

1 **Integrating methods for ecosystem service assessment and valuation: mixed methods or mixed**  
2 **messages?**

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22 **Abstract**

23 A mixed-method approach was used to assess and value the ecosystem services derived from the  
24 Dogger Bank, an extensive shallow sand bank in the southern North Sea. Three parallel studies were  
25 undertaken that 1) identified and quantified, where possible, how indicators for ecosystem service  
26 provision may change according to two future scenarios, 2) assessed members of the public's  
27 willingness-to-pay for improvements to a small number of ecosystem services as a consequence of a  
28 hypothetical management plan, and 3) facilitated a process of deliberation that allowed members of  
29 the public to explore the uses of the Dogger Bank and the conflicts and dilemmas involved in its  
30 management. Each of these studies was designed to answer different and specific research  
31 questions and therefore contributes different insights about the ecosystem services delivered by the  
32 Dogger Bank. This paper explores what can be gained by bringing these findings together post hoc  
33 and the extent to which the different methods are complementary. Findings suggest that mixed-  
34 method research brings more understanding than can be gained from the individual approaches  
35 alone. Nevertheless, the choice of methods used and how these methods are implemented strongly  
36 affects the results obtained.

37

## 38 **1. Introduction**

39 The concept of ecosystem services, the contributions of ecosystems to human well-being (de Groot  
40 et al., 2010), is a useful approach for demonstrating the links between humans and the environment.  
41 It is readily acknowledged that many of these services go unrecognised (or under-recognised) in the  
42 environmental management process (Daily, 1997; Dasgupta et al., 2000). Cumulative impacts and  
43 trade-offs between them are overlooked (Phal-Wostl, 2007; Lester et al., 2010). This often occurs  
44 because they may be used indirectly, or enjoyed directly (but maybe unconsciously), but are not  
45 traded through markets (Böhnke-Henrichs et al., 2013). It may also result because the links between  
46 environment and human well-being are indirect, occurring at different spatial and temporal scales  
47 (Corvalan et al., 2005). To overcome this problem, quantification and valuation of ecosystem  
48 services has been advocated as a solution (e.g. Liu et al., 2010). Valuation can be approached from  
49 multiple perspectives, including ecological value (the degree to which an ecosystem component  
50 contributes to an objective or condition such as an ecosystem service; Farber et al., 2002), economic  
51 value (often expressed in monetary terms; Brown, 1984) and socio-cultural value (or shared social  
52 values obtained through social interaction, open dialogue and social learning; Stagl, 2004).

53 Through assessment and valuation, the link between ecosystem services and human well-being is  
54 made more explicit (Fisher et al., 2009). Evidence of this link should therefore improve  
55 environmental decision-making, ensuring valued ecosystems continue to deliver the services  
56 essential to human well-being (Daily et al., 2009). Thus far, the many challenges involved in  
57 ecosystem service assessments and valuations have limited their use (Laurans et al., 2013), but  
58 within many environmental management circles, including marine planning, there is a growing call  
59 for wider ecosystem service assessment and valuation (e.g. Mooney et al., 2005; Börger et al.,  
60 2014a).

### 61 **1.1 Quantification of ecosystem services through ecological assessment**

62 Interest in ecosystem service quantification has led to numerous ecological assessments of  
63 ecosystem services. These typically identify indicators of ecosystem services, attempt their  
64 quantification and spatial mapping (e.g. Burkhard et al., 2012; Crossman et al., 2013) and  
65 demonstrate how they have changed over time and/or model how they may change into the future  
66 (e.g. Martín-López et al., 2010). For marine and especially offshore ecosystems, no examples known  
67 to the authors exist that involve all these steps and apply them to multiple ecosystem services. Such  
68 assessments, however, may be particularly useful for ecosystem management because they  
69 facilitate the analysis of ecosystem service trade-offs made between alternative management  
70 options or possible future scenarios.

71 Being based on suitable indicators, outcomes of ecological assessments reflect ecosystem change  
72 (Hattam et al., 2015). They demonstrate the ecological importance of the system and can also assist  
73 with identifying the processes involved in ecosystem service supply (e.g. Cook et al., 2014). This  
74 facilitates the identification of drivers of change, which can also inform ecosystem management.  
75 Ecological assessments allow the investigation of a broad range of ecosystem services based on  
76 existing data. Hence they help identify and quantify the most important ecosystem services and  
77 those most intensely affected by human activities in an area. It is important to note, that while  
78 ecological assessments explore how the supply of ecosystem services change over time, they do not  
79 provide information about the value of these ecosystem services to society. By quantifying expected

80 changes they can, however, inform the development and application of valuation studies that  
81 explicitly aim to assess the social and economic value of the benefits derived from ecosystem  
82 services. In an attempt to encourage ecological assessments of ecosystem services, guidelines to do  
83 this have been produced by organisations and institutions (e.g. IPIECA, 2011; EU, 2014).

## 84 **1.2 Economic valuation of ecosystem services**

85 Economic valuation of the benefits from ecosystems is commonly the next step in the assessment  
86 (Defra, 2007). Economic valuation provides a common currency for units of value. This, it is argued,  
87 provides a means for comparing the costs of environmental protection with the benefits generated,  
88 and for comparing different management or policy goals, including environmental protection  
89 (Balmford et al., 2002; Hanley and Barbier, 2009). A further justification is that it should encourage  
90 more sustainable use of the environment and better motivate its conservation and protection (Daily  
91 and Matson, 2008; Tallis et al., 2008). Public bodies are increasingly offering guidance to  
92 environmental managers on how to undertake such valuations (e.g. HM Treasury, 2003; Pearce et  
93 al., 2006; Defra, 2007; Hansjürgens et al., 2012; Baker and Ruting, 2014) and incorporate the findings  
94 into policy and practice (e.g. Defra, 2010).

95 The value of ecosystem service benefits that are not traded in markets can be assessed using non-  
96 market valuation techniques (Cooper et al., 2013). Borrowing the logic of voluntary exchange in the  
97 market, such assessments typically aim to gauge people's willingness to trade some fraction of their  
98 wealth or income for an increase in ecosystem service provision. This willingness-to-pay (WTP) is  
99 interpreted as an indicator of the change in utility the person expects from the consumption of these  
100 increased ecosystem services. When WTP cannot be assessed through market data, survey-based  
101 techniques, such as the contingent valuation method (CVM) (Carson and Hanemann, 2005) and  
102 discrete choice experiments (DCE) (Hanley et al., 1998, Louviere et al., 2000) can be employed.  
103 These methods elicit WTP in a hypothetical market setting created in the survey interview. In the  
104 marine environment, the majority of valuation studies have been applied to coastal and near-shore  
105 ecosystems (e.g. Ressurreição et al., 2012; Hynes et al., 2013; Loomis and Santiago, 2013), but a  
106 growing number of applications to offshore and deep-sea sites and fauna can be found (e.g. McVittie  
107 and Moran, 2010; Wattage et al., 2011; Jobstvogt et al., 2014; Aanesen et al., 2015).

