

1 **Bridging the divide: A framework for social-ecological coherence in Marine Protected Area**  
2 **network design**

3 Siân E. Rees<sup>1\*</sup>, Nicola Foster<sup>1</sup>, Olivia Langmead<sup>1,2</sup>, Charly Griffiths<sup>2</sup>, Steve Fletcher<sup>1,3</sup>, Simon  
4 J. Pittman<sup>1,4</sup>, David E. Johnson<sup>5,6</sup>, Martin Attrill<sup>1</sup>.

5 <sup>1</sup> Marine Institute, 3<sup>rd</sup> Floor Marine Building, Plymouth University, Plymouth PL4 8AA, UK.

6 <sup>2</sup> Marine Biological Association of the United Kingdom.

7 <sup>3</sup> UNEP World Conservation Monitoring Centre.

8 <sup>4</sup> National Oceanic and Atmospheric Administration.

9 <sup>5</sup> Seascope Consultants Ltd.

10 <sup>6</sup> Global Ocean Biodiversity Initiative Programme Coordinator.

11 \*Corresponding author e-mail: [sian.rees@plymouth.ac.uk](mailto:sian.rees@plymouth.ac.uk)

12

13 **Abstract**

- 14 1. Marine Protected Areas (MPAs) and networks of MPAs are being implemented  
15 globally as a spatial management tool for achieving conservation objectives. There  
16 has been considerable progress in reaching the prescribed 10 % protected area  
17 target for 2020 outlined in the Convention on Biological Diversity Aichi Target 11 and  
18 the United Nations Sustainable Development Goal 14.
- 19 2. Application of MPA network design principles (e.g. representativity, ecological  
20 connectivity) which underpin ecological coherence are still lacking or insufficient in  
21 many regions. Poor ecological coherence hinders the ecological performance of MPA  
22 networks leading to dysfunction in the flow of ecosystem services and reduced  
23 ecosystem benefits with potentially negative consequences for human wellbeing
- 24 3. This paper presents four pivotal focus points for future progress that can bridge a  
25 gap between the ecological and the social systems. The aim is to shift the discourse  
26 of “ecological coherence” further into the social sphere and hence support the  
27 alignment of the process of designating ecologically coherent MPA networks with  
28 the ‘triple bottom line’ of economic development, environmental sustainability and  
29 social inclusion as described in the SDGs to achieve social-ecological coherence in  
30 MPA network design.

31

32 Key words: Ocean, Marine Protected Areas; Sustainable Development Goals; ecosystem  
33 services; ecological coherence.

34

## 35        **1. Introduction**

36 Marine Protected Areas (MPAs) are regarded as an important tool for the maintenance of  
37 marine ecosystem functionality, health, and ecosystem integrity through the conservation  
38 of significant species, habitats, or entire ecosystems (Sobel & Dahlgren, 2004). There is  
39 growing evidence that, when properly designed, resourced and managed, MPAs are an  
40 effective spatial management tool for achieving conservation objectives (Edgar et al., 2014;  
41 Lester et al., 2009; Sciberras, Jenkins, Kaiser, Hawkins & Pullin, 2013; Sheehan, Stevens, Gall,  
42 Cousens & Attrill, 2013; Stewart et al., 2009). Developments in social-ecological systems  
43 (SES) research emphasize the crucial interdependencies between the natural and the human  
44 system (Berkes, Folke & Colding, 2000; Liu et al., 2007) (Figure 1). From a SES perspective,  
45 protecting the habitats and species, which are the subject of conservation management  
46 measures within MPAs, supports ecological functions and processes (Pollnac et al., 2010;  
47 Potts et al., 2014). In turn, this delivers flows of ecosystem services that support human  
48 wellbeing (e.g. food, flood protection, opportunities for recreation) (Arkema et al., 2013;  
49 Arkema et al., 2015; McCook et al., 2010; Pollnac et al., 2010; Potts et al., 2014; Rees et al.,  
50 2014; Rees, Rodwell, Attrill, Austen & Mangi, 2010; Roberts, Bohnsack, Gell, Hawkins &  
51 Goodridge, 2001) (Figure 1). Given the high level of functional and spatial connectivity  
52 within marine ecosystems and variable and uncertain distribution of risks from ecosystem  
53 disturbances, individual MPAs are not considered to be adequate to safeguard the  
54 important ecosystem processes and services they underpin (Jones, Srinivasan & Almany,  
55 2007; Margules & Pressey, 2000) and networks of MPAs are needed (Olsen et al., 2013).

56 Global MPA policy has developed to address the broader spatial requirements for marine  
57 conservation within this SES context. In 2004, Convention on Biological Diversity (CBD)  
58 Parties decided that “marine and coastal protected areas are essential tools and approaches  
59 in the conservation and sustainable use of marine and coastal biodiversity”, committing to a  
60 target of “effective conservation of at least 10% of each of the world’s ecological regions by  
61 2010” (UNEP/CBD/COP/DEC/VII/5). In 2010, CBD Parties adopted the Strategic Plan for  
62 Biodiversity 2011-2020, including its 20 Aichi Biodiversity Targets. Among these targets,  
63 Parties reaffirmed the importance of area-based conservation measures, including MPAs, as  
64 a tool for the conservation of biological diversity and the sustainable use of its components.  
65 Specifically, Aichi Target 11 states that, ‘by 2020, at least 17% of terrestrial and inland

66 water, and 10% of coastal and marine areas, especially areas of particular importance for  
67 biodiversity and ecosystem services, are conserved through effectively and equitably  
68 managed, ecologically representative and well-connected systems of protected areas and  
69 other effective area-based conservation measures, and integrated into the wider landscapes  
70 and seascapes' (CBD, 2010). Aichi target 11 notably expands upon the quantitative 10%  
71 spatial target for protected areas and, through the qualitative aspects (Ecologically  
72 representative; Areas of particular importance for biodiversity and ecosystem services;  
73 Management equity and effectiveness; Well-connected and; Integration into wider  
74 landscape and seascape (Rees, Foster, Langmead, Pittman & Johnson, 2017). These  
75 qualitative aspects of Aichi reflect best practices developed in MPA network design by  
76 broadening the scope of conservation planning to be more systematic (Margules & Pressey,  
77 2000) and also enable the wider consideration of the relationship between the protection of  
78 biodiversity and human wellbeing. The qualitative aspects of Aichi Target 11 link to the  
79 principles of "ecological coherence" (Ardron, 2008; Laffoley, Brockington & Gililand, 2006),  
80 whereby a "network of MPAs" (a collection of individual MPAs or reserves operating  
81 cooperatively and synergistically, at various spatial scales) is designed to

- 82 • Interact and support the wider environment (OSPAR, 2006, , Sects. 5.3, 6);
- 83 • Maintain the processes, functions, and structures of the intended protected features  
84 across their natural range (Laffoley, Brockington & Gililand, 2006);
- 85 • Function synergistically as a whole, such that the individual protected sites benefit  
86 from each other to achieve the above two objectives (based on OSPAR, 2006, , Sect.  
87 5.2);
  - 88 ○ Additionally, an ecologically coherent network of MPAs may be designed to  
89 be resilient to changing conditions (OSPAR, 2006, , Sect. 5).

90

91 In recognition of the importance of these qualitative aspects of Aichi Target 11 the  
92 Conference of the Parties to the CBD (Decision XI/24, 2012), invited Parties to undertake  
93 major efforts to achieve all elements of Aichi Biodiversity Target 11. Progress towards this  
94 goal has been slow. The fourth edition of the Global Biodiversity Outlook (GBO 4) reported  
95 that while the quantitative elements of Aichi Target 11 (the 10% protected areas target) are  
96 on track to be achieved at the global level by 2020 for marine areas within national

97 jurisdiction, the other elements relating to ecological representation, coverage of areas  
98 important for biodiversity, management effectiveness, governance, and integration of  
99 protected areas into wider seascape, still need more attention in order to be achieved  
100 (Secretariat of the Convention on Biological Diversity, 2014).

101 Since GBO 4 there has been further sustained progress towards the 10% spatial target  
102 (Lubchenco & Grorud-Colvert, 2015). The MPAtlas reports that 2.98% of the global ocean is  
103 within an MPA, with 7.29% in national jurisdictions (Marine Conservation Institute, 2017).  
104 Proposed MPAs will add a further 3.15%, with an additional 6.33% of MPAs designated  
105 within national jurisdictions (Marine Conservation Institute, 2017). Whilst this increase  
106 represents a significant achievement in terms of increasing the spatial protection of marine  
107 habitats and species within national jurisdictions, a significant gap remains in areas beyond  
108 national jurisdiction and other parameters of ecological coherence, that are the cornerstone  
109 of Aichi target 11, are potentially lost (e.g. well-connected, ecologically representative)  
110 (Jones & De Santo, 2016). Furthermore, arguments have been put forward that suggest that  
111 the 'ease of establishment' of MPAs (in some planning areas) has overridden the need to  
112 underpin ecological coherence of marine systems (Devillers et al., 2015). Overall, it can be  
113 argued that spatial targets alone, which confer no positive or negative biodiversity  
114 outcomes, will potentially undermine efforts to halt the continued degradation and loss of  
115 marine habitats and species (D. Spalding et al., 2016; Jones & De Santo, 2016) which, in turn,  
116 then further impairs the ability of marine systems to continue to provide ecosystem services  
117 that underpin human wellbeing (Worm et al., 2006).

