1 **Assessing the effects of habitat patches ensuring propagule supply and**
2 **different costs inclusion in marine spatial planning through**
3 **multivariate analyses.**

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13 **Abstract**

14 Marine Protected Areas are considered key tools for conservation of coastal ecosystems. However,
15 many reserves are characterized by several problems mainly related to inadequate zonings that often
16 do not protect high biodiversity and propagule supply areas precluding, at the same time, economic
17 important zones for local interests. The Gulf of Naples is here employed as a study area to assess
18 the effects of inclusion of different conservation features and costs in reserve design process. In
19 particular eight scenarios are developed using graph theory to identify propagule source patches and
20 fishing and exploitation activities as costs-in-use for local population. Scenarios elaborated by
21 MARXAN, software commonly used for marine conservation planning, are compared using
22 multivariate analyses (MDS, PERMANOVA and PERMDISP) in order to assess input data having
23 greatest effects on protected areas selection.

24 MARXAN is heuristic software able to give a number of different correct results, all of them near to
25 the best solution. Its outputs show that the most important areas to be protected, in order to ensure
26 long-term habitat life and adequate propagule supply, are mainly located around the Gulf islands. In
27 addition through statistical analyses it allowed us to prove that different choices on conservation
28 features lead to statistically different scenarios. The presence of propagule supply patches forces
29 MARXAN to select almost the same areas to protect decreasingly different MARXAN results and,
30 thus, choices for reserves area selection.

31 The multivariate analyses applied here to marine spatial planning proved to be very helpful
32 allowing to identify i) how different scenario input data affect MARXAN and ii) what features have
33 to be taken into account in study areas characterized by peculiar biological and economic interests.

34 **Keywords:** marine conservation planning, MARXAN, multivariate analyses, connectivity analysis,
35 graph theory.

36 **1 Introduction**

37 Human populations and their demands for land, energy, and natural resources are exponentially
38 growing, creating pressures on ecosystems that are not expected by conventional approaches to
39 natural resource management (Leisinger et al. 2002). The Ecosystem-Based Management (EBM)
40 approach (Katsanevakis et al. 2011) was developed to tackle this problem from a holistic point of
41 view, involving management of species habitats and human activities. Ecosystem management is
42 best thought as “the process of ecosystem-based management of human activities” (Grumbine,
43 1991; Kay and Schneider, 1994) using appropriate management and protection tools, such as
44 Marine Protected Areas (MPAs) (Browman and Stergiou, 2004; Halpern et al. 2010; Rassweiler et
45 al. 2012). MPAs guarantee the conservation of marine biodiversity (Appolloni et al., 2017;
46 Donnarumma et al., 2018; Ferrigno et al., 2017), raising ecosystem services (Franzese et al., 2017,
47 2015; Picone et al., 2017) and produce economic benefits increasing commercial fish sizes and
48 biomass (i.e Guidetti et al. 2008; Fenberg et al. 2012) and enhancing visitors flows through
49 sustainable practice of marine activities, such as diving and yachting (McCook et al. 2010; Lopes et
50 al. 2015).

51 In this framework protected areas are the keys for marine environment conservation and
52 improvement of local economies; however they often are not sufficient to achieve their
53 conservation objectives (Fraschetti et al. 2005a; Guidetti et al. 2008; Martín-García et al. 2015).
54 Too often relevant sites characterized by high number of species (Russo et al. 2005a, 2005b),
55 presence of important habitats for ecosystem functions (Fraschetti et al. 2005a) and propagule
56 sources, are located in areas of partial or null protection. At the same time, management efforts are
57 often vain since local populations consider protection policies merely as tools for biodiversity
58 conservation, with no economic feedbacks (Badalamenti et al. 2000). This also applies to Italian
59 MPAs, characterized by several management problems, mostly related to political and
60 administrative reasons, such as limited availability of funds, precariousness of management bodies
61 (Francour et al. 2001; Messina, 2005) and inadequate zonings that preclude important zones for
62 economic activities (Badalamenti et al. 2000).

63 In order to overcome these criticisms, the Systematic Conservation Planning approach was
64 developed (Margules and Pressey, 2000). This is based on the explicit definition and quantification
65 of conservation objectives to be achieved and on minimization of costs linked to the protection
66 (Kirkpatrick, 1983, Smith et al. 2006).