## 108 **1.3 Alternatives to economic valuation**

109 Economic valuation interprets private households as consumers of ecosystem services rather than as  
110 citizens holding attitudes and values regarding the provision of ecosystem services for society  
111 (Blamey et al., 1995; Orr, 2007). Consequently, this framework has been criticised from both within  
112 the field of economics (e.g. Aldred 2006; Parks and Gowdy, 2013) and elsewhere (e.g. Adams, 2014).  
113 Economic valuation techniques such as survey-based elicitation of WTP and concepts such as  
114 ecosystem services and natural capital frame the nature-society relationship into one of utility and  
115 exchange prefiguring commodification as a reasonable response (Kallis et al., 2013). Gómez-  
116 Baggethun et al. (2010) argue that even though the focus on economic valuation and payment  
117 schemes has attracted political support for conservation, it has also led to the commodification of a  
118 growing number of ecosystem services and the reproduction of the neoclassical economics  
119 paradigm and market logic to tackle environmental problems. There are competing values and  
120 interests relating to the environment between different groups and communities, something that  
121 also creates conflict among the groups and among communities across space and time (Martinez-

122 Alier et al., 1998). Kosoy and Corbera (2010) highlight three invisibilities in the commodification of  
123 ecosystem services: (i) the technical difficulties and ethical implications that exist when narrowing  
124 down the complexity of ecosystems to a service or range of services, and how that changes the way  
125 we relate to and perceive nature; (ii) the fact that commodification of ecosystem services requires a  
126 single exchange-value, which in turn denies the multiplicity of values attributed to these services (i.e.  
127 there are values beyond monetary values that are important); and (iii) the fact that it reproduces  
128 rather than addresses existing inequalities in the access to natural resources and services.

129 Non-monetary approaches such as deliberative group discussions (Wilson and Howarth, 2002),  
130 citizens' juries (Spash, 2007) and q-methodology (Pike et al., 2014) utilise group based activities and  
131 participatory and deliberative approaches to attain detailed information about people's relationship  
132 with the natural environment and the socio-cultural values they place on it (Christie et al., 2012).  
133 Deliberation can refer to two kinds of discussions: one that involves a group of people who through  
134 deliberation carefully weigh reasons for and against some proposition, and another that involves an  
135 interior process by which an individual weighs reasons for and against courses of action (Fearon,  
136 1998). Unlike conventional non-market valuation techniques such as CVM or DCE, which attempt to  
137 elicit pre-existing preferences or those constructed at the time of the interview, deliberative group  
138 methods, including citizens' juries, are based on the assumption that the values people hold  
139 regarding matters of collective choice can be constructed through the process of reasoned discourse  
140 with other members of society (Wilson and Howarth, 2002; Howarth and Wilson, 2006; Spash,  
141 2007). In recognition of this, and the criticisms against economic valuation, public bodies are also  
142 providing guidance on a range of deliberative methods for the assessment of ecosystem services  
143 (e.g. Fish et al., 2011).

#### 144 **1.4 Integrating methods**

145 Despite calls for the integration of methods that elicit ecological, socio-cultural and economic values  
146 (e.g. de Groot et al., 2010; Lopes and Videira, 2013), most ecosystem service assessments focus on  
147 just one of these approaches, or combine ecological assessments with some form of economic or  
148 non-monetary valuation (e.g. Pascual et al., 2011; Pascual et al., 2012). In some cases mixed  
149 methods are applied drawing on both economic and non-monetary techniques (e.g. Szabó, 2011;  
150 Kenter et al., 2013). What rarely happens is a synthesis of the findings arising from the different  
151 approaches. Only two published papers have been identified within this study that attempt to  
152 integrate the outputs from biophysical, socio-cultural and economic approaches using empirical data  
153 (Castro et al., 2014; Martín-Lopez et al., 2014). Research into mixed-methods, however, indicates  
154 that multi-strategy approaches to research can bring more understanding than can be gained from  
155 the individual approaches alone (Bryman, 2006). Effort is therefore needed to understand how the  
156 different approaches to ecosystem service assessment and valuation support each other, or not, as  
157 the case may be.

158 Using the Dogger Bank (a shallow sandbank in the southern North Sea) as a case study, this paper  
159 explores the complementarities between three approaches to ecosystem service assessment and  
160 valuation: 1) an ecological assessment, which identified and quantified, where possible, indicators  
161 for ecosystem services delivered by the Dogger Bank and explored how these services may change  
162 according to two future scenarios, 2) a DCE, which assessed members of the UK public's WTP for  
163 improvements to a small number of ecosystem services provided by the Dogger Bank as a  
164 consequence of hypothetical management plans, and 3) a citizens' jury workshop that allowed

165 members of the UK public to explore the uses of the Dogger Bank and the conflicts and dilemmas  
166 involved in its management. Complementarity analysis is just one approach to combining mixed  
167 method data (see e.g. Brannen, 2005), but is particularly suitable for data that have been collected  
168 through different methods at the same time (Teddlie and Tashakkori, 2009). The exploration of  
169 complementarities between these methods was undertaken retrospectively and was not planned as  
170 part of the original study. The approach taken is therefore only an example of how a synthesis stage  
171 could be undertaken. Ideally, integration should be planned from the outset with full understanding  
172 of what is required of the integrating approach. The growing call for evidence-based policy and  
173 practice however, combined with limited opportunities for primary data collection, suggests that  
174 such retrospective synthesis of data pertinent to ecosystem service assessments and valuation may  
175 become increasingly relevant.

176 By exploring the complementarities between the approaches used in this study, this paper “*seeks*  
177 *elaboration, enhancement, illustration, clarification of the results from one method with the results*  
178 *from another*” (Greene et al., 1989, p. 259). It therefore addresses the following research questions:  
179 To what extent do the different approaches used complement each other? How can the different  
180 methods be used more effectively together? And how can the findings be better incorporated into  
181 environmental management?

182 The paper is structured as follows. Section two introduces the Dogger Bank before providing a brief  
183 description of the methods used in each sub-study and the approach used to explore the  
184 complementarities between these methods. This is followed in section three by a presentation of  
185 the results. The findings are then discussed in section four, with conclusions provided in section five.

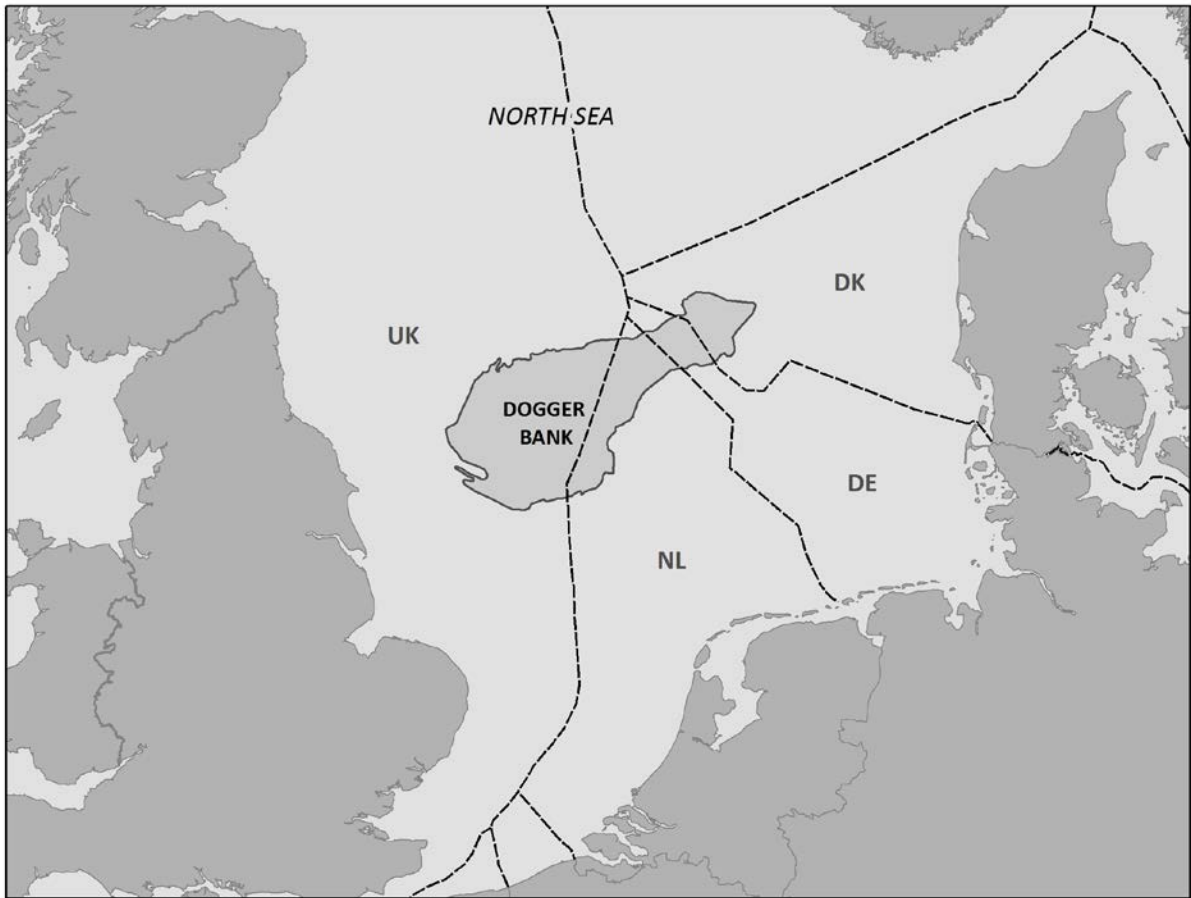
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## 187 **2. Case study and methods**