118 Since GBO 4 a number of assessments at a regional MPA network level have been  
119 undertaken to assess whether MPA networks are ecologically coherent in their current  
120 configuration. Sub-regional assessments for parameters of ecological coherence of MPA  
121 designations in North America (Jessen, Morgan & Bezaury-Creel, 2016); The Caribbean  
122 (Pittman et al., 2014); the UK (Lieberknecht, Mullier & Ardron, 2014; Ridgeway,  
123 Cornthwaite, Wright & Davies, 2014); Northern Ireland (Barnard, Burdon, Strong & Atkins,  
124 2014); the Celtic Seas (Rees, Foster, Langmead & Griffiths, 2015b); the OSPAR region  
125 (Johnson et al., 2014; OSPAR, 2013); Chile (Tognelli, Fernández & Marquet, 2009); The  
126 English Channel (Foster et al., 2014); the Baltic (Piekäinen & Korpinen, 2008); and the NE  
127 Atlantic (Evans, Peckett & Howell, 2015), demonstrate that whilst progress is being made

128 towards the 10% protected area target, and some areas are moving towards ecological  
129 coherence, none of the existing MPA networks are ecologically representative of the full  
130 range of ecosystems nor are they well-connected. Additionally, whilst there has been  
131 progress towards the development of methods to assess management effectiveness  
132 (Hockings, Stolton, Leverington, Dudley & Courrau, 2006; International Union for the  
133 Conservation of Nature, 2016). Regional assessments of management effectiveness reveal a  
134 lack of progress in meeting conservation objectives and establishing management plans for  
135 networks of protected areas (OSPAR, 2013; Rodríguez-Rodríguez, Rodríguez & Abdul Malak,  
136 2016). There is also lack of a formal process for reporting management effectiveness at a  
137 national level scale to support regional assessments (Foster et al., 2014; OSPAR, 2013).

### 138 *1.1 A new policy context*

139 Further priority is given to the relationship between oceans and human wellbeing in the  
140 United Nations (UN) Sustainable Development Goals (SDGs), designed to succeed the  
141 Millennium Development Goals (MDGs) as reference goals for the international  
142 development community for the period 2015-2030. The SDGs advocate a 'triple bottom line'  
143 approach to maintaining human wellbeing; these being economic development,  
144 environmental sustainability and social inclusion (Sachs, 2012). SDG Goal 14 to 'conserve  
145 and sustainably use the oceans, seas and marine resources for sustainable development'  
146 reaffirms the CBD 10% spatial target (SDG 14.5), but places this ecological goal firmly within  
147 the economic and social context of SES to aid global development (Figure 1). There are  
148 notable alignments between Aichi Target 11 and the SDGs not only in terms of SDG 14, but  
149 also in terms of synergies with Goal 1: End poverty in all its forms everywhere and; Goal 13:  
150 Take urgent action to combat climate change and its impacts (Diz, Morgera & Wilson, 2017;  
151 Rees, Foster, Langmead, Pittman & Johnson, 2017).

152 The SDGs provide an opportunity to address a more fundamental issue. Namely, global  
153 conservation policy in relation to the marine environment has seen major advances in  
154 recent years but the building blocks of conservation planning (the broader goals of achieving  
155 ecological coherence in conservation planning) are not following the same trajectory. It is  
156 noted that the discipline of conservation biology (from where ecological coherence is  
157 rooted) has grown from the 'deep green' idea that nature has an intrinsic value and that we

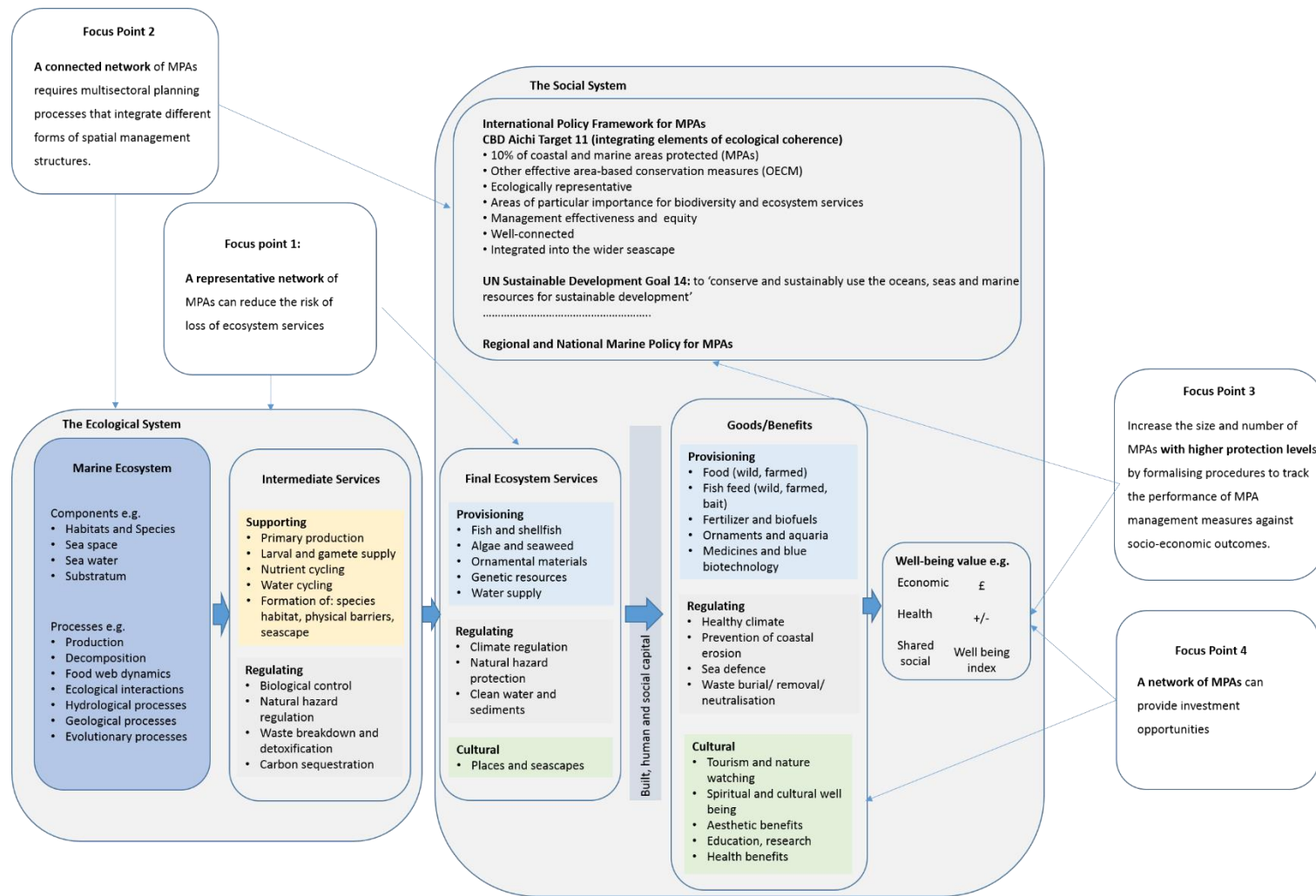
158 should protect nature ‘for nature’s sake’ (Vucetich, Bruskotter & Nelson, 2015). This idea, is  
159 shared, to some extent, by the general populous but is limited by a broad spectrum of  
160 factors such as: other competing values; institutional frameworks; social norms and;  
161 knowledge of what is or is not acceptable in terms of ‘harm’ to nature (burden of proof)  
162 (Vucetich, Bruskotter & Nelson, 2015). This ‘deep green’ idea has, in the past, pervaded in  
163 the development of conservation policy, which often appears to lack any explicit connection  
164 between the ecological and the social system. In addressing this gap there has been a  
165 movement to “restore and reemphasize the fundamental links between nature and human  
166 wellbeing” though the development and application of the ecosystem services framework  
167 to conservation policy (Armsworth et al., 2007; Millennium Ecosystem Assessment, 2005;  
168 Natural Capital Committee, 2014; TEEB, 2010).

169 Increasingly, it is becoming recognized that approaches rooted firmly in ecological science  
170 are not the only solution to conservation issues (Hicks et al., 2016). Here we present a set of  
171 four focus points (Figure 1) for future development that can construct a bridge between the  
172 ecological and the social systems. The aim is to shift the discourse on “ecological coherence”  
173 further into the social sphere and hence support the alignment of the process of designating  
174 ecologically coherent MPA networks with the ‘triple bottom line’ of economic development,  
175 environmental sustainability and social inclusion as described in the SDGs to achieve social-  
176 ecological coherence in MPA network design.

