in temporary lagoon definitions

Hydrology temporality : used by 80% of definitions

Word cloud coastal lagoon corpus



Word cloud temporary lagoon corpus