### 188 **2.1 The Dogger Bank**

189 Covering an area of 18,700 km<sup>2</sup>, the submerged sandbank of the Dogger Bank is located in the  
190 southern part of the North Sea (Figure 1). It is an important location for commercial fishing as well as  
191 actual and potential energy generation. The UK government is planning the world’s largest offshore  
192 wind farm to be installed on its section of the Dogger Bank (Forewind, 2010). It also provides a  
193 number of other less recognised benefits, for example, it acts as a nursery ground for fish (Diesing et  
194 al., 2009; Hufnagl et al., 2013) and it makes a contribution to carbon storage and sequestration,  
195 which in turn supports the regulation of the climate. In addition it is of cultural importance:  
196 fishermen and archaeologists have found a number of prehistoric remains on the Dogger Bank, and  
197 a small number of recreational anglers and scuba divers visit the Dogger Bank every year. As a  
198 consequence of its ecological importance and its vulnerability to human pressures, the UK, Germany  
199 and the Netherlands have designated their parts of the Dogger Bank as a Special Area of  
200 Conservation (SAC) under the EU Habitats and Species Directive (92/43/EEC) for the protection of  
201 Annex I Habitat H1110 ‘sandbanks which are slightly covered by seawater all the time’ (EC, 1992).  
202 This designation requires that all human activities within the SAC are regulated to fulfil the  
203 conservation objectives for the site. Management measures are currently under negotiation  
204 between the UK, Germany and the Netherlands before submission to the EU. Proposals for these  
205 management measures formed the backdrop to the DCE and citizens’ jury scenarios.

206 **Figure 1: Location of the Dogger Bank (UK - United Kingdom; DK – Denmark; DE – Germany; NL –**  
207 **Netherlands).**



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## 210 **2.2 Methods applied**

211 The ecosystem service framework and indicators defined by Hattam et al. (2015) formed the basis  
212 for this study. The three assessment and valuation studies then proceeded in parallel. The  
213 exploration of complementarities was undertaken *post hoc* and was not originally foreseen during  
214 the study development and planning phase.

215

### 216 **2.2.1 Ecological assessment**

217 The main aim of the ecological assessment was to explore which ecosystem services are subject to  
218 change under different future scenarios. Indicators of ecosystem service quantity and quality were  
219 developed for all ecosystem services identified as relevant for the Dogger Bank (for details see  
220 Hattam et al., 2015). For clarity and to facilitate the assessment, indicators of ecosystem services  
221 (i.e. of ecosystem service supply) are considered distinct to indicators of ecosystem benefits (i.e. the  
222 outputs of ecosystem services, created and derived by humans). Attempts were made to quantify  
223 each of the indicators identified. The absence of appropriate data meant that indicators for only six  
224 of the ecosystem services identified could be assessed (Table 1).

225 To evaluate how the services provided by the case study sites may change in the future, present day  
 226 (2000-2009) provision was assessed and compared against intermediate future provision (2040-  
 227 2049). Two contrasting scenarios were used based on the IPCC 2002 National Enterprise (A2) and  
 228 Global Community (B1) scenarios (IPCC 2000), a description can be found in Groeneveld et al.  
 229 (submitted) and at [http://www.marine-](http://www.marine-vectors.eu/Core_pages/Future_scenarios_and_policy_implications_with_rele)  
 230 [vectors.eu/Core\\_pages/Future\\_scenarios\\_and\\_policy\\_implications\\_with\\_rele](http://www.marine-vectors.eu/Core_pages/Future_scenarios_and_policy_implications_with_rele)). Briefly, both  
 231 scenarios encompass intermediate levels of economic growth but A2 envisages modest local  
 232 environmental policy and limited global environmental policy, whilst B1 has ambitious local and  
 233 global environmental policy. These global scenarios were augmented with location specific  
 234 information (e.g. the B1 scenario included the construction of the existing planned wind farm on the  
 235 UK sector and related fishing restrictions). Ecosystem service indicators were then assessed using  
 236 various types of data, including measured data (e.g. fish catch data), modelled data (POLCOMS-  
 237 ERSEM model output; Artioli et al., 2014) and data reported in the literature. Additionally, expert  
 238 judgment was used to qualitatively identify possible effects of the scenario on ecosystem service  
 239 provision. See Hattam et al. (2014) for more detail.

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241 **Table 1: Ecosystem services and their indicators as assessed in the Dogger Bank.**

<b>Ecosystem services</b>	<b>Dogger Bank specific indicators</b>	<b>Measurement (Units) - measured over time</b>
<b>Food provision - wild capture sea food</b>	Population of nephrops, cod, haddock and flatfish species such as plaice, turbot and lemon sole	Biomass (tonnes km <sup>-2</sup> ) of fish and shellfish
	Quality of the populations of nephrops, cod, haddock and flatfish species such as plaice, turbot and lemon sole	Species composition, age profile; length profile; % affected by disease; mortality rates
<b>Biotic raw material</b>	Population of sandeels	Same measurement units as for food provision)
	Quality of the populations of sandeels	Same measurement units as for food provision
<b>Climate regulation</b>	Air-sea and sediment-water fluxes of carbon and CO <sub>2</sub> , scaled to the area covered by the Dogger Bank	Modelled (mg C m <sup>-2</sup> d <sup>-1</sup> )
	Levels of carbon in different components of the marine ecosystem, as per generic indicators scaled to the area covered by the Dogger Bank	Modelled carbon levels: biomass of carbon (g m <sup>-2</sup> ); dissolved organic or inorganic carbon (mg C m <sup>-3</sup> ); suspended organic or inorganic carbon (mg C m <sup>-3</sup> ); buried particulate organic or inorganic carbon (mg C m <sup>-2</sup> )
	Permanence of carbon sequestration, scaled to the area covered by the Dogger Bank	% of annual carbon turnover from sediments
	Air-sea fluxes of other greenhouse gases (e.g. dimethyl sulphide, methane, nitrous	Examined, but neither modelled nor empirically determined (µg greenhouse

<b>Ecosystem services</b>	<b>Dogger Bank specific indicators</b>	<b>Measurement (Units) - measured over time</b>
	oxide), scaled to the area covered by the Dogger Bank	gases m <sup>-2</sup> d <sup>-1</sup> ) data available
<b>Migratory and nursery habitat</b>	Spawning: abundance of cod, sandeels, plaice, nephrops Nursery: abundance of sprat, nephrops	Abundance m <sup>-2</sup> and species diversity
<b>Gene pool protection</b>	Diversity of species and sub-species, phylogenetic distance, Biodiversity Intactness Index	Expert judgement on species change and changes to Biodiversity Intactness Index
<b>Leisure, recreation and tourism</b>	Species of recreational interest e.g. harbour porpoise, grey seal, seabirds, fish	Count data of key species of recreational interest
	Area of biotopes of key interest to recreational users, scaled to the area covered by the Dogger Bank	Expert judgement on changes in area of biotopes of key interest to recreational users

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### 243 **2.2.2 Discrete Choice Experiment (DCE)**

244 In the absence of market data for the majority of ecosystem services provided by the Dogger Bank,  
 245 primary valuation data were also collected through a survey with members of the public (Börger et  
 246 al., 2014b). The survey used a DCE (Hanley et al., 1998; Louviere et al., 2000) to elicit the WTP of  
 247 members of the UK public for securing some future positive environmental change (or to prevent  
 248 some negative change from happening) on the Dogger Bank. As far as possible, the attributes of the  
 249 DCE were linked to the ecosystem service indicators developed for the ecological assessment and  
 250 targeted towards indicators for which no quantitative data were available.