67 From the stakeholders points of view, “costs” are those deriving from different uses (costs-in-use)
68 of a resource if it had not been included in a reserve. In terrestrial and marine protected areas, where
69 extractive and exploitation activities are forbidden, costs are measured as the highest economic
70 values of activities in absence of protection policies (Naidoo et al. 2006).

71 In this context conservation features are the items preserved by protection policies, identified
72 according to objectives of the protected area. Other than habitats patches, a typical conservation
73 feature to be taken into account in conservation planning, is the propagule exchange between
74 habitat patches (connectivity), since this is a critical bio-ecological process structuring marine
75 populations and affecting ecosystems resilience (Botsford et al., 2009; Palumbi, 2004; Roberts et
76 al., 2003a; Sale et al., 2005).

77 Graph theory offers a wealth of powerful tools and algorithms to analyse network connectivity in
78 many ecological fields (Strogatz, 2001; Lesne, 2006; Grubestic et al. 2008) providing a favourable
79 trade-off between how well a model represents reality and the amount of required data (Keitt et al.
80 1997; Calabrese and Fagan, 2004; Bodin and Norberg, 2007). Within a seascape context, graph
81 theory allows to identify patches of specific habitat that can ensure propagule supply to the other
82 patches of the same habitat.

83 The selection of protected areas following systematic approach is a complex problem, solvable in
84 some cases only by using mathematical heuristic algorithms. A powerful approach for its flexibility
85 and rapidity is the simulated annealing algorithm, as implemented in MARXAN software (Ball et
86 al. 2009), inspired to the annealing process of metals and glass (Metropolis et al. 1953). The main
87 benefit of this method is that the algorithm indicates a plethora of solutions that can be submitted to
88 stakeholders.

89 The aims of the present investigation are: (i) to apply an easy method to identify propagule habitats
90 source patches in order to include them in MARXAN input data, (ii) to find a method via
91 community ecology multivariate analyses to assess if and which conservation features and costs are
92 more relevant in protected area selection.

93 **2 Materials and methods**

94 ***2.1 Study area***

95 The Gulf of Naples habitats map is shown in Figure 1. In order to simplify its understanding, some
96 explanations with a list of abbreviations and RAC/SPA codes are reported in supplementary
97 materials. The study area covers about 1051 Km² of the whole Gulf; its morphology changes
98 radically moving from North-West to South-East sectors. The first sector is characterized by a
99 rugged bottom, due to the presence of two deep canyons and a large number of rocky outcrops
100 (mostly remains of submarine volcanic cones) that host most of the precious coralligenous habitats
101 (C). The South-East side is very regular, consisting mostly of a large muddy platform (VTC and DE
102 habitats) that gently degrades until 200 m depth even if a single emergent rocky relief, represented
103 by Vico Equense rocky outcrop (Russo, 1997, 1992), is here present.

104 On north side and close to the coastline, sandy habitats are present, principally: SFBC, SGCF, GI
105 and SVMC. The latter, in the harbours and in the inner part of the Gulf is also present as high
106 anthropic impacted *facies* (SVMC (STP)).

107 South-East side coastline and islands are dominated by high rocky cliffs and boulders that
108 determine suitable sites for infralittoral algae habitat (AP) on the shallow part and for coralligenous
109 habitats on the deeper part.

110 To the south side of the Gulf there is a relevant C-SCA habitat, an important coralligenous *facies*
111 characteristic of the shallow part of the continental slope. Environmentally and economically
112 important species such as *Corallium rubrum* (Linnaeus, 1758) and other alcyonacea as
113 *Paramuricea clavata* (Risso, 1826) are here present (Bo et al. 2009; Bavestrello et al. 2014).

114 Around all islands, shallow bottoms are mostly characterized by seagrass meadows of *Posidonia*
115 *oceanica* (Delile, 1813). There also are evidences of *Posidonia oceanica* dead mattes in the inner
116 part of the Gulf, as a result of strongly anthropogenic pressures (Pergent al. 1995; Costantino et al.
117 2010).