177

178 **Figure 1:** The social-ecological system. Marine ecosystems are essential to maintain human wellbeing. The links between ecosystems (marine)  
 179 and human well-being (adapted from NCC 2012) REF The policy frameworks from the CBD Aichi Target 11 and the UN Sustainable  
 180 Development Goal 14 influence how marine ecosystems are managed with the aim to underpin human wellbeing. Four focus points are  
 181 presented to develop social-ecological coherent MPA network.

182





183 [Figure 1 here]

## 184 2. Focus points

### 185 **Focus point 1: A representative network of MPAs is more likely to reduce the risk of loss of** 186 **ecosystem services**

187 Representativity refers to the inclusion of the full range of ecosystems, habitats, biotic  
188 diversity, ecological processes, and environmental gradients (e.g. depth, wave exposure)  
189 within the MPA network (HELCOM, 2010; OSPAR, 2006; Roberts et al., 2003; Rondinini,  
190 2010; UNEP-WCMC, 2008). The objective in applying this criterion to MPA networks is to  
191 ensure representative coverage of all biodiversity and biogeographic regions within the  
192 network (Jackson, Hiscock, Evans, Seeley & Lear, 2008; Roberts et al., 2003). The key  
193 premise behind representativity is that the full range of biodiversity is protected worldwide.  
194 This includes the species, as well as evolutionary patterns, distinct communities, refugia  
195 habitats in anticipation of environmental change and a range of key ecological processes  
196 that sustain global biodiversity (Spalding et al., 2007). Also, often included in processes for  
197 MPA network design, is a criterion for 'replication'. Replication of habitats and species  
198 within an MPA network aims to ensure natural variation and to minimize the effects of  
199 damaging events and long-term changes (resilience), adequate replication of all habitats and  
200 species is recommended within MPA networks (HELCOM, 2010; OSPAR, 2007). Replication  
201 enhances the resilience of ecosystems to change and reduces the possibility that  
202 catastrophic events may wipe out entire populations of species or habitats within the  
203 network (HELCOM, 2010; OSPAR, 2007; Roberts et al., 2003).

204 Representativity (and replication) of species and habitats within an MPA network aims to  
205 underpin ecological resilience and to spread risk (of permanent loss, regime shifts) across a  
206 geographically broad region. From a social perspective the notion of 'insurance' is familiar  
207 for material goods. The valuation of goods and benefits derived from marine ecosystems  
208 falls firmly within the social system (Figure 1). According to the insurance hypothesis from  
209 an ecological perspective, biodiversity can provide insurance for ecosystems against  
210 potential future declines in their functioning because the more species that are present  
211 provides a greater likelihood that some will maintain functioning even if others are lost  
212 (Naeem & Li, 1997). Although species diversity does not necessarily guarantee high

213 resilience, in theory, ecosystems with high functional redundancy (functional overlap) will  
214 be more robust to loss of species than ecosystems with low functional redundancy (Naeem  
215 1998). In coastal marine systems, however, limited research indicates that low functional  
216 redundancy could be typical even in the highest diversity ecosystems such as coral reefs  
217 (Micheli & Halpern 2005), yet very little is known about seascape redundancy with  
218 reference to habitat patch types. Ultimately, the loss of functional processes or regime shifts  
219 can impact upon the realization or delivery of ecosystem services that support human  
220 wellbeing (Folke et al., 2004).

221 Several researchers have argued that the CBD target of 10% is too low to achieve the  
222 objective of protecting biodiversity underpinning ecosystem services and meeting  
223 socioeconomic priorities (O'Leary et al., 2016). At the 2016 IUCN World Conservation  
224 Congress in Hawai'i, Resolution 50 calls on the Director General and the IUCN to "designate  
225 and implement at least 30% of each marine habitat in a network of highly protected MPAs  
226 and other effective area based conservation measures (OECMs), with the ultimate aim of  
227 creating a fully sustainable ocean, at least 30% of which has no extractive activities, subject  
228 to the rights of indigenous peoples and local communities" (IUCN, 2016). Proposals to  
229 achieve this encourage IUCN State and Government Agency Members to commit to a  
230 programme of work to designate and implement 30% of national waters as MPAs and  
231 OECMs; to engage in the process of establishing MPAs in areas beyond national jurisdiction  
232 (ABNJ) and to develop a new legally-binding instrument under the United Nations Law of  
233 the Sea "for the conservation and sustainable use of marine biological diversity in areas  
234 beyond national jurisdiction, and that such a new instrument contains a robust mechanism  
235 for establishing effectively and equitably managed, ecologically representative and well  
236 connected systems of marine protected areas, including reserves. Additionally IUCN  
237 member States are urged to accelerate progress towards achieving Aichi Target 11 and all  
238 Parties to the CBD are encouraged to develop post 2020 targets to achieve spatial  
239 management measures via MPAs for 30% of marine areas.

240 It must be noted that IUCN resolutions do not have any legal standing and that it is  
241 governments and competent international organisations that must further these resolutions  
242 into national and international policy. From a social perspective, SDG14 aims for the  
243 conservation and sustainable use of all the oceans, seas and marine resources, underpinned

244 by networks of MPAs (10% spatial coverage). Processes to determine the risk of loss of  
245 ecosystem goods and benefits and identify the potential societal consequences in relation  
246 to current levels of representativity within MPA networks may resonate further with  
247 governments and civil society to increase ambition for marine conservation (and sustainable  
248 resource use). There are recent innovations in next generation risk assessments for coupled  
249 natural-human systems (Elliott et al., 2017; Holsman et al., 2017) that can be applied to  
250 marine systems. At this stage, however, without an understanding of risk, an ecologically  
251 representative network of MPAs (meeting the CBD Aichi target 11 and SGD 14 10% target)  
252 may only be considered as a minimum spatial requirement to 'insure' for human wellbeing.

253 **Focus point 2: A connected network of MPAs requires multisectoral planning processes**  
254 **that integrate different forms of spatial management structures.**

255 Functional connectivity in ecological systems describes the extent to which populations in  
256 different parts of a species' range are linked by the exchange of eggs, larvae, recruits or  
257 other propagules, juveniles or adults (Palumbi, 2003). The connectivity between two  
258 populations is dependent on: (i) the larval characteristics of the species (e.g. duration of the  
259 planktonic stage and swimming behaviour of propagules), (ii) the abundance of the source  
260 population, (iii) the availability and suitability of surrounding habitat, and (iv) the  
261 characteristics of the physical environment (e.g. speed and direction of ocean currents,  
262 temperature, salinity) (Shanks, Grantham & Carr, 2003; Treml, Halpin, Urban & Pratson,  
263 2008). The movements of adult life stages also influences connectivity and MPA  
264 performance and therefore requires consideration in MPA network design (Green et al.,  
265 2015; IUCN-WCPA, 2008; Olds et al., 2016). Understanding larval dispersal and marine  
266 population connectivity remains a highly complex analytical challenge. Processes to model  
267 connectivity require interdisciplinary approaches that combine high-resolution biophysical  
268 modeling and empirical data on movement capabilities of individual species (Cowen,  
269 Gawarkiewicz, Pineda, Thorrold & Werner, 2007).

270 Progress towards MPA networks that are considered well-connected are usually based on  
271 broad structural connectivity metrics that serve as spatial proxies for actual functional  
272 connectivity e.g. distance between MPAs. Geopolitical boundaries such as territorial limits  
273 of sovereign nations (i.e. exclusive economic zone boundaries) often appear to hamper

274 structural connectivity between MPA networks. Recent sub-regional assessments reveal  
275 that there is virtually no connectivity of MPAs across jurisdictional boundaries (Foster et al.,  
276 2014; Jessen, Morgan & Bezaury-Creel, 2016; Rees, Foster, Langmead & Griffiths, 2015a). As  
277 stated earlier there also remain relatively few MPAs in ABNJ (Marine Conservation Institute,  
278 2017). Whilst understanding connectivity and translating this to MPA network planning  
279 remains challenging, the gaps in connectivity point towards a compounding societal  
280 challenge of how to further marine biodiversity protection in synergy with other  
281 management structures that operate across jurisdictional boundaries and in ABNJ.

282 The potential for OECMs aside from statutory MPAs to contribute to ecologically  
283 representative and well-connected MPA networks is increasingly receiving attention  
284 (Borrini-Feyerabend et al., 2014; Diz et al., 2017; Dunn, Maxwell, Boustany & Halpin, 2016;  
285 Jonas, Barbuto, Jonas, Kothari & Nelson, 2014; Laffoley et al., 2017; Spalding, Meliane,  
286 Milam, Fitzgerald & Hale, 2013; Woodley et al., 2012). There is currently no formal  
287 definition of an OECM under the CBD though a IUCN Task Force on ‘Other Effective Area  
288 based Conservation Measures’ has, so far, defined OECMs as “a geographical space where  
289 de-facto conservation of nature and associated ecosystem services and cultural values is  
290 achieved and expected to be maintained in the long term regardless of specific recognition  
291 and dedication” (Borrini-Feyerabend et al., 2014).