251 The survey was undertaken online during December 2013. It presented respondents with  
 252 hypothetical management measures drawn from the negotiations held by the Dogger Bank Steering  
 253 Group about proposed fisheries management plans for the Dogger Bank (NSRAC, 2012).  
 254 Respondents were informed that management would regulate fisheries and wind farm development  
 255 (JNCC, 2011) and that these regulations would affect different aspects, or attributes, of the  
 256 ecosystem: overall species diversity; the protection of seals, porpoises and seabirds; and the spread  
 257 of invasive species. Respondents were asked to choose between the current, no cost situation and  
 258 different management scenarios, each with differing impacts on the ecosystem attributes and  
 259 associated implementation costs (Table 2). The inclusion of the cost component means that the  
 260 value respondents attach to the different attributes can be inferred from respondents' stated  
 261 choices and expressed as marginal WTP. For further details see Börger et al. (2014b).

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266 **Table 2: Choice attributes (current, no costs situation in italics)**

Attribute	Description in the questionnaire	Levels
Diversity of species	<p>Reducing or removing trawling in some parts of the Dogger Bank will:</p> <ul style="list-style-type: none"> <li>• Increase the diversity of fish, invertebrates and other marine species</li> <li>• Enhance the natural functions provided by the Dogger Bank (contributing to the regulation of climate, maintenance of clean water and support of fish populations)</li> </ul>	<i>No change</i> , 10% increase in species diversity, 25% increase in species diversity
Protection of porpoises, seals and seabirds	<p>The Dogger Bank provides a natural home for porpoises and seals, and is a feeding ground for seabirds.</p> <ul style="list-style-type: none"> <li>• These animals and birds are sometimes accidentally caught in fishing nets.</li> <li>• The use of harmful nets will be regulated or forbidden on some parts of the Dogger Bank meaning these animals will be better protected.</li> <li>• Fishing vessels will not be banned from the whole area.</li> </ul>	<i>Not protected</i> , protected on 25% of the Dogger Bank area, protected on 50% of the Dogger Bank area
Invasive species	<p>The construction of wind turbines on the Dogger Bank provides space for invasive species, increasing the ability to spread elsewhere.</p> <ul style="list-style-type: none"> <li>• They may affect the survival of species normally found there.</li> <li>• The higher the numbers of turbines and the closer they are, the greater the likelihood of invasive species becoming established.</li> </ul>	<i>Restricted spread</i> , wide spread
Additional tax	<p>Monitoring and enforcing the Dogger Bank management plan will be costly. The government therefore needs to raise additional funds through taxes.</p> <ul style="list-style-type: none"> <li>• The tax is payable by all households in the UK for the next 5 years.</li> <li>• If the overall funds people are willing to contribute do not cover the cost of monitoring and enforcement, the plan cannot be put into action.</li> </ul>	£0, £5, £10, £20, £30, £40, £60

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268 **2.2.3 Citizens’ jury**

269 As an alternative to economic valuation, a citizens’ jury workshop on the Dogger Bank was held in  
 270 Newcastle, UK, in October 2013 with 19 members of the UK public. Participants were selected from  
 271 the database of a marketing company, according to particular criteria (e.g. age, gender, socio-  
 272 demographic status). It was anticipated that there would be a lack of knowledge among workshop  
 273 participants about the Dogger Bank, and hence background information would need to be provided  
 274 to facilitate discussions. Accordingly, the workshop was based on the principles of a citizens’ jury in

275 which expert witnesses are invited to state their case to a group of jurors selected from the general  
276 public (Huitema et al., 2007). Expert witnesses are people who are knowledgeable of the issue in  
277 question or strong advocates of particular positions in the debate. After hearing all the witnesses'  
278 accounts, the jurors (the participants) deliberate together on the issue in attempt to reach a  
279 common 'verdict' or conclusion. As consensus-seeking processes may silence minority perspectives  
280 (Travers, 1987), the primary aim of the Dogger Bank workshop was not to get participants to arrive  
281 at a common conclusion. Instead, it aimed to understand all the diverging perspectives and  
282 positions, arguments, nuances and stakes which are represented among the participants, as well as  
283 how the group setting influenced the formation of opinions. It therefore explored shared social  
284 values, focusing on aspects of use and non-use of the Dogger Bank.

285 Participants were provided with information from expert witnesses about the Dogger Bank  
286 environment, the uses of the Dogger Bank and their impacts on the marine environment. Witnesses  
287 included representatives of the fishing and wind energy sectors, a marine biologist and a speaker  
288 putting forward the position of environmental non-governmental organisations (ENGOS) involved  
289 with discussions on the Dogger Bank management plan. After hearing the witness presentations,  
290 participants were divided into four groups for two rounds of facilitated discussion. The first round  
291 focused on "what does the ocean mean to you?", "what should we use the ocean for?", and "uses of  
292 the Dogger Bank and the implications of this use". The second session focused on "conflicts and  
293 dilemmas in the management of the Dogger Bank" and "ranking competing uses of the Dogger  
294 Bank". Throughout the workshop, participants were reminded that the word 'use' was meant to  
295 cover all things provided by the ocean and the Dogger Bank that respondents and society might find  
296 of value or meaningful. This avoided the need to use the term ecosystem services and the discussion  
297 of the meaning of ecosystem services that might result. More information about the workshop can  
298 be found in Hattam et al. (2014).

#### 299 **2.2.4 Exploration of complementarities**

300 The synthesis of the findings from the above methods was undertaken once the results were  
301 available from each stage. The three methods described were applied concurrently, which allowed  
302 for a parallel track analysis (Teddlie and Tashakkori, 2009). Parallel track analyses are particularly  
303 suited to exploring complementarities as the data are analysed at the same time and the findings  
304 emerge together. This is the most common mixed analysis technique and "*although the ... sets of  
305 analyses are independent, each provides an understanding of the phenomenon under investigation.  
306 These understandings are linked, combined, or integrated into meta-inferences*" (Teddlie and  
307 Tashakkori, 2009, p. 266).

308 The first stage in the assessment was to explore the complementarities between methods  
309 themselves and the way they were applied, rather than between the outcomes of those methods.  
310 This involved examining the complementarities between the work steps taken in the application of  
311 the methods, followed by a matrix cross-tabulation, in which each method was compared against a  
312 set of criteria. Criteria ranged from what is being valued and how the value is expressed, to the types  
313 of data used, the approach to data analysis and interpretation, the transferability of related  
314 outcomes and the strengths and weaknesses of the methods. The second stage focused on the  
315 complementarities between the results. This drew loosely on Greene (2007) and involved data  
316 transformation, whereby the quantitative findings from the DCE were expressed as a narrative to

317 facilitate the comparison of mixed data types. Using matrix cross-tabulation, the relationships  
318 between findings were examined. This focused on the convergences and divergences between the  
319 findings and the trade-offs for management implied by them. The final stage in the assessment  
320 involved the drawing of inferences and conclusions. This provides just one example of how to  
321 explore the complementarities and combine the outputs of different methods.