118 In order to preserve the great habitats variety characterizing the Gulf four MPAs were also
119 established: the Underwater Parks of Baia (B) and Gaiola (G), the Regno di Nettuno (RN) and
120 Punta Campanella (PC) MPAs. Their protection is ensured through three zoning regimes: no-take
121 zone (A) where all activities that may disturb or damage marine environments are forbidden; buffer
122 zone (B) where impacting activities are strictly regulated; transitional zone (C), where anthropic
123 activities are regulated according to a sustainable development.

124

125 **Figure 1** - Gulf of Naples RAC/SPA habitats map (code in Supp1) divided in the eight cardinal sectors (black lines). MPAs and zonation are also
 126 shown: a) Regno di Nettuno; b) Underwater Park of Baia c) and Gaiola; d) Punta Campanella.

127 **2.2 Patches connectivity**

128 In recent years, the number of studies applying graph theory to terrestrial landscapes increased
 129 remarkably (Fall et al. 2007; Ferrari et al. 2007; Jordán et al. 2007; Minor and Urban, 2008;
 130 Pascual-Hortal and Saura, 2008). In the present study, nodes are habitats patches and links represent
 131 the likelihood (p_{ij}) of a meroplanktonic organism to directly disperse between patches i and j
 132 (without passing through any other intermediate habitat patch). Values of p_{ij} are quantified using
 133 patch areas and Euclidian distance (Treml et al. 2012). Here is assumed that a benthic species, at the
 134 end of its meroplanktonic larval stage, is attracted by the adult stage habitat (Pawlik, 1992) within
 135 the Gulf. Indeed, Levin (2006) suggests that larval retention in the natal habitat is more frequent
 136 than suspected and thus populations could be less open than previously thought.

137 In order to ensure long-term habitat life, connectivity among patches of the same habitat (Treml et
 138 al. 2008) is assessed through Probability of Connection (PC) using ConeforSensinode 2.2 (Saura
 139 and Torné, 2009) software.

140 From graph theory, PC is the likelihood that two points randomly placed within the landscape fall
 141 into habitat areas that are reachable from each other (interconnected). Essentially, it is a measure of
 142 the likelihood that a patch is a source of propagules.

143 To assess PC, mixed habitats (i.e. AP-SFBC or C-SGCF) are grouped on the base of the dominant
 144 habitat (Table 1). Groups whose dominant habitats are not mentioned by Habitat directive
 145 (92/43/EEC), and described later, are excluded in the following analyses.

146 Patches that summed together concur at least to the 60% of total likelihood to be propagule source
 147 are taken into account as conservation features (see below), thus ensuring adequate larval supply
 148 (Fahrig, 2001).

Group name	Habitats
AP(PC)	AP, AP-C, AP-SFBC, AP-SGCF, AP-GI
C(PC)	C, C-SCA, C-SGCF
SFBC(PC)	SFBC, SFBC-AP
HP(PC)	HP, HHP, HP-HCn

149 **Table 1** – Group of habitats based on the dominant ones and mentioned in Habitat directive
 150 (92/43/ECC).

151 **2.3 Targets definition and MPAs gaps**

152 Choosing habitats percentage to be protected is a basic approach used in conservation planning that
 153 guides placement of protected areas and ensure the persistence of biodiversity (Margules and
 154 Pressey, 2000). There is no single value that can be used to ensure biodiversity protection (Groves,
 155 2003), however the politically convenient 10-12 % used as conservation target does not appear
 156 satisfactory, especially without evidence of biological data or conservation merit. On the other
 157 hand, increasing protection percentage (over 40% of a total habitat in an area) might be very

158 difficult to realize and may only be useful for scientific conservation exercises or assessments.
159 Thus, in the present investigation the targets of conservation are established taking into account the
160 importance of specific habitats regulated by European laws, resiliency and redundancy of different
161 assemblages (Svancara et al., 2005) and experts judgements. In particular, considering IUCN
162 guidelines, RAC/SPA protocol (UNEP/MAP) and annexes 1 and 3 of Habitat directive
163 (92/43/EEC), that focus on three habitat types [1. Reefs that includes AP habitat on the shallow
164 parts, and C habitat (coralligenous habitat is also inserted in Marine Strategy directive –
165 2008/56/CE) on the deeper part; 2. Submerged sandbanks, including SFS and SFBC habitats; 3.
166 *Posidonia oceanica* beds], different protection percentages of each habitat in the Gulf of Naples
167 were chosen (Table 2). DC, DE and VTC habitats show the lowest amount of total area to protect
168 (0.01%) considering the huge extension of these three on seascape. Since SVMC (STP) and Pm are
169 damaged habitats due to human activities, they are not considered.
170