292 Potential OECMs may include some of the spatial management measures of Regional  
293 Fisheries Management Organizations (RMFOs) some of which, such as Vulnerable Marine  
294 Ecosystems (VMEs), are coincidental or overlap with Ecologically or Biologically Significant  
295 Areas (EBSAs) described by CBD Regional Workshops (Johnson et al., in review). The North  
296 East Atlantic Fisheries Commission (NEAFC) has been identified as an RFMO that has  
297 implemented ‘good practice’ through enacting closures to protect deep sea ecosystems  
298 from bottom towed fishing gear (Hoydal, Johnson & Hoel, 2014; Wright, Ardron, Gjerde,  
299 Currie & Rochette, 2015). In Australia, spatial closures that are enacted for fisheries by the  
300 Australian Fisheries Management Authority (AFMA) exceed the spatial extent of areas that  
301 are designated as Commonwealth Marine Reserves (CMR). It is argued by Bax and Cresswell  
302 (2012) that AMFA regulated areas are more restrictive on fishing activities than the  
303 proposed zonation of fisheries activities in the CMRs. Similar arguments can be put forward  
304 for environmental protection measures implemented by the International Maritime

305 Organization (Particularly Sensitive Sea Areas, Special Areas) and the International Seabed  
306 Authority (Areas of Particular Environmental Interest). Diz et al (2017) also describe how  
307 locally managed marine areas (LMMAs) with targeted biodiversity conservation can support  
308 fishing communities.

309 From an SES perspective and to improve social and ecological coherence of MPA networks  
310 though connectivity there is a need for States and competent international organizations to  
311 collaborate to join up and recognize areas of ecological significance that support the  
312 delivery of ecosystem goods and benefits and to coordinate protective measures through  
313 multi sectoral planning to achieve this end.

314 There remains a diverse set of sectoral and political interests involved in the establishment  
315 of multilateral agreements between countries for the protection of shared resources. From  
316 a national perspective, ocean policy needs to reflect the importance of connected marine  
317 ecosystems with an interdepartmental structure that mandates this policy. Moving forward  
318 with such structures it should be considered a priority to invest in capacity building to train  
319 practitioners with interdisciplinary skills who can facilitate the inclusion of a diverse set of  
320 stakeholders into new shared governance structures to develop equitable rights and  
321 management with regards to a network of MPAs and OECMs that is both socially and  
322 ecological coherent. For ABNJ the prospect of a future legally binding “Implementing  
323 Agreement for the protection of biodiversity beyond national jurisdiction” (BBNJ), with a  
324 proposed focus on four distinct topics (the so-called “package”) and one being area-based  
325 management tools, provides an important opportunity to make progress on this focus point  
326 (Long & Rodriguez Chaves, 2015) .

327 **Focus point 3. Increase the size and number of MPAs with higher protection levels by**  
328 **formalising procedures to track the performance of MPA management measures against**  
329 **socio-economic outcomes.**

330 The World Commission on Protected Areas (WCPA) states that the ecological coherence of  
331 MPA networks is supported by sites with a range of protection levels that are designed to  
332 meet objectives that a single reserve cannot achieve (WCPA/IUCN, 2007). Indeed those  
333 areas that have proven to have the most benefits for biodiversity are ‘no-take’ marine  
334 reserves (IUCN Ia Strict Nature Reserve) where extractive activities are strictly controlled

335 (Edgar et al., 2014; Sciberras, Jenkins, Kaiser, Hawkins & Pullin, 2013). From a perspective of  
336 habitat recovery, some no-take MPAs have been shown to support complete shifts in the  
337 structure of ecosystems and reversal of trophic cascades (Behrens & Lafferty, 2004;  
338 Guidetti, 2007; Salomon, Shears, Langlois & Babcock, 2008). The potential of these highly  
339 protected sites to enhance sustainable economic development is strongly supported with  
340 evidence in the academic literature (Aburto-Oropeza et al., 2008; Halpern, Lester & Kellner,  
341 2009; McCook et al., 2010). However, the practical reality is that no-take MPAs, particularly  
342 in the nearshore environment, are largely viewed as being unequitable and have, in many  
343 places, been difficult to implement because of social and political opposition (Agardy et al.,  
344 2003).

345 Equity, the premise that there is a fair distribution of benefits and costs between individuals  
346 and groups of people, is a subject that is recognized as having a potential to influence  
347 intended conservation outcomes (Tallis, Polasky, Lozano & Wolny, 2012) and it is  
348 embedded in the Aichi Target 11 text. Some accounts emerging from the academic  
349 literature demonstrate how supporting studies that document the ecological, social and  
350 economic impacts of MPA management measures (i.e. proof of the societal benefits of  
351 protection) can convince stakeholders of the efficacy area with higher protection levels  
352 (Erisman et al., 2017; Oliver et al., 2015; Rees et al., 2016; Vandeperre et al., 2011). From a  
353 community perspective these sites are essentially 'control sites' that support experimental  
354 design to robustly demonstrate the impact of management measures on the ecological  
355 system (e.g. reef recovery (Sheehan, Stevens, Gall, Cousens & Attrill, 2013)) and  
356 consequently benefits to the socio-economic system (e.g. increased landings (Rees et al.,  
357 2016)).

358 From a perspective of social-ecological coherence and achieving higher protection levels  
359 there is a need to formalize equity in the decision making process and track MPA  
360 performance beyond biological metrics. This can be achieved through the development of  
361 protocols for the monitoring and reporting on the effectiveness of MPAs (at an individual  
362 site and network level) that include socio-economic performance indicators (monetary and  
363 non-monetary) alongside conservation objectives for an MPA to reveal which characteristics  
364 of MPAs are most beneficial and acceptable to communities and how management  
365 measures can promote these.

366 Lessons can be learnt from behavioral psychology in that peoples' intentions to choose pro-  
367 environmental behavior (e.g. to agree and comply with no-take zones) is predominantly  
368 influenced by self-interest and pro-social motives (Bamberg & Möser, 2007). Areas with  
369 higher protection levels that can be used as 'control sites' for scientific monitoring  
370 essentially support equity via the opportunity for interested parties to be involved with  
371 rather than excluded from MPA management. This is an alternative consensus building  
372 approach, grounded in motivations that support human well-being (what can the MPA  
373 provide for me/my community), which may, in the long-term lead to greater social  
374 acceptability and broader spatial protection at higher levels.

387 **Focus point 4: Networks of MPAs can provide investment opportunities.**

388 Policy appraisal tools, applied by governments, are essential to consider the wider costs and  
389 benefits to society of an intervention, e.g. an MPA or a network of MPAs. Progress towards  
390 designation of ecologically coherent MPA networks, has, in some cases, slowed down or  
391 ground to a halt when subject to a policy appraisal at the government level (McGowan &  
392 Possingham, 2015; Rees et al., 2015). For example, Fletcher et al (2015) highlight a number  
393 of weaknesses in the recent Impact Assessment (IA) undertaken by UK Government to take  
394 forward the designation of the second round of MPAs (Marine Conservation Zones) required  
395 to work towards an ecologically coherent network of MPAs in England and Wales~~the UK.~~  
396 Costs are presented as quantified monetary values calculated using conventional economic  
397 assessment methods adapted to specific marine sectors, whereas benefits are described in  
398 non-monetary qualitative terms using an ecosystem services framework not tailored to  
399 specific sectors. This difference in methodology limits the policy appraisal tool's ability to  
400 fairly assess the costs and benefits of effective conservation. Furthermore, no method is  
401 employed in the IA to take into account the cost of inaction (i.e. of doing nothing) despite  
402 evidence that demonstrates that there are opportunity costs associated with delayed  
403 conservation action or inaction (Grantham, Wilson, Moilanen, Rebelo & Possingham, 2009)  
404 and that the overall health and functionality of the marine environment is deteriorating  
405 (Jackson et al., 2001; Lotze et al., 2006; Worm et al., 2006), thus, requiring a corresponding  
406 declining economic baseline. Additionally, there is no consideration of the benefits of an  
407 ecologically coherent network of MPAs versus site-based costs. The result of this policy  
408 appraisal process is that where an MPA is contested, (considered to be inequitable though

409 for example, loss of income, opportunity or rights) then gaps appear in the MPA network  
410 that undermine ecological coherence. It is argued that such contention can lead to a  
411 network of 'residual' MPAs that afford no step-change in the management of activities and  
412 therefore no additional benefits for biodiversity (Devillers et al., 2015).