### 322 **3. Results**

323 This section presents summary results for each method used. It emphasises the types of results  
324 obtained and key findings only. Full details on how these results were derived can be found in  
325 Hattam et al. (2014) and Börger et al. (2014b).

#### 326 **3.1 Ecological assessment**

327 Ecological indicators for this assessment were selected according to those that would best reflect  
328 the quantity and quality of the ecosystem service provision. To quantify these indicators, ecological  
329 assessments of ecosystem services as performed in this study require data relating to both the  
330 functioning of ecosystems, as well as quantifying what species or habitats are present or absent.  
331 While ecological data are available for the Dogger Bank, they are largely unsuitable for such  
332 assessments being either insufficiently resolved spatially, incomplete, or poorly resolved and  
333 understood in that area. If indicators could not be quantified, they were not replaced with inferior  
334 indicators, the services were simply left unassessed. Limitations in data availability and knowledge  
335 therefore restricted the possibilities for the ecological assessment of ecosystem services based on  
336 secondary data.

337 Quantitative data were available to assess the current state of 20 indicators corresponding to six  
338 ecosystem services. Modelled future projections, however, were only available for the indicators of  
339 climate regulation (Butenschön and Kay, 2013). Assessments of change are therefore primarily based  
340 on the expert judgment of the multidisciplinary authors and mainly serve as an example of how  
341 changes in ecosystem services may be measured. The main output of this assessment is a qualitative  
342 statement of change (Table 3) for each of the ecosystem service indicators listed in Table 1.  
343 Information obtained from these indicators represents only a partial account of the situation found  
344 on the Dogger Bank. Where the assessment was based on expert judgment, or where indicators  
345 were insufficiently supported by data for any kind of assessment, the results highlight data gaps and  
346 areas for future study.

347 As might be expected, the B1 (Global Community) scenario presents a much more positive future  
348 than A2 (National Enterprise) in terms of ecosystem service delivery (Table 3). Under the B1 scenario  
349 most indicators are anticipated to show upward trends or no change from the present. The  
350 downward trend for the fishery mortality indicator (see sea food and raw materials) requires care in  
351 its interpretation as it actually translates into positive overall change for fish stocks. Under A2 most  
352 indicators show downward trends or no change, suggesting that the related ecosystem services are  
353 decreasing. While useful in intimating future trends in ecosystem service supply, this assessment  
354 does not support the drawing of conclusions about changes in the relative values or importance of  
355 individual ecosystem services.

356

357 **Table 3: Future trends in ecosystem service provision from the Dogger Bank area under two**  
 358 **alternative scenarios. Indicators in italics have been assessed using modelled data, assessments of**  
 359 **change in all other indicators are based on expert opinion.**

Ecosystem services	High level indicator	Specific indicator	Dogger Bank	
			A2 scenario	B1 scenario
Food provision - wild capture seafood	Fish/shellfish populations	Biomass	↓	↑
		Abundance	↓	↑
	Quality of the fishery	Species composition	↓	↔
		Age profile	↓	↑
		Length profile	↓	↑
		Fishing mortality	↑	↓
		% affected by disease	↔	↔
Biotic raw materials	Quantity of raw materials	Biomass	↓	↑
	Quality of raw materials	Mortality	↑	↓
Climate regulation	Air–sea and sediment– water fluxes of carbon and CO <sub>2</sub>	<i>Air-sea flux</i>	↑	↑
		<i>Carbon burial</i>	↔	↔
		<i>Total organic carbon</i>	↓	↑
	Air–sea and sediment– water fluxes of other greenhouse gases	<i>Air-sea flux</i>	?	?
Gene pool protection	Genetic diversity	Species diversity	↔	↑
		Biodiversity intactness index	↓	↑
Nursery and migratory habitat	Number and diversity of species using the area for nursery or reproduction	Abundance of fish/shellfish eggs	↓	↑
		Abundance of fish/shellfish larvae	↓	↑
	Dependence of off-site (commercial) populations	Dependence of off-site commercial species	↔	↔
		Area of habitat or density of biogenic habitat creating species “used” or identified as important for nursery or reproduction	Area of biogenic habitat	N/A
Leisure, recreation and tourism	Species of recreational interest	Seals, cetaceans and birds	↓	↑ (but opposite for birds)

Ecosystem services	High level indicator	Specific indicator	Dogger Bank	
			A2 scenario	B1 scenario
	Biotopes of recreational interest		↔	↓

360  
361

### 362 3.2 Discrete Choice Experiment (DCE)

363 Four types of results were produced from the DCE (Börger et al., 2014b):

- 364 1. Coefficients from choice models, which indicate the effect of attributes on choices;
- 365 2. WTP estimates as an expression of value and as an indicator of expected utility change  
366 resulting from the ecosystem changes described in the choice attributes (Table 4);
- 367 3. Respondent-specific determinants of different coefficient patterns (and thus WTP estimates)  
368 allowing differentiation between groups of respondents who hold different preferences; and
- 369 4. Measures of unobserved, i.e. random, heterogeneity of preferences across respondents.

370 Results show that the respondents hold significant values for environmental benefits generated by  
371 the proposed management measures. Ecosystem attributes positively affect choice (i.e. the  
372 probability that a management option is chosen over the business-as-usual option), while cost  
373 negatively affects choice. These respective influences increase with the level of the attribute/cost.  
374 WTP for the protection of porpoises, seals and seabirds was higher than for restricting the spread of  
375 invasive species and general species diversity respectively. This implies that restrictions to fishing  
376 using nets that protect these charismatic species are preferred to restrictions to fishing using bottom  
377 trawling techniques that protect species diversity in general, as explained by the management  
378 scenario that framed the choice tasks.

379 Respondents who are members of an environmental organisation and have previously taken a ferry  
380 or flight over the North Sea prefer management measures for the Dogger Bank more often than  
381 respondents without these characteristics. Holding attitudes that favour the introduction of a  
382 management plan to protect species diversity and charismatic species also increases the WTP of  
383 respondents for different increases in the corresponding attributes. In addition, random preference  
384 heterogeneity is present that cannot be accounted for by respondent characteristics and attitudes.  
385 These findings show how DCEs can allow for some degree of diversity in values between  
386 respondents.

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396 **Table 4: Implicit prices of consequences of a hypothetical Dogger Bank management plan as**  
 397 **elicited in the DCE survey (Börger et al., 2014b)**

	Attributes	Mean WTP (£)	95% confidence interval
Species diversity	- no change*		
	- 10% increase	4.19	[0.70 - 7.69]
	- 25% increase	7.76	[5.15 - 10.35]
Protection of charismatic species	- no protection*		
	- on 25% of Dogger Bank area	24.02	[20.66 - 27.38]
	- on 50% of Dogger Bank area	30.32	[27.02 - 33.62]
Invasive species	- restricted spread*		
	- wide spread	-25.39	[-28.51 - -22.28]

WTP was calculated from a random parameters logit model with 5,000 Halton draws based on a sample of 973 respondents completing six choice tasks each. Confidence intervals were computed based on the bootstrapping approach by Krinsky and Robb (1986).

\* Indicates the current, no cost situation.