Conservation feature	Area to be conserved (%)
AP	40
AP-C	30
AP-GI	20
AP-SFBC	20
AP-SGCF	20
C	40
C-SCA	20
C-SGCF	20
DC	0.01
DE	0.01
GI	20
GI-AP	20
SFBC	20
SFBC-AP	20
SFS	20
SFS-AP	20
SGCF	20
SGCF-AP	20
SGCF-C	20
SVMC	20
VTC	0.01
HCn	20
HP	40
HHP	30
HP-HCn	20
AP(PC)	20
C(PC)	20
SFBC(PC)	20
HP(PC)	20

171 **Table 2**– Targets (total area percentage of each habitat) having to be protected in the Gulf to ensure
172 long-term habitats conservation.

173

174 Gap analyses on Gulf of Naples MPAs were carried out in order to assess: i) if current MPAs
 175 zonations are enough to achieve conservation targets and ii) how much MPAs area is considered by
 176 MARXAN algorithms. In this investigation only no-take areas (A zones) and buffer areas (B zones)
 177 are considered since they are characterized by stronger constraints than the transitional areas (C
 178 zone).

179 **2.4 Data collection and computation of costs**

180 Habitats present in the Gulf of Naples seascape and anthropic activities are georeferenced and
 181 mapped using ArcGIS for Desktop 10.1 © ESRI at the scale 1:50,000. Professional fishing [large-
 182 scale (LSF) and small-scale (SSF) fishing] and exploitation activities, [aquaculture (Acq), beach
 183 resorts (B), yachting (Y), diving (D) and commercial shipping (CS)] conducted in the study are also
 184 considered following the Systematic Costs Assessment method (Appolloni et al., 2018).

185 **2.5 Identification of priority areas to be protected: MARXAN analysis.**

186 R package version 1.0.0 (Hanson and Watts, 2015) of MARXAN v 2.43 software (Ball et al. 2009)
 187 is used to assess priority areas that allow to achieve conservation targets minimizing impacts on
 188 local economies. Study area is divided in 10,454 hexagons Planning Units (PUs) of 10 ha each. PUs
 189 are used as potential candidate areas to be selected by MARXAN. The extent of each conservation
 190 feature and sums of costs are calculated in each PU.

191 PUs needed for commercial shipping activities, such as ports and bays marked on nautical charts,
 192 are *a priori* excluded in MARXAN analyses since they cannot be included in a reserve if chosen by
 193 software being unmovable areas characterized by fixed infrastructures.

194 MARXAN routine is carried out and replicated three times, in order to obtain three best solutions
 195 (showing PUs selected, at least, at the minimum level of 95 of conservation targets at the lowest
 196 possible cost) of each 8 different scenarios (Table 3).

Costs	Conservation features	
	Habitat	Habitat + Connectivity
No activities	No	Con_No
Fishing Activities (LSF, SSF)	Fish	Con_Fish
Exploitation Activities (Acq, B,Y,D,CS)	Exp	Con_Exp
All (Fishing activities + Exploitation activities)	All	Con_All

197 Table 3 - Combination of conservation features (Habitat and Habitat + Connectivity) and costs
 198 (Appolloni et al., 2018) to build the 8 different scenarios.

199 In order to compare scenarios a fixed Boundary Length Modifier (BLM) parameter is chosen
200 (BLM=1). MARXAN runs 100 times for each scenario, with 10^6 iterations for each execution. The
201 program is run using the algorithm of simulating annealing followed by another heuristic algorithm
202 called iterative improvement (Fisher et al. 2008).
203 Finally, to simplify the interpretation of MARXAN outputs and to highlight the most important
204 aspects for the present investigation, numbers of PUs selected in each of eight cardinal sectors
205 (Figure 1) (N, NE, E, SE, S, SW, W, NW) are reported for each scenario.

206 **2.6 Scenarios comparison**

207 Using the three best solutions for each scenario as replicates of the same “sampling”, PUs selected
208 patterns out of three best solutions are taken into account to assess differences among scenarios,
209 using Jaccard similarity index.