413 Undeniably the purpose of policy appraisal processes are to define social and economic  
414 equity in the decision-making processes and this can identify inequitable trade-offs between  
415 biodiversity conservation and socio-economic objectives. However, equity is more than a  
416 narrow trade-off between resource use and rights occurring directly within the boundaries  
417 of the MPA. MPAs may have both localised and broader societal benefits. A series of studies  
418 in different parts of the world are contributing to a body of evidence that supports this. For  
419 example, an economic investment by the US government (American Recovery and  
420 Reinvestment Act of 2009) to restore degraded coastal habitat (blue infrastructure) has led  
421 to job creation in the short term, further economic benefits through the rebuilding of  
422 fisheries and coastal tourism and benefits to coastal economies, such as higher property  
423 values and improved water quality (Edwards, Sutton-Grier & Coyle, 2013). McCook et al.  
424 (2010) demonstrate that the economic returns of the rezoning of the Great Barrier Reef  
425 Marine Park are estimated to be 130 times greater than the cost of management. Further  
426 protection for corals and fish could potentially have knock on benefits (opportunity costs)  
427 for the tourist industry and commercial fisheries (McCook et al., 2010). Arkema et al. (2015)  
428 showed that presence of intact reefs and coastal vegetation reduce the likelihood and  
429 magnitude of losses resulting from extreme weather events and sea-level rise. Jackson,  
430 Rees, Wilding, & Attrill (2015) demonstrate that, by providing habitat for species during  
431 essential life history stages, seagrass (*Posidonia oceanica*) meadows are worth around €78  
432 million every year to commercial fishing and €112 million to recreational fishing in the  
433 Mediterranean. Investment in effective conservation will underpin this value and the  
434 associated employment. In the U.S. Virgin Islands, economic valuation has estimated that  
435 nearshore coral reefs are worth approximately US\$200 million annually (Van-Beukering,  
436 Brander, Zanten, Verbrugge & Lems, 2011) and in Hawai'i are estimated at US\$360 million  
437 per year (Cesar & Beukering, 2004). These are powerful socio-political arguments for  
438 investment in conservation.



439 New strategies are required from Governments to move decision-making beyond site-based  
440 cost benefit analysis towards broader strategies for investment in ecosystems (Natural  
441 Capital Committee, 2014). It is possible for identified centralized costs (e.g. enforcement or  
442 management) to become opportunities for investment (supporting sustainable growth) or  
443 offsetting (loss of jobs) rather than a direct trade off against site based ecosystem service  
444 benefits. Flagship projects led by national governments that integrate investment (both  
445 public and private) with the conservation of priority biodiversity areas e.g. The Brazil Blue  
446 Fund are pioneers in the development of coastal and marine conservation strategies that  
447 aim to underpin sustainable development in a new accounting model. Exactly how an  
448 'ecology coherent' network of MPAs may support such investment strategies is yet to be  
449 fully substantiated. However, the reduction of risk (of loss of benefits) through planning for  
450 aspects of ecological coherence, such as representativity of habitats and species within an  
451 MPA network (focus point one), along with case studies that demonstrate positive social  
452 and economic outcomes (Focus point 3) would seem to support such investment strategies.  
453 Such an approach might enable MPA managers to become more influential in marine spatial  
454 planning activities that envision future scenarios of the optimal use and allocation of  
455 maritime space.

### 456 **3. Conclusion**

457 Despite the development of appropriate criteria, thresholds and policy frameworks (to  
458 develop ecologically coherent networks of MPAs, overall progress towards achieving them is  
459 slow. Whilst biodiversity considerations underpin MPA selection, the SDGs with their 17  
460 goals to "transform our world" are broadening the focus of ecological sustainability to  
461 encompass social and economic objectives. This leads us to a wider consideration of how  
462 conservation can underpin human well-being and how the current drive towards  
463 ecologically coherent networks of MPAs can be aligned with broader policy objectives.

464 The key premises are that 1) MPAs are an effective spatial management tool for achieving  
465 conservation objectives; and 2) Ecologically coherent networks support the high level of  
466 functional and spatial connectivity within marine ecosystems so that the network as a whole  
467 supports those ecosystem services that underpin human wellbeing. The focus points  
468 presented here are directed at those in a position to influence MPA policy and/or MPA

469 management with the intention of shifting the discourse of “ecological coherence” into the  
470 social and economic sphere. Reframing the discourse for ecological coherence in this way  
471 offers opportunities for integration with other disciplines beyond conservation biology such  
472 as individuals or groups that specialize, for example, in risk management, finance,  
473 investment, natural capital assessments and performance management. There are also  
474 opportunities for new partnerships with wider stakeholder groups who operate in the  
475 marine environment but under different sectoral management strategies e.g. ocean energy.  
476 Such integration may advance progress towards the aim of ecologically coherent networks  
477 of MPAs and therefore support the ecological, social and economic goals (the ‘triple bottom  
478 line’ of sustainable development) outlined in the SDGs.

479

480        **4. Acknowledgements**

481        The authors would like to thank WWF who funded the ‘Assessment of the Ecological  
482        coherence of the Celtic Seas MPA network’ which initiated ideas for this paper. Also the  
483        participants of the ‘Expert meeting’ to share experiences and lessons learned on achieving  
484        qualitative elements of Aichi Target 11 in marine and coastal areas, convened by the  
485        Secretariat of the Convention on Biological Diversity and the Secretariat of the Global Ocean  
486        Biodiversity Initiative (Berlin, 24-26 February 2016) whose ideas and discussions informed  
487        this paper. The outputs presented here reflect the views of the named authors and are not  
488        the consensus of the CBD expert group. This work was funded with ‘in-kind’ support from  
489        the authors’ institutions. DJ would like to recognize support from the Global Ocean  
490        Biodiversity Initiative International Climate Initiative supported financially by the German  
491        government, Federal Ministry for the Environment, Nature Conservation, Building and  
492        Nuclear Safety, (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit)  
493        (BMUB)).

494

495        **5. References**

- 496        Aburto-Oropeza, O., Ezcurra, E., Danemann, G., Valdez, V., Murray, J. & Sala, E. (2008)  
497        'Mangroves in the Gulf of California increase fishery yields'. *Proceedings of the National*  
498        *Academy of Sciences*, 105 (30), pp. 10456-10459.
- 499  
500        Agardy, T., Bridgewater, P., Crosby, M. P., Day, J., Dayton, P. K., Kenchington, R., . . . Peau, L.  
501        (2003) 'Dangerous targets? Unresolved issues and ideological clashes around marine  
502        protected areas'. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 13 (4), pp. 353-  
503        367.
- 504  
505        Ardron, J. A. (2008) 'The challenge of assessing whether the OSPAR network of marine  
506        protected areas is ecologically coherent'. *Hydrobiologia*, 606 pp. 45-53.
- 507  
508        Arkema, K. K., Guannel, G., Verutes, G., Wood, S. A., Guerry, A., Ruckelshaus, M., . . . Silver,  
509        J. M. (2013) 'Coastal habitats shield people and property from sea-level rise and storms'.  
510        *Nature Clim. Change*, 3 (10), pp. 913-918.
- 511  
512        Arkema, K. K., Verutes, G. M., Wood, S. A., Clarke-Samuels, C., Rosado, S., Canto, M., . . .  
513        Guerry, A. D. (2015) 'Embedding ecosystem services in coastal planning leads to better  
514        outcomes for people and nature'. *Proceedings of the National Academy of Sciences*, 112  
515        (24), pp. 7390-7395.
- 516  
517        Armsworth, P. R., Chan, K. M. A., Daily, G. C., Ehrlich, P. R., Kremen, C., Ricketts, T. H. &  
518        Sanjayan, M. A. (2007) 'Ecosystem-Service Science and the Way Forward for Conservation'.  
519        *Conservation Biology*, 21 (6), pp. 1383-1384.
- 520  
521        Bamberg, S. & Möser, G. (2007) 'Twenty years after Hines, Hungerford, and Tomera: A new  
522        meta-analysis of psycho-social determinants of pro-environmental behaviour'. *Journal of*  
523        *Environmental Psychology*, 27 (1), pp. 14-25.
- 524  
525        Barnard, S., Burdon, D., Strong, J. & Atkins, J. (2014) *The Ecological Coherence and Economic*  
526        *& Social Benefits of the Northern Ireland MPA Network*. Hull, UK, (Report No. YBB238-F-  
527        2014). Available.
- 528  
529        Bax, N. & Cresswell, I. (2012) Marine reserves not about closing fisheries, but about  
530        preserving ocean health. *The Conversation. The Conversation Trust (UK) Limited.*,
- 531  
532        Behrens, M. D. & Lafferty, K. D. (2004) 'Effects of marine reserves and urchin disease on  
533        southern Californian rocky reef communities'. *Marine Ecology Progress Series*, 279 pp. 129-  
534        139.

535  
536 Berkes, F., Folke, C. & Colding, J. (2000) *Linking Social and Ecological Systems: Management*  
537 *Practices and Social Mechanisms for Building Resilience*. Cambridge: University Press.

538  
539 Borrini-Feyerabend, G., P. , Bueno, T., Hay-Edie, B., Lang, A., Rastogi, A. & Sandwith, T.  
540 (2014) *A primer on governance for protected and conserved areas, Stream on Enhancing*  
541 *Diversity and Quality of Governance*. Gland, Switzerland: IUCN. Available.

542  
543 CBD (2010) 'Convention on Biological Diversity. COP 10. Decision X/2.Strategic Plan for  
544 Biodiversity 2011-2020'.