398

### 399 **3.3 Citizens' jury**

400 Deliberations between respondents allowed multiple views on the ocean and the Dogger Bank to  
 401 emerge. Participants were able to influence each other to generate new positions, with the shared  
 402 experience affecting the outcomes. Responses to the questions “what does the ocean mean to  
 403 you?” and “what should we use it for?” indicated the participants’ views on the ocean as well as  
 404 concerns over its use. Remarks such as “the integrity of the ocean”, “importance of the function of  
 405 the ecosystem”, “the beauty of the natural environment”, as well as use of words such as  
 406 preservation, sustainability, protection and responsibility highlight the importance of the ocean  
 407 beyond economic values. At the same time however, the importance of the economic uses of the  
 408 ocean was embedded in participants’ understanding, as the ocean was also viewed as a “human  
 409 resource” and used for “getting the resource(s) [for humans].”

410 The key output of the citizens’ jury workshop is an identification of discourses. A qualitative  
 411 discourse analysis of these deliberations identified two main themes:

- 412 • that fishing should be prioritised over wind farm development, and
- 413 • that conservation should be a priority, but with specific caveats.

414 The prioritisation of fishing arose from what was considered to be a lack of evidence supporting the  
 415 potential impacts or benefits arising from the construction of a wind farm on the Dogger Bank. It  
 416 also arose out of the perceived historical legitimacy of fishing (“*Fishing has been in place for years ...*  
 417 *I don't feel that they are going to impact now because they have been there for so long.*”) and the  
 418 ability of the expert fisheries witness to demonstrate the sustainability of the fishery on the Dogger  
 419 Bank.

420 Conservation was a thread in many of the discussions with participants recognising the intrinsic  
 421 value of the Dogger Bank. Conservation was not considered to exclude the use of the Dogger Bank  
 422 for economic purposes, but ensuring this use is balanced and sustainable was highlighted by jury  
 423 members. Many participants agreed that multiple activities should be allowed on the Dogger Bank

424 through a system of zoning supporting both economic and non-economic uses. However, they felt  
425 that they lacked the information to discuss such zoning in more detail.

426 The deliberative exercises demonstrated the necessity for careful facilitation to ensure all views are  
427 heard and to understand the ways in which participants influence each other. For example,  
428 discussion uncovered that one of the participants worked in the energy management sector and was  
429 knowledgeable about renewable energy. This participant suggested convincingly during the question  
430 and answer session of the witnesses that offshore wind farms could lead to negative changes in  
431 biodiversity without reducing electricity bills. In the absence of data proving otherwise, this  
432 argument can be demonstrated to have influenced other participants' views on offshore wind farms.

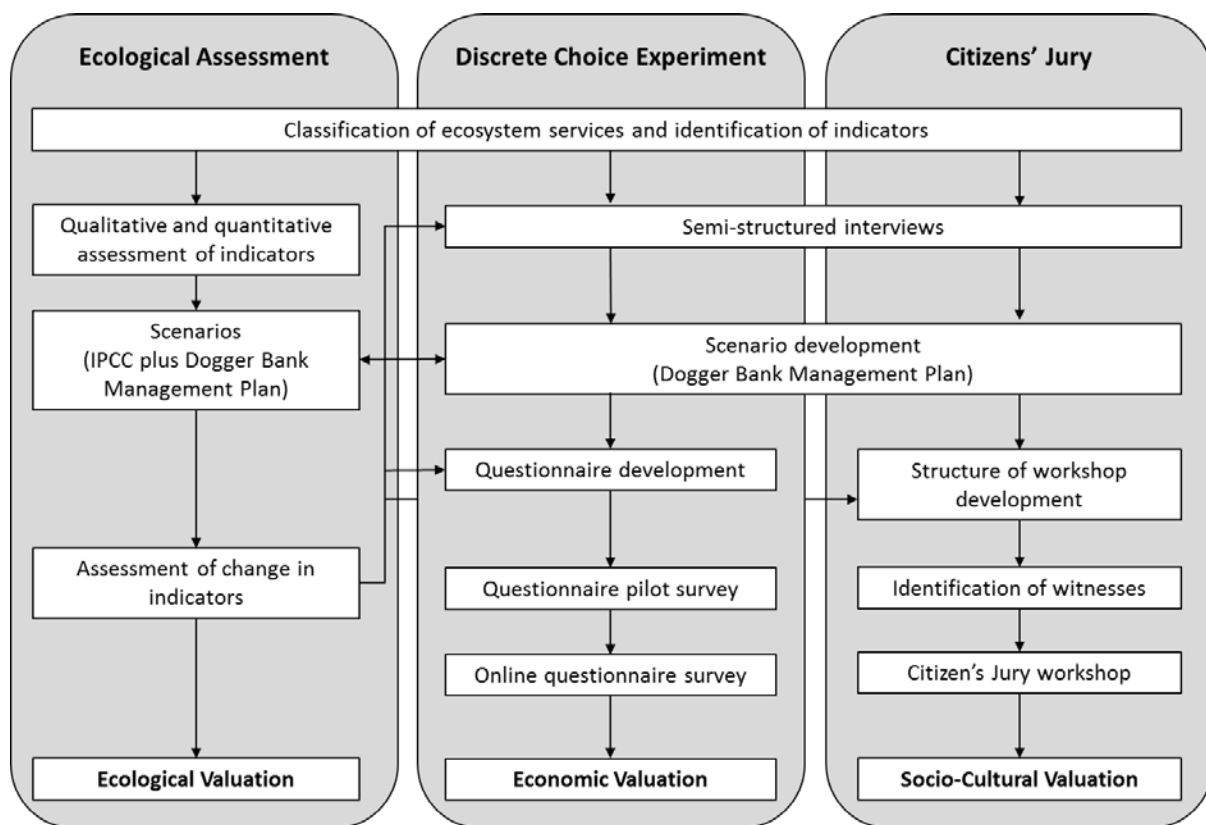
### 433 **3.4 Integration of findings**

434 In drawing together the three datasets, it is important to acknowledge the limitations of each. For  
435 example, the lack of quantitative data in the ecosystem service indicator assessment limits the  
436 understanding gained from their assessment. Consequently, the outputs largely reflect the direction  
437 of change indicated by the scenario narratives and the interpretation of the scenarios by the  
438 researchers. In the discrete choice experiment, the use of management measures to frame the  
439 choice experiment is novel, but makes interpretation of the results more challenging. It is not  
440 entirely clear whether respondents make choices on the basis of the management measure or the  
441 outcome of management (i.e. the attributes). The latter is more likely according to findings from a  
442 think aloud exercise conducted during the survey testing stage. For the citizens' jury workshop, more  
443 juries with different jurors and follow-up sessions with the same jurors would be needed to increase  
444 the level of confidence in the findings, it is possible that a jury with different jurors could have  
445 produced different results. Lastly, the size of the combined dataset is small, being based on only  
446 three studies. Had this integration been planned from the outset, the three methods may have been  
447 applied differently and additional or larger datasets sought. Despite these shortcomings, the  
448 potential to learn more from the combination of the data requires further attention. This will help to  
449 demonstrate the extent to which the data complement each other and whether a mixed methods  
450 approach can overcome any of the weaknesses in the individual methods.

#### 451 **3.4.1 Complementarities in work-flow**

452 Figure 2 demonstrates how the workflow for the different methods overlapped and where the  
453 development of methods supported each other. The ecological assessments were particularly  
454 important in terms of framing the DCE and focusing the citizens' jury, at both the preparatory and  
455 final stages. The preparatory stages of the DCE and the citizens' jury were also complementary. Both  
456 methods drew on the same exploratory semi-structured interviews with members of the public that  
457 were used to set the scene. As anticipated, there was little flow from the DCE and citizens' jury back  
458 to the ecological assessment, except during the development of scenarios.

459



460

461 **Figure 2: Complementarities in work-flow between methods.**

462

463 **3.4.2 Complementarities between methods**

464 In terms of methodological detail, Table 5 presents the matrix developed to compare across the  
 465 three methods applied in this study. Complementarities are explored in terms of values assessed,  
 466 what is being valued, the directness with which ecosystem services are addressed, information  
 467 sources used, level of engagement with the public, transferability of the results, the output units,  
 468 weaknesses and limitations, strengths (overcoming weaknesses) and complementarities.