210 Thus, distance-based permutation multivariate analysis of variance (PERMANOVA; Anderson,
211 2001) is carried out on binary solutions matrix in order to understand if different conservation
212 features or costs produce statistical differences among selected PUs patterns.

213 The design for the analysis involved the factors Conservation Features (CF, fixed, 2 levels) and
214 Activities (Act, 4 levels, fixed), $n = 2$. Each term in the analysis is tested by 4,999 random
215 permutations. *Post hoc* pair-wise comparisons using the PERMANOVA *t*-statistic and 4,999
216 permutations on CFxAct factor are also conducted.

217 Multivariate patterns are visualized through MDS ordination plot.

218 Permutation tests of multivariate dispersion (PERMDISP; Anderson et al. 2006) based on Jaccard
219 similarity matrices are carried out for the interaction term CFxAct to investigate possible effects of
220 inclusion of different conservation features and costs on heterogeneity of scenarios clusters.

221 **3 Results**

222 **3.1 Patches connectivity**

223 The most important patches, concurring to 60.37% of total likelihood to be sources of group AP,
224 cover 489.62 ha. They are present: in the west sector of the Gulf, where there is the largest patch,
225 and scattered along the coast between the North and the South-East sectors of the Gulf.

226 The most important patches, concurring to 66.79% of total likelihood to be source of group C, cover
227 2302.97 ha. They are present principally in the South sector of the Gulf around the island, where
228 there is the largest patch, and in the West sector, arising from old volcanic cones, close to the
229 islands of the Gulf.

230 The most important patches, concurring to 65.69% of total likelihood to be source of group SFBC,
231 cover 1183.79 ha. They are present as two large patches in North-West and East sectors of the Gulf.

232 The most important patches, concurring to 61.34 of total likelihood to be source of group HP cover
 233 2074.45 ha. They extend principally in the West and North-West sectors of Gulf surrounding
 234 islands.

235 3.2 Gap analysis on MPAs current zonations

236 MPAs A and B zones cover a total area of 2958.65 hectares (3.04% of total study area).

237 Gap analysis (Figure 2) shows that targets of: AP-C, C-SGCF, DC, DE, GI, SFBC-AP, SFS, SFS-
 238 AP, SGCF-AP, SGCF-C and VTC habitats are met.

239 Nevertheless the areas of AP (17% of the total protected area), C (18% of the total protected area),
 240 and HP (38% of the total protected area) are not enough to guarantee habitats preservation.

241 According to the above result, MPAs giving the higher contribution to meet the conservation targets
 242 are the Underwater Park of Gaiola and the Regno di Nettuno MPAs, protecting their exclusive
 243 habitats (SFS, SFBC-AP).

244 Only HP(PC) propagule supply is adequately protected by Regno di Nettuno MPA while other
 245 groups are not enough to ensure their propagule supply.

246
 247 **Figure 2** – Total percentages of habitats and connectivity patches protected in each MPA of the
 248 Gulf of Naples.

249 3.3 MARXAN analyses and scenarios comparison

250 Best solution percentages of PUs selected ($\%_{PUs}$) in each sector in the eight different sectors, for
 251 each scenario obtained by MARXAN runs, are shown in Figure 3. Conservation areas selected by
 252 MARXAN are mainly concentrated around islands, principally in the South and West sectors ($\%_{PUs}$
 253 $> 6\%$). In addition, the North-West sector, including the greatest patch of SFBC habitat, is also
 254 often selected ($\%_{PUs} > 4\%$). On the contrary, conservation areas are rarely selected in North-East
 255 ($\%_{PUs} < 2\%$) and East ($\%_{PUs} < 3\%$) sectors of the Gulf.

256

257 **Figure 3** – Numbers of PUs in each Gulf of Naples cardinal sector are shown for the three best
 258 solution of each scenarios a) No; b) Con_No; c) Fish; d) Con_Fish; e) Exp; f) Con_Exp; g) All; h)
 259 Con_All.