545  
546 Cesar, H. S. J. & Beukering, P. v. (2004) 'Economic Valuation of the Coral Reefs of Hawai'i'.  
547 *Pacific Science*, 58 (2), pp. 231-242.

548  
549 Cowen, R. K., Gawarkiewicz, G., Pineda, J., Thorrold, S. R. & Werner, F. E. (2007) 'Population  
550 Connectivity in Marine Systems An Overview'. *Oceanography*, 20 (3), pp. 14-21.

551  
552 D. Spalding, M., Meliane, I., J. Bennett, N., Dearden, P., G. Patil, P. & D. Brumbaugh, R.  
553 (2016) 'Building towards the marine conservation end-game: consolidating the role of MPAs  
554 in a future ocean'. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26 pp. 185-  
555 199.

556  
557 Devillers, R., Pressey, R. L., Grech, A., Kittinger, J. N., Edgar, G. J., Ward, T. & Watson, R.  
558 (2015) 'Reinventing residual reserves in the sea: are we favouring ease of establishment  
559 over need for protection?'. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 25  
560 (4), pp. 480-504.

561  
562 Diz, D., Johnson, D., Riddell, M., Rees, S., Battle, J., Gjerde, K., . . . Roberts, J. M. (2017)  
563 'Mainstreaming marine biodiversity into the SDGs: The role of other effective area-based  
564 conservation measures (SDG 14.5)'. *Marine Policy*,

565  
566 Diz, D., Morgera, E. & Wilson, M. (2017) 'Marine policy special issue: SDG synergies for  
567 sustainable fisheries and poverty alleviation'. *Marine Policy*,

568  
569 Dunn, D. C., Maxwell, S. M., Boustany, A. M. & Halpin, P. N. (2016) 'Dynamic ocean  
570 management increases the efficiency and efficacy of fisheries management'. *Proceedings of*  
571 *the National Academy of Sciences*, 113 (3), pp. 668-673.

572

573 Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., . . .  
574 Thomson, R. J. (2014) 'Global conservation outcomes depend on marine protected areas  
575 with five key features'. *Nature*, 506 (7487), pp. 216-220.

576  
577 Edwards, P. E. T., Sutton-Grier, A. E. & Coyle, G. E. (2013) 'Investing in nature: Restoring  
578 coastal habitat blue infrastructure and green job creation'. *Marine Policy*, 38 pp. 65-71.

579  
580 Elliott, M., Burdon, D., Atkins, J. P., Borja, A., Cormier, R., de Jonge, V. N. & Turner, R. K.  
581 (2017) "'And DPSIR begat DAPSI(W)R(M)!" - A unifying framework for marine environmental  
582 management'. *Marine Pollution Bulletin*, 118 (1), pp. 27-40.

583  
584 Erisman, B., Heyman, W., Kobara, S., Ezer, T., Pittman, S., Aburto-Oropeza, O. & Nemeth, R.  
585 S. (2017) 'Fish spawning aggregations: where well-placed management actions can yield big  
586 benefits for fisheries and conservation'. *Fish and Fisheries*, 18 (1), pp. 128-144.

587  
588 Evans, J. L., Peckett, F. & Howell, K. L. (2015) 'Combined application of biophysical habitat  
589 mapping and systematic conservation planning to assess efficiency and representativeness  
590 of the existing High Seas MPA network in the Northeast Atlantic'. *ICES Journal of Marine  
591 Science: Journal du Conseil*,

592  
593 Fletcher, S. & Rees, S. (2015) *Marine Conservation Zone Impact Assessment Review. A  
594 report for The Wildlife Trusts by the Centre for Marine and Coastal Policy Research,  
595 Plymouth University*. 31 pp. Available.

596  
597 Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. & Holling, C. S.  
598 (2004) 'Regime Shifts, Resilience, and Biodiversity in Ecosystem Management'. *Annual  
599 Review of Ecology, Evolution, and Systematics*, 35 (1), pp. 557-581.

600  
601 Foster, N. L., Sciberras, M., Jackson, E., Ponge, B., Toison, V., Carrier, S., . . . Attrill, M. (2014)  
602 *Assessing the Ecological Coherence of the Channel MPA Network. Report prepared by the  
603 Marine Institute for the Protected Area Network Across the Channel Ecosystem (PANACHE)  
604 project. INTERREG programme France (Channel) England funded project*. 156 pp. Available.

605  
606 Grantham, H. S., Wilson, K. A., Moilanen, A., Rebelo, T. & Possingham, H. P. (2009) 'Delaying  
607 conservation actions for improved knowledge: how long should we wait?'. *Ecology Letters*,  
608 12 (4), pp. 293-301.

609  
610 Green, A. L., Maypa, A. P., Almany, G. R., Rhodes, K. L., Weeks, R., Abesamis, R. A., . . .  
611 White, A. T. (2015) 'Larval dispersal and movement patterns of coral reef fishes, and  
612 implications for marine reserve network design'. *Biological Reviews*, 90 (4), pp. 1215-1247.

613  
614 Guidetti, P. (2007) 'Potential of Marine Reserves to Cause Community-Wide Changes  
615 beyond Their Boundaries

616 EL Potencial de Reservas Marinas para Provocar Cambios a Nivel de Comunidad Más Allá de  
617 sus Límites'. *Conservation Biology*, 21 (2), pp. 540-545.

618  
619 Halpern, B. S., Lester, S. E. & Kellner, J. B. (2009) 'Spillover from marine reserves and the  
620 replenishment of fished stocks'. *Environmental Conservation*, 36 (04), pp. 268-276.

621  
622 HELCOM (2010) *Towards an ecologically coherent network of well-managed Marine*  
623 *Protected Areas – Implementation report on the status and ecological coherence of the*  
624 *HELCOM BSPA network. Balt. Sea Environ. Proc. No. 124B. 148 pp. Available.*

625  
626 Hicks, C. C., Levine, A., Agrawal, A., Basurto, X., Breslow, S. J., Carothers, C., . . . Levin, P. S.  
627 (2016) 'Engage key social concepts for sustainability'. *Science*, 352 (6281), pp. 38-40.

628  
629 Hockings, M., Stolton, S., Leverington, F., Dudley, N. & Courrau, J. (2006) *Evaluating*  
630 *Effectiveness: A framework for assessing management effectiveness of protected areas. 2<sup>nd</sup>*  
631 *Edition. Gland, Switzerland and Cambridge, UK: IUCN. 121 pp. Available.*

632  
633 Holsman, K., Samhuri, J., Cook, G., Hazen, E., Olsen, E., Dillard, M., . . . Andrews, K. (2017)  
634 'An ecosystem-based approach to marine risk assessment'. *Ecosystem Health and*  
635 *Sustainability*, 3 (1), pp. e01256-n/a.

636  
637 Hoydal, K., Johnson, D. & Hoel, A. H. (2014) *Regional governance: the case of NEAFC and*  
638 *OSPAR. Chapter 16: 225-238. eds. Garcia, S.M., Rice, J. and Charles, A., Governance for*  
639 *Fisheries and Marine Conservation: Interaction and co-evolution. Wiley-Blackwell*

640  
641 International Union for the Conservation of Nature (2016) 'Green List'. International Union  
642 for Conservation of Nature. (Accessed: 23 September 2016).

643  
644 IUCN-WCPA (2008) *Establishing Marine Protected Area Networks—Making It Happen. .*  
645 *Washington, D.C: IUCN, World Commission on Protected Areas, National Oceanic and*  
646 *Atmospheric Administration and The Nature Conservancy. 118 pp. Available.*

647  
648 IUCN (2016) *IUCN Resolutions, Recommendations and other Decisions. Gland, Switzerland:*  
649 *IUCN. 106pp pp. Available.*

650  
651 Jackson, E. L., Hiscock, K., Evans, J. L., Seeley, B. & Lear, D. B. (2008) *Investigating the*  
652 *existing coverage and subsequent gaps in protection and providing guidance on*

653 *representativity and replication for a coherent network of Marine Protected Areas in*  
654 *England's territorial waters*. Plymouth: Marine Life Information Network (MarLIN), Marine  
655 Biological Association of the UK. Natural England Commissioned Reports, Number 018. 1-  
656 138 pp. Available.

657

658 Jackson, E. L., Rees, S. E., Wilding, C. & Attrill, M. J. (2015) 'Use of a seagrass residency index  
659 to apportion commercial fishery landing values and recreation fisheries expenditure to  
660 seagrass habitat service'. *Conservation Biology*, 29 (3), pp. 899-909.

661

662 Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B.  
663 J., . . . Warner, R. R. (2001) 'Historical Overfishing and the Recent Collapse of Coastal  
664 Ecosystems'. *Science*, 293 (5530), pp. 629-637.

665

666 Jessen, S., Morgan, L. & Bezaury-Creel, J. (2016) *Dare to be Deep: SeaStates Report on North*  
667 *America's Marine Protected Areas (MPAs)*. Ottawa, Seattle, and México City: Canadian Parks  
668 and Wilderness Society, Marine Conservation Institute. 52 pp. Available at:  
669 <http://cpaws.org/uploads/CPAWS-Oceans-Report-2016.pdf>.