469 The three method approach has allowed different values for ecosystem services to be assessed  
 470 supporting an assessment of the supply of ecosystem services (via the ecological assessment) and  
 471 the demand for some of these services (through the DCE and the citizens' jury). None of the  
 472 methods used capture all aspects of ecosystem service supply or demand, however. Despite drawing  
 473 across a diverse range of information sources, as found elsewhere (e.g. Liqueete et al., 2013) there is  
 474 a bias towards services for which more data and understanding exist (e.g. food provision and carbon  
 475 sequestration). The bundling of services within the valuation stages also means the findings are hard  
 476 to interpret in terms of individual ecosystem services. The outcome is therefore a partial  
 477 understanding of the ecosystem services of the Dogger Bank and how they will change.  
 478 Nevertheless, the findings from the DCE and the indicators may be useful for similar assessments in  
 479 other locations. The results of the DCE are drawn from a national survey and therefore could be  
 480 used in benefit transfer, if applied to sites with comparable characteristics and facing similar  
 481 management scenarios (Richardson et al., 2014). The indicators used in the ecological assessment  
 482 could also be transferred, but tailoring to different locations would be necessary.



483 **Table 5: Method comparison and complementarity (as undertaken in this study).**

<b>Assessment method</b>	<b>Ecological assessment</b>	<b>Discrete choice experiment</b>	<b>Citizens' jury</b>
<b>Value type</b>	Ecological value.	Economic (non-use) value.	Social/cultural value.
<b>What is being valued?</b>	Supply of individual ecosystem services.	Management and management outcomes. Demand for benefits arising from bundles of ecosystem services.	Activities/uses. Demand for environmental outcomes.
<b>Output/unit</b>	Units of quantity (e.g. tonnes of fish landed or available to be landed; tonnes of carbon sequestered) Units of quality (e.g. fish mortality rates, age profile).	Monetary values.	Discourses/ themes. Preference ranking.
<b>Directly address ecosystem services?</b>	Direct.	Direct and indirect. Bundle of ecosystem services.	Indirect. Bundle of ecosystem services.
<b>Information sources</b>	Literature <sup>a</sup> , expert opinion, ecosystem models, secondary data <sup>b</sup> .	Literature, expert opinion, preparatory interviews (with the public), survey data.	Literature, expert opinion (stakeholders), deliberation (with public).
<b>Public engagement</b>	No.	Yes.	Yes.
<b>Transferability of results</b>	Indicators may be transferred, but: <ul style="list-style-type: none"> <li>• may need tailoring to specific site;</li> <li>• may respond differently in different sites.</li> </ul>	Potential use of results in benefit transfer (when targeted to similar ecosystem type, management scenarios with defined ecosystem services).  Limited understanding of why one attribute favoured over others.	Findings are specific to location/issue of interest.
<b>Weaknesses/ limitations</b>	Some ecosystem services easier to quantify and assess than others, leading to bias in findings. Absence of appropriate data limits applicability, especially in the marine environment.	Focuses on limited number and bundled ecosystem services. Meaning of monetary values influenced by questionnaire design. Bundling of services limits understanding of trade-offs. Communicating ecosystem services is challenging.	Links to ecosystem services are weak. Influenced by: workshop design, witnesses and information provided, more knowledgeable participants. Communicating ecosystem services is challenging.

<b>Assessment method</b>	<b>Ecological assessment</b>	<b>Discrete choice experiment</b>	<b>Citizens' jury</b>
<b>Strengths (overcoming weaknesses)</b>	Focus on multiple ecosystem services, provided data/literature and experts are available.	Provide monetary estimates of ecosystem services value relevant to cost-benefit analysis.	Provides in depth understanding of theme/discourse emergence.
<b>Method complementarity</b>	Provides broad picture of ecosystem service change. Helps identify ecosystem services suitable for valuation. All ES considered equal. Combined with preference data, useful for exploration of mismatches between ecosystem services supply and demand.	Provides monetary value estimates for ecosystem services with no market value.	Captures detail of people's priorities not reflected in monetary valuation.

484 The strengths of each of the methods help identify where the methodological complementarities lie.  
485 The scope of the ecological assessment has the potential to be broad and can therefore offer a more  
486 rounded assessment of how ecosystems and the services they deliver may change as a result of  
487 human action or environmental variability. It thus provides insights on the capacity of an ecosystem  
488 to generate ecosystem services and it can also direct where it may be more useful to focus valuation  
489 studies. Both the DCE and the citizens' jury help understanding society's demand for ecosystem  
490 services and how changes resulting from management actions may be valued. In the case of the DCE,  
491 these outputs generate information on the contribution of ecosystem services to human well-being  
492 and into the hierarchy of preferences for ecosystem services. DCE outputs may also be used in cost-  
493 benefit analysis. The information obtained from the citizens' jury can augment these findings by  
494 providing greater understanding of why people hold the priorities that they do. Combining the three  
495 methods can be used to explore mismatches between ecosystem service supply and demand, and  
496 consequently identify any trade-off that may be necessary or preferable to make through  
497 environmental policy and ecosystem management.

### 498 **3.4.3 Complementarities between results and the trade-offs implied**

499 Identifying complementarities between the results of the three methods is challenging, given the  
500 limited size of the dataset and some of the limitations present in how the individual approaches  
501 were applied. Nevertheless, some complementarities are apparent between the findings, as are  
502 implied trade-offs (Table 6). Overlap between the three methods focuses on the impacts of  
503 management activities on fisheries, wind farm construction and conservation measures. The  
504 exploration of complementarities therefore concentrates on this overlap.

505 In the context of conservation issues, preferences for the supply and demand for ecosystem services  
506 appear to move in the same direction. The DCE and citizens' jury both indicate preferences for  
507 conservation, especially of charismatic species. This in turn indicates a preference for the outcomes  
508 of the B1 (Global Community) scenario of the ecological assessment. Conservation measures on the  
509 Dogger Bank will in part be delivered through fisheries management (NSRAC, 2012) and here there is  
510 implied disagreement between the findings. The ecological assessment indicates that the closure of  
511 fisheries would be beneficial for ecosystem services supplied by the Dogger Bank (scenario B1). The  
512 DCE results suggest that restrictions to net fishing would be preferred over restrictions to bottom  
513 trawling. This means that preferences for conservation of charismatic species would be met, but  
514 bottom trawling would continue to deliver fish but with no benefit to species diversity. In contrast,  
515 the outcomes of the citizens' jury suggest that, in terms of use of the Dogger Bank, fishing should be  
516 prioritised over other uses as a result of historical legitimacy.

517 In terms of wind farm construction the picture is less clear. The B1 scenario would see a substantial  
518 increase in the number of wind turbines constructed on the Dogger Bank (while the A2 scenario  
519 would only see some increase). While the acceptability of offshore wind farms was not assessed in  
520 the DCE, the relationship between offshore wind farms and fisheries has implications for the supply  
521 of fish. Fishing does not usually occur in wind farming areas, due to concerns over gear  
522 entanglement and infrastructure damage (Mackinson et al., 2006). Any increase in wind farm extent  
523 will therefore reduce fishing opportunities, in partial contradiction with the preferences expressed in  
524 the DCE results and complete contradiction with those from the citizens' jury.

525 Despite these apparent contradictions in findings, the methods do offer complementarities. Both  
 526 DCE and the citizens' jury lend support to management aimed at achieving the B1 scenario of the  
 527 ecological assessment and not the A2 scenario. Furthermore, they provide enhanced understanding  
 528 of why this is the case. The DCE and the citizens' jury findings also largely agree, but the partial  
 529 disagreement is illustrative of the complexity behind people's understanding of and demands for  
 530 fisheries management. Where partial agreements or disagreements between findings occur, this  
 531 indicates areas where trade-offs may arise when management decisions are taken. It highlights a  
 532 mismatch between the supply and demand for ecosystem services in an area. The main trade-off  
 533 implied by this work is in the context of fisheries restrictions and the interaction between fisheries  
 534 and wind farms.