260 Comparing costs (Figure 4a), number of PUs selected and perimeter surrounding selected PUs in
 261 each scenario (Figure 4b), it appears evident that MARXAN selects less PUs in those scenarios
 262 where costs are not considered, highlighting that it can efficiently minimize selected areas , and,
 263 thus, can better meet local population needs. Moreover, without considering costs, MARXAN
 264 produces outputs characterized by the lowest amount of selected PUs and perimeter. Conservation
 265 features pairs scenarios show that, the more activities are inserted as inputs the more costs lost for
 266 prioritization are, according to other studies where stakeholders needs are considered (Ives et al.,
 267 2015; Mazor et al., 2014a, 2014b; Ruiz-frau et al., 2015). This trend seems to have no effect on the
 268 amount of PUs selected that are almost the same in those scenarios. At the end, scenarios where
 269 connectivity patches are considered need more: costs, PUs and total perimeter, than those scenarios
 270 where only habitats are considered.

271
 272 **Figure 4** – a) Costs required to achieve conservation targets. b) PUs needed to achieve conservation
 273 targets; they are correlated with the total perimeter of selected PUs.

274 PERMANOVA on the full dataset detects a significant CFxAct interaction (Table 4, bold). Such
 275 findings indicate that different considerations about conservation feature and activities produce
 276 different scenarios.

Source	df	SS	MS	Pseudo-F	P(perm)
CF	1	6804.9	6804.9	7.3938	0.0002
Act	3	33280	11093	12.053	0.0002
CFxAct	3	4412.4	1470.8	1.5981	0.0002
Total	23	59223			

277 **Table 4** - Summary of results of PERMANOVA tests for differences related to conservation
 278 features and activities factors.

279 Results of PERMANOVA are tested and validated by pair-wise test where significant statistical
 280 differences are detected within Act levels between Habitat and Connectivity scenarios, except for
 281 scenario where activities are not considered (Figure 5a). Pair wise test shows similar results
 282 comparing pairs of activities within CF levels (Figure 5b). Data of x-axis scenarios in Figures 5 are
 283 ordered from those where no activities are included (n° of activities = 0) to those where all activities
 284 are included (n° of activities = 7). All pair-wise tests show that *p*-values and number of activities
 285 included in the scenarios are strongly negatively correlated (the more activities are included in the
 286 scenarios the more they are different from each other).

295

296 **Figure 6** - MDS plot of CFxAct interaction factors. Black symbols indicate habitats as conservation
 297 features while white symbols indicate conservation features composed by habitats and connectivity
 298 patches.

299 In general, results of PERMDISP show a significant difference ($p= 0.0002$) between levels of factor
 300 CFxAct. Distances from centroids highlight negative correlation with the number of considered
 301 activities decreasing differences among scenarios (Figure 7). In particular, including patches
 302 connectivity determines more homogenous clusters (Figure 7) and thus more similar scenarios
 303 (Figure 6).

304

305 **Figure 7** - Mean ($\pm$ SE, $n = 3$) multivariate dispersion of solutions in each scenario around CFxAct
 306 centroids.

307 **3.4 Gap analysis on MPAs areas considered by MARXAN**

308 In all selected MARXAN scenarios, Regno di Nettuno and Punta Campanella MPAs show the
 309 highest contribution to the protection, $12.39\% \pm 1.1\%$ and $5.99\% \pm 1.85\%$ of their areas
 310 respectively. Although the Underwater Park of Gaiola MPA covers very low scenarios areas (1.06%
 311 $\pm 0.32\%$), its total extension is almost always selected for protection by MARXAN. On the
 312 contrary the Underwater Park of Baia is rarely selected especially in those scenarios where
 313 exploitation activities are considered (Figure 8).

314

315 **Figure 8** - MPAs areas fractions (expressed in percentages) of total selected MARXAN scenario
 316 area.

4 Discussion

In the present investigation the Gulf of Naples with its four MPAs were rightly considered as network being very close to each other.

All these MPAs present problems from conservation, social, cultural and economic points of view since their covered area is not enough to guarantee protection of natural features. In addition, they are considered by a good part of local communities as coercive tools established by central government aimed mainly at conservation objectives, making difficult all efforts needed to maintain them.

Moreover, the objective targets defined by UICN, RAC/SPA protocol, Habitat and Marine Strategy Framework Directives, cannot always be guaranteed in the MPAs of Gulf of Naples. Indeed some habitats are either completely absent (AP-GI, C-SCA) or below their own targets objectives (AP, C, SFBC and HP) in the protection design. Connectivity analysis shows similar results being sources of propagule patches not adequately protected probably due to geographically patches location. Thus, AP(PC) patches are located in areas characterized by high costs while C(PC) group is mainly composed by C-SCA habitats located at high depth, rarely taken into account for protection in Italian marine reserves.