670

671 Johnson, D., Ardron, J., Billett, D., Hooper, T., Mullier, T., Chaniotis, P., . . . Corcoran, E.  
672 (2014) 'When is a marine protected area network ecologically coherent? A case study from  
673 the North-east Atlantic'. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 24 (S2),  
674 pp. 44-58.

675

676 Jonas, H. D., Barbuto, V., Jonas, H. C., Kothari, A. & Nelson, F. (2014) 'New Steps of Change:  
677 Looking Beyond Protected Areas to Consider Other Effective Area-Based Conservation  
678 Measures'. *PARKS*, 20 (2),

679

680 Jones, G. P., Srinivasan, M. & Almany, G. R. (2007) 'Population Connectivity and  
681 Conservation of Marine Biodiversity'. *Oceanography*, 20 (3), pp. 100-111.

682

683 Jones, P. J. S. & De Santo, E. M. (2016) 'Viewpoint – Is the race for remote, very large marine  
684 protected areas (VLMPAs) taking us down the wrong track?'. *Marine Policy*, 73 pp. 231-234.

685

686 Laffoley, D., Brockington, S. & Gililand, P. M. (2006) *Developing the concepts of good*  
687 *environmental status and marine ecosystem objectives: some important considerations*.  
688 Peterborough, UK: English Nature Research Reports, No 689. 38 pp. Available.

689

690 Laffoley, D., Dudley, N., Jonas, H., MacKinnon, D., MacKinnon, K., Hockings, M. & Woodley,  
691 S. (2017) 'An introduction to 'other effective area-based conservation measures' under Aichi  
692 Target 11 of the Convention on Biological Diversity: Origin, interpretation and emerging  
693 ocean issues'. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 27 pp. 130-137.



694  
695 Lester, S. E., Halpern, B. S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B. I., Gaines, S.  
696 D., . . . Warner, R. R. (2009) 'Biological effects within no-take marine reserves: a global  
697 synthesis'. *Marine Ecology Progress Series*, 384 pp. 33-46.

698  
699 Lieberknecht, L., Mullier, T. & Ardron, J. (2014) *Assessment of the ecological coherence of*  
700 *the UK's marine protected area network. A report prepared for the Joint Links*. Available.

701  
702 Liu , J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., . . . Taylor, W. W. (2007)  
703 'Complexity of Coupled Human and Natural Systems'. *Science*, 317 (5844), pp. 1513-1516.

704  
705 Long, R. & Rodriguez Chaves, M. (2015) 'Anatomy of a new international instrument for  
706 marine biodiversity beyond national jurisdiction: frst impressions of the preparatory  
707 process. '. *Environmental Liability, Law, Policy and Practice.*, 23 (6), pp. 213-229.

708  
709 Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., . . .  
710 Jackson, J. B. C. (2006) 'Depletion, Degradation, and Recovery Potential of Estuaries and  
711 Coastal Seas'. *Science*, 312 (5781), pp. 1806-1809.

712  
713 Lubchenco, J. & Grorud-Colvert, K. (2015) 'Making waves: The science and politics of ocean  
714 protection'. *Science*, 350 (6259), pp. 382-383.

715  
716 Margules, C. R. & Pressey, R. L. (2000) 'Systematic conservation planning'. *Nature*, 405  
717 (6783), pp. 243-253.

718  
719 Marine Conservation Institute (2017) 'MPAtlas [On-line]. Available at [www.mpatlas.org](http://www.mpatlas.org)'.  
720 [Online]. Available at: [www.mpatlas.org](http://www.mpatlas.org) (Accessed: 13.04.2016).

721  
722 McCook, L. J., Ayling, T., Cappo, M., Choat, J. H., Evans, R. D., De Freitas, D. M., . . .  
723 Williamson, D. H. (2010) 'Adaptive management of the Great Barrier Reef: A globally  
724 significant demonstration of the benefits of networks of marine reserves'. *Proceedings of*  
725 *the National Academy of Sciences*, 107 (43), pp. 18278-18285.

726  
727 McGowan, J. & Possingham, H. P. (2015) *Submission to the Commonwealth Marine Reserves*  
728 *Review . A report by the ARC Centre of Excellence for Environmental Decisions The University*  
729 *of Queensland*. 4 pp. Available.

730  
731 Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: Synthesis*.  
732 Washington, D.C.: World Resources Institute. 155 pp. Available.

733

734 Naeem, S. & Li, S. (1997) 'Biodiversity enhances ecosystem reliability'. *Nature*, 390 (6659),  
735 pp. 507-509.

736

737 Natural Capital Committee (2014) *The State of Natural Capital: Restoring our Natural Assets.*  
738 *Second report to the Economic Affairs Committee.* 86 pp. Available.

739

740 O'Leary, B. C., Winther-Janson, M., Bainbridge, J. M., Aitken, J., Hawkins, J. P. & Roberts, C.  
741 M. (2016) 'Effective Coverage Targets for Ocean Protection'. *Conservation Letters*, 9 (6), pp.  
742 398-404.

743

744 Olds, A. D., Connolly, R. M., Pitt, K. A., Pittman, S. J., Maxwell, P. S., Huijbers, C. M., . . .  
745 Schlacher, T. A. (2016) 'Quantifying the conservation value of seascape connectivity: a global  
746 synthesis'. *Global Ecology and Biogeography*, 25 (1), pp. 3-15.

747

748 Oliver, T. A., Oleson, K. L. L., Ratsimbazafy, H., Raberinary, D., Benbow, S. & Harris, A. (2015)  
749 'Positive Catch & Economic Benefits of Periodic Octopus Fishery Closures: Do Effective,  
750 Narrowly Targeted Actions 'Catalyze' Broader Management?'. *PLoS ONE*, 10 (6), pp.  
751 e0129075.

752

753 Olsen, E. M., Johnson, D., Waever, P., Goni, R., Ribeiro, M. C., Rabaut, M., . . . Zaharia, T.  
754 (2013) *Achieving ecologically coherent MPA networks in Europe: Science needs and*  
755 *priorities.* Ostend, Belgium: European Marine Board. 1-88 pp. Available.

756

757 OSPAR (2006) *Guidance on developing an ecologically coherent network of OSPAR marine*  
758 *protected areas.* London, UK: OSPAR Commission. 11 pp. Available.

759

760 OSPAR (2007) *Background document to support the assessment of whether the OSPAR*  
761 *Network of Marine Protected Areas is ecologically coherent.* London, UK: OSPAR  
762 Commission. Available.

763

764 OSPAR (2013) *An assessment of the ecological coherence of the OSPAR Network of Marine*  
765 *Protected Areas in 2012.* London, UK: OSPAR Commission. 76 pp. Available.

766

767 Palumbi, S. R. (2003) 'Population genetics, demographic connectivity, and the design of  
768 marine reserves'. *Ecological Applications*, 13 (sp1), pp. 146-158.

769

770 Piekäinen, H. & Korpinen, S. (2008) *Towards an Assessment of Ecological Coherence of the*  
771 *Marine Protected Areas Network in the Baltic Sea Region.* Available.

772

773 Pittman, S. J., Monaco, M. E., Friedlander, A. M., Legare, B., Nemeth, R. S., Kendall, M. S., . . .  
774 Caldwell, C. (2014) 'Fish with Chips: Tracking Reef Fish Movements to Evaluate Size and  
775 Connectivity of Caribbean Marine Protected Areas'. *PLoS ONE*, 9 (5), pp. e96028.

776  
777 Pollnac, R., Christie, P., Cinner, J. E., Dalton, T., Daw, T. M., Forrester, G. E., . . . McClanahan,  
778 T. R. (2010) 'Marine reserves as linked social–ecological systems'. *Proceedings of the*  
779 *National Academy of Sciences*, 107 (43), pp. 18262-18265.

780  
781 Potts, T., Burdon, D., Jackson, E., Atkins, J., Saunders, J., Hastings, E. & Langmead, O. (2014)  
782 'Do marine protected areas deliver flows of ecosystem services to support human welfare?'.  
783 *Marine Policy*, 44 (0), pp. 139-148.

784  
785 Rees, S., Foster, N., Langmead, O. & Griffiths, C. (2015a) *Assessment of the Ecological*  
786 *Coherence of the MPA Network in the Celtic Seas: A report for WWF-UK by the Marine*  
787 *Institute, Plymouth University and The Marine Biological Association of the United*  
788 *Kingdom*. . 167 pp. Available.

789  
790 Rees, S., Foster, N., Langmead, O. & Griffiths, C. (2015b) 'Assessment of the Ecological  
791 Coherence of the MPA Network in the Celtic Seas: A report for WWF-UK by the Marine  
792 Institute, Plymouth University and The Marine Biological Association of the United  
793 Kingdom'. [in, 120. (Accessed: Rees, S., Foster, N., Langmead, O. & Griffiths, C.