Regno di Nettuno MPA reflects its primary vocation being established in order to protect *Posidonia oceanica* meadows, their patches propagule sources and, at same time, protecting, its exclusively habitat: SFBC-AP and SGCF-C. Similarly, the Underwater Park of Gaiola MPA is established in order to protect the roman aquaculture facilities, that created the perfect substrate for the dominants AP-C habitats, (Russo et al., 2008). In addition, its exclusive habitats are also protected: SFS, SFS-AP SGCF-C and C-SGCF.

Results of gap analyses suggest that reserves are often not sufficiently extended to ensure habitats long-term life (Airame et al. 2003; Roberts et al. 2003b; Russo et al. 2005a, 2005b; Russo and Di Stefano, 2005; Frascchetti et al. 2005b), since their areas are simply not enough and/or their propagule supply patches are often unprotected. In addition, zones contributing to species persistence are often excluded from many reserve designs (Haight and Snyder, 2009; Begger et al. 2010; Hitt et al. 2011). Results also demonstrate the needs to revise MPAs location and zonation, since most of them were established in the '90s when systematic conservation planning took its first theoretical steps.

Connectivity is a landscape-specific function dependent by habitats-patches patterns that can be described by graph theory, commonly used to evaluate terrestrial reserve connectivity (i.e. Girvan and Newman, 2002; Cabeza, 2003; Önal and Briers, 2005; Rayfield et al. 2008). Nevertheless, there are few studies that use graph theory at seascape level to assess connectivity among

351 patches(Kininmonth et al., 2010; Treml et al., 2012, 2008) and, thus, further investigations are
352 needed (Grober-Dunsmore et al. 2009). However, considering that the study area is relatively small
353 and sheltered on three sides, it was possible to use graph theory in order to assess sources propagule
354 patches of seascape, even without hydrodynamic and genetic information (Bradbury et al. 2008).
355 However, the potential contribution of each basin to enhance the dispersal propagule and the
356 consequent expansion of assemblages in the area, strongly depends on the key functional paths
357 (patterns of links and nodes) among the patches thus genetic analyses could be helpful to assess the
358 effectiveness of the method in marine realms. In the present investigation few large size patches are
359 responsible for sustaining the overall habitat connectivity, ensuring propagule supply and supplying
360 source for ecological fluxes between otherwise weakly connected habitats. At the end, even with
361 some bias, including connectivity aspects in conservation issues may help to guarantee that
362 resilience of assemblages is adequately considered for the reserve network design (Galpern et al.,
363 2011).

364 MARXAN results hold that total conservation areas needed to ensure the persistence of habitats
365 range between 4.10% and 4.26% of the whole study area. In the present study a rather simple
366 approach to incorporate connectivity into a widely used reserve-design tool (MARXAN) is
367 presented. In all eight scenarios the most important areas to be protected are located around the
368 islands. Around islands of West sector, there is the largest meadow of *Posidonia oceanica* and in
369 the South sector the largest patch of C-SCA is also present. There is an important longshore area,
370 outside the Gulf in the North-West sector, that is often selected by MARXAN where the largest
371 patch of SFBC is located. Such results emphasize that the quality of information on habitat patterns
372 substantially affect the dispersal patterns of the models (Magris et al. 2015).

373 Recent applications developed methods for quantitatively addressing connectivity in relation to
374 spatial dependences between conservation features (Edwards et al. 2009; Beger et al. 2010; White et
375 al. 2014). In this study the general question of how to include multiple-habitats connectivity into
376 planning processes is tackled, testing the common assumption that patch size and their functional
377 paths provide an accurate estimate of potential connection in heterogeneous seascapes subjected to
378 multiple stressors. Areas to be protected are also assessed by planning processes with ecologically-
379 informed connectivity parameters and thus, strong connections between different protected areas are
380 simultaneously ensured for a wide range of habitats.