794  
795 Rees, S., Sheehan, E., Foster, N., Rees, A., Gall, S., Pittman, S. & Shellock, R. (2015)  
796 *Consultation on the second tranche of Marine Conservation Zones 2015. Response from the*  
797 *Marine Institute at Plymouth University*. Plymouth University. 8 pp. Available.

798  
799 Rees, S. E., Ashley, M., Evans, L., Mangi, S., Rodwell, L., Attrill, M., . . . Rees, A. (2016) *An*  
800 *evaluation framework to determine the impact of the Lyme Bay Marine Protected Area and*  
801 *the activities of the Lyme Bay Consultative Committee on ecosystem services and human*  
802 *wellbeing. A report to the Blue Marine Foundation by research staff the Marine Institute at*  
803 *Plymouth University, Exeter University and Cefas*. Pp139. Available.

804  
805 Rees, S. E., Fletcher, S., Gall, S. C., Friedrich, L. A., Jackson, E. L. & Rodwell, L. D. (2014)  
806 'Securing the benefits: Linking ecology with marine planning policy to examine the potential  
807 of a network of Marine Protected Areas to support human wellbeing'. *Marine Policy*, 44 (0),  
808 pp. 335-341.

809  
810 Rees, S. E., Foster, N. L., Langmead, O., Pittman, S. & Johnson, D. E. (2017) 'Defining the  
811 qualitative elements of Aichi Biodiversity Target 11 with regard to the marine and coastal  
812 environment in order to strengthen global efforts for marine biodiversity conservation  
813 outlined in the United Nations Sustainable Development Goal 14'. *Marine Policy*,

814  
815 Rees, S. E., Rodwell, L. D., Attrill, M. J., Austen, M. C. & Mangi, S. C. (2010) 'The value of  
816 marine biodiversity to the leisure and recreation industry and its application to marine  
817 spatial planning'. *Marine Policy*, 34 (5), pp. 868-875.

818  
819 Ridgeway, A., Cornthwaite, A., Wright, H. & Davies, J. (2014) *Identifying the remaining MCZ*  
820 *site options that would fill big gaps in the existing MPA network around England and*  
821 *offshore waters of Wales & Northern Ireland*. JNCC. Available at:  
822 <http://jncc.defra.gov.uk/page>.

823  
824 Roberts, C. M., Bohnsack, J. A., Gell, F., Hawkins, J. P. & Goodridge, R. (2001) 'Effects of  
825 Marine Reserves on Adjacent Fisheries'. *Science*, 294 (5548), pp. 1920-1923.

826  
827 Roberts, C. M., Branch, G., Bustamante, R. H., Castilla, J. C., Dugan, J., Halpern, B. S., . . .  
828 Warner, R. R. (2003) 'Application of ecological criteria in selecting marine reserves and  
829 developing reserve networks'. *Ecological Applications*, 13 (1), pp. S215-S228.

830  
831 Rodríguez-Rodríguez, D., Rodríguez, J. & Abdul Malak, D. (2016) 'Development and testing of  
832 a new framework for rapidly assessing legal and managerial protection afforded by marine  
833 protected areas: Mediterranean Sea case study'. *Journal of Environmental Management*,  
834 167 pp. 29-37.

835  
836 Rondinini, C. (2010) *Meeting the MPA network design principles of representation and*  
837 *adequacy: developing species-area curves for habitats*. JNCC Report No. 439. 1-45 pp.  
838 Available.

839  
840 Sachs, J. D. (2012) 'From Millennium Development Goals to Sustainable Development  
841 Goals'. *The Lancet*, 379 (9832), pp. 2206-2211.

842  
843 Salomon, A. K., Shears, N. T., Langlois, T. J. & Babcock, R. C. (2008) 'CASCADING EFFECTS OF  
844 FISHING CAN ALTER CARBON FLOW THROUGH A TEMPERATE COASTAL ECOSYSTEM'.  
845 *Ecological Applications*, 18 (8), pp. 1874-1887.

846  
847 Sciberras, M., Jenkins, S. R., Kaiser, M. J., Hawkins, S. J. & Pullin, A. S. (2013) 'Evaluating the  
848 biological effectiveness of fully and partially protected marine areas'. *Environmental*  
849 *Evidence*, 2 (1), pp. 1-31.

850  
851 Secretariat of the Convention on Biological Diversity (2014) *Global Biodiversity Outlook 4*.  
852 Montréal. 155 pp. Available.

853

854 Shanks, A. L., Grantham, B. A. & Carr, M. H. (2003) 'Propagule Dispersal Distance and the  
855 Size and Spacing of Marine Reserves'. *Ecological Applications*, 13 (1), pp. S159-S169.

856

857 Sheehan, E. V., Stevens, T. F., Gall, S. C., Cousens, S. L. & Attrill, M. J. (2013) 'Recovery of a  
858 Temperate Reef Assemblage in a Marine Protected Area following the Exclusion of Towed  
859 Demersal Fishing'. *PLoS ONE*, 8 (12), pp. e83883.

860

861 Sobel, J. & Dahlgren, C. P. (2004) *Marine Reserves: A Guide to Science, Design and Use*.  
862 Washington DC: Island Press.

863

864 Spalding, M., Meliane, I., Milam, A., Fitzgerald, C. & Hale, L. (2013) 'Protecting Marine  
865 Spaces: Global Targets and Changing Approaches'. *Ocean Yearbook*, 27 pp. 213-248.

866

867 Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., . . .  
868 Robertson, J. (2007) 'Marine Ecoregions of the World: A Bioregionalization of Coastal and  
869 Shelf Areas'. *BioScience*, 57 (7), pp. 573-583.

870

871 Stewart, G. B., Kaiser, M. J., Côté, I. M., Halpern, B. S., Lester, S. E., Bayliss, H. R. & Pullin, A.  
872 S. (2009) 'Temperate marine reserves: global ecological effects and guidelines for future  
873 networks'. *Conservation Letters*, 2 (6), pp. 243-253.

874

875 Tallis, H., Polasky, S., Lozano, J. S. & Wolny, S. (2012) *Inclusive wealth accounting for  
876 regulating ecosystem services. Inclusive Wealth Report 2012. Measuring progress toward  
877 sustainability* Cambridge, uk. Available.

878

879 TEEB (2010) *The Economics of Ecosystems and Biodiversity: The Ecological and Economic  
880 Foundations*. London, Washington DC: UNEP. 411 pp. Available.

881

882 Tognelli, M. F., Fernández, M. & Marquet, P. A. (2009) 'Assessing the performance of the  
883 existing and proposed network of marine protected areas to conserve marine biodiversity in  
884 Chile'. *Biological Conservation*, 142 (12), pp. 3147-3153.

885

886 Treml, E., Halpin, P., Urban, D. & Pratson, L. (2008) 'Modeling population connectivity by  
887 ocean currents, a graph-theoretic approach for marine conservation'. *Landscape Ecology*, 23  
888 (1), pp. 19-36.

889

890 UNEP-WCMC (2008) *National and Regional Networks of Marine Protected Areas: A Review  
891 of Progress*. Cambridge, UK: UNEP-WCMC. 156 pp. Available.

892

893 Van-Beukering, P. J. H., Brander, L., Zanten, B. v., Verbrugge, E. & Lems, K. (2011) *The*  
894 *Economic Value of the Coral Reef Ecosystems of the United States Virgin Islands. Report*  
895 *number R-11/06. Institute for Environmental Studies (IVM), Amsterdam.*

896

897 Vandeperre, F., Higgins, R. M., Sanchez-Meca, J., Maynou, F., Goni, R. & Martin-Sosa, P.  
898 (2011) 'Effects of no-take area size and age of marine protected areas on fisheries yields: a  
899 meta-analytical approach'. *Fish Fish*, 12

900

901 Vucetich, J. A., Bruskotter, J. T. & Nelson, M. P. (2015) 'Evaluating whether nature's intrinsic  
902 value is an axiom of or anathema to conservation'. *Conservation Biology*, 29 (2), pp. 321-  
903 332.

904

905 WCPA/IUCN (2007) *Establishing networks of marine protected areas: A guide for developing*  
906 *national and regional capacity for building MPA networks. Non-technical summary report.*  
907 Gland, Switzerland: IUCN. 16 pp. Available.

908

909 Woodley, S., Bertzky, B., Crawhall, N., Dudley, N., Londoño, J. M., MacKinnon, K., . . .  
910 Sandwith, T. (2012) 'MEETING AICHI TARGET 11: WHAT DOES SUCCESS LOOK LIKE FOR  
911 PROTECTED AREA SYSTEMS?'. *PARKS*, 18 (1), pp. 23-34.

912

913 Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., . . . Watson, R.  
914 (2006) 'Impacts of Biodiversity Loss on Ocean Ecosystem Services'. *Science*, 314 (5800), pp.  
915 787-790.

916

917 Wright, G., Ardron, J., Gjerde, K., Currie, D. & Rochette, J. (2015) 'Advancing marine  
918 biodiversity protection through regional fisheries management: A review of bottom fisheries  
919 closures in areas beyond national jurisdiction'. *Marine Policy*, 61 pp. 134-148.

920

921

922

923