381 Significant differences among scenarios including or excluding propagule source patches are
382 detected. Such finding allows MARXAN to develop more resilient scenarios, since a dynamic
383 seascape is considered (Johst et al., 2011). Seascape with many connectivity patches should better
384 resist to threats because if a source of propagules is destroyed there are many others that can ensure

385 a sufficient propagules supply. However, targets for connectivity patches are arbitrarily decided by
386 experts' judgements and it is not sure that 20% of total amount is enough to guarantee a sufficient
387 propagules supply in case of strong threats, due to the lack of experimental evidence. Multivariate
388 (PERMANOVA and PERMDISP) analyses results show that the choices of conservation features,
389 as well as costs types, have great importance in selecting different priority areas, and draw
390 significantly different scenarios on the base of the localization of the PUs selected. In particular,
391 including or excluding some activities produces differences among scenarios directly correlated
392 with the amount of human activities chosen, as highlighted by PERMDISP. The more activities are
393 considered, the fewer PUs candidate to be selected by MARXAN are, and thus activities become
394 constraints for the software producing more homogeneous replicates clusters, highlighting the
395 importance of including as many as possible activities in a marine territory.

396 In the same way, the choices on conservation features to be included in MARXAN runs influence
397 its outputs. Including habitat patches and sources of propagule, forces MARXAN to consider areas
398 where habitat and connectivity targets can be achieved together, thus lowering the number of PUs
399 candidate to be selected by MARXAN.

400 In this study the multivariate statistics are easily adapted to provide novel insights in conservation
401 planning about scenarios comparison. To date, multivariate analysis in conservation planning is
402 used to distinguish distinct groups of similar solutions of a scenario, thereby providing alternative
403 reserve configurations to decision-makers (Airame et al. 2003; Linke et al. 2011). As previously
404 pointed out (e.g. Weeks et al. 2010; Levy and Ban, 2012), different scenarios may be generated by
405 changing input data. MDS as well as more complex multivariate analyses, PERMANOVA and
406 PERMDISP, are here applied. From the data evaluation, it is possible to conclude that, although
407 MDS is a key tool to indicate which solutions should be presented to stakeholders in reserve design
408 phase, other statistical multivariate analyses, such as PERMANOVA and PERMDISP, give new
409 insights about key data driving the configuration of reserve networks designs (Harris et al. 2014). In
410 particular, PERMANOVA combined with pair-wise tests is recommended for a better
411 comprehension of the main key inputs affecting the selected PUs patterns in each scenario. On the
412 other hand, PERMDISP, measuring the heterogeneity among scenarios replicates, assesses the
413 relevance of both conservation features and costs as a unique feature characterizing each scenario.
414 Our findings show that priority areas are mainly selected on the basis of conservation features (only
415 habitats or habitats and connectivity patches); conversely, the type of costs does not produce
416 statistical differences on spatial patterns of PUs selected. This in in accordance with Weeks et al.,
417 (2010), who state that effectiveness of opportunity costs are sensitive to the spatial scale at which
418 analysis are performed. At large spatial scales costs can change dramatically from an area to another

419 in relation to culture, richness and the capacity of people to increase their welfare. On the contrary,
420 in a contest such as the Gulf of Naples, where one large population cost measure can be considered,
421 costs types do not significantly affect outputs of MARXAN.

422 However, even if MARXAN proved to be a very useful tool for conservation planning, it is
423 advisable to consult marine environmental stakeholders in order to suggest the best zoning and
424 positioning of MPAs network in the Gulf of Naples (Klein et al. 2008), since too often a mere
425 systematic approach has been used to identify systems of marine reserves along extensive
426 coastlines, neglecting important conservation and socio-economic factors (i.e. Leslie et al. 2003;
427 Klein et al. 2008; Giakoumi et al. 2013)

428 **5 Conclusions**

429 In the present investigation a method to assess the most important areas to be preserved in order to
430 ensure long term habitats life, including source of propagule patches, is suggested.

431 In order to evaluate the most important factors that influence MARXAN results, four scenarios
432 features are considered: habitats distribution and connectivity as conservation features, fishing and
433 exploitation activities as costs. Results of statistical multivariate analysis (PERMANOVA) show
434 that the choice on conservation features influences selection of priority areas. Indeed, including
435 connectivity patches forces MARXAN results to take into account areas where it is possible to
436 protect both habitat and source propagule patches. Such findings also prove that a systematic
437 approach, both in conservation and costs assessments, should always be taken into account
438 improving habitat protection and minimizing impacts of protected areas on local economies.

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