535

536 **Table 6: Complementarities between results and indicated trade-offs.**

	Topic of overlap		
	Conservation	Fisheries	Offshore Wind Farms
<b>Ecological assessment</b>	Scenario B1 with least human pressure better for ecosystem services.	Suggests limitations to fisheries most favourable to supply of all ecosystem services.	B1 scenario would see extensive offshore wind development on the Dogger Bank.
<b>Discrete choice experiment</b>	WTP for charismatic species and species diversity conservation. WTP for conservation of charismatic species greater than for species diversity.	Preference for net fishing restrictions over restrictions to bottom trawling.	Preferences for or against wind farms not directly assessed. Respondents WTP for responsible wind farm design that limits invasive species.
<b>Citizens' jury</b>	Conservation a priority, although with caveats.	Fisheries considered historically legitimate.	Fisheries preferred over wind farms.
<b>Trade-offs?</b>	No. General agreement.	Yes. Partial agreement.	Yes. Limited agreement.

537

538 **4. Discussion**

539 Börger et al. (2014a) highlight a growing demand for wider assessment and valuation of marine  
 540 ecosystem services in support of marine planning. For example, in the UK, ecosystem services have  
 541 been identified as a priority research area by the Marine Management Organisation, the  
 542 Government body responsible for marine planning (MMO, 2014). In addition, there is a move  
 543 towards national assessments of ecosystem services through the Intergovernmental science-policy  
 544 Platform on Biodiversity and Ecosystem Services (IPBES) in support of the Convention on Biodiversity  
 545 and, for example, the European Unions' Biodiversity Strategy to 2020. Assessment of marine  
 546 ecosystem services, however, often lags behind the assessment of terrestrial ecosystem services,  
 547 hindered by inadequate knowledge and lack of data (Townsend et al., 2014). Applying a mixed-

548 method approach may therefore provide useful insights by delivering a more comprehensive  
549 understanding.

#### 550 **4.1 Do the methods complement each other?**

551 Three key areas of complementarities have been explored: between the work-stages of each  
552 method, between the methods themselves and between the findings. Complementarity between  
553 work stages is apparent, but this largely depends upon the communication within the  
554 multidisciplinary research team. In this case different aspects of the work did feed into each other,  
555 for example, sharing of preparatory semi-structured interviews between the DCE and citizens' jury,  
556 the use of multidisciplinary teams to develop scenarios and ensure ecological content validity in the  
557 DCE and citizens' jury.

558 In terms of methodological complementarity, the different stages of the assessment can be used to  
559 enhance each other. For example, the data gaps emerging from the ecological assessment were  
560 used to direct the DCE and citizens' jury, and each method covers a different aspect of value and  
561 more or fewer ecosystem services. Despite limitations in data availability, the ecological assessment  
562 was the broadest in scope. In contrast, the DCE and citizens' jury provided greater detail about more  
563 focused topics and particularly about demands for different ecosystem services or management  
564 outcomes. The ecological assessments help to identify how those demands might be met..

565 The findings from the Dogger Bank case study show complementarities between results.  
566 Conservation priorities were clearly demonstrated in the DCE and citizens' jury. This supports  
567 management actions that would lead to the more conservation focused scenario (B1 Global  
568 Community), which suggests a more positive future for ecosystem services. Even where divergence  
569 between findings is apparent (i.e. in the case of fisheries priorities), complementarities are evident  
570 as the outcomes from the citizens' jury improve understanding of why this divergence occurred.  
571 Potential mismatches between supply and demand for ecosystem services are highlighted, as are  
572 possible conflicts between management objectives desirable from an ecosystem perspective (e.g.  
573 fisheries closures) and those preferred by society (e.g. fish). The outcome is a more comprehensive  
574 understanding of the complex issues relating to the management of the Dogger Bank, which may  
575 better inform decision-making.

#### 576 **4.2 Does the application of the mixed-methods approach overcome any of the weaknesses of the 577 individual methods?**

578 The ecological assessment provides a general picture of how the Dogger Bank ecosystem may  
579 change. It reflects the capacity of the Dogger Bank to supply ecosystem services and identifies  
580 services worth exploring in valuation studies. The DCE elaborates upon this, through the provision of  
581 estimates of monetary value for little explored ecosystem services and those for which no secondary  
582 data exist. The citizens' jury furthers this understanding through an in-depth exploration of people's  
583 values, providing some explanation of individuals' priorities. The citizens' jury also allows greater  
584 understanding of members of the public's preferences for ecosystem management of the Dogger  
585 Bank and can be used to infer societal demand for ecosystem services beyond their economic value.  
586 Only by applying the different methods do the trade-offs between the supply of ecosystem services  
587 and the different demands for ecosystem services become apparent.

#### 588 **4.3 Applying the methods more effectively: lessons learnt**

589 The findings from the three distinct methods applied here suggest a mixture of messages. These  
590 raise a number of issues that need to be considered if greater integration of findings is to be  
591 achieved from similar studies in future. Lessons include the need to plan for integration; the need  
592 for better understanding of what integrating involves; the limitations of data availability; and the  
593 need to carefully consider the use of scenarios across the approaches.

#### 594 **4.3.1 Planning for mixed method integration**

595 Method integration requires planning from the outset. Greater complementarity could have been  
596 found with different method combinations (i.e. using other methods than those applied here or  
597 applying the same methods in different ways). For example, the citizens' jury discussions could have  
598 been conducted differently with additional deliberative sessions or information from different  
599 witnesses provided to participants. Ecosystem services could have been focused on more explicitly  
600 to allow greater comparability to the DCE. In the DCE, ecosystem services could have been  
601 decoupled from the management scenarios and focused more clearly on the ecosystem service  
602 indicators used in the ecological assessment. The bundling of services in the DCE made the valuation  
603 outcomes harder to interpret and only indirectly addresses potential future changes in the provision  
604 of ecosystem services. To some extent context influenced design of both the DCE and the citizens'  
605 jury. Respondents' unfamiliarity with the Dogger Bank necessitated simplification, and consequently  
606 bundling, that may be unnecessary in more familiar settings. The design and focus of individual  
607 studies and any integrating stage therefore requires very careful co-planning to minimise unwanted  
608 divergence.

#### 609 **4.3.2 Understanding data integration**

610 Understanding what is needed for data integration could also influence the way in which individual  
611 valuations are undertaken. For example, greater emphasis could be placed on quantitative rather  
612 than qualitative data collection, or different approaches to integration could be used.  
613 Complementarity mixed-methods studies are typically used to measure different as well as  
614 overlapping aspects of the same issue. Other approaches, such as triangulation, require that  
615 different methods are used to study the same issue (Green et al., 1989). In situations where  
616 additional numerical data are available, quantitative integration may be possible. Martín-López et al.  
617 (2014) draw on multiple quantitative data sources to which, once standardised, they apply principal  
618 component analysis to identify the relationships between biophysical, socio-cultural and monetary  
619 values. Ecosystem service assessment and valuation researchers may be able to learn lessons from  
620 disciplines where application and integration of mixed-methods is more commonplace (e.g. Greene  
621 2007; Teddlie and Tashakkori, 2009).

#### 622 **4.3.3 Impacts of data limitations**

623 The availability of suitable data hindered all methods used in this study, but in particular the  
624 ecological assessment. This absence of data, especially prevalent in the marine environment,  
625 presents a difficulty for future assessments. It is recognised as one of the main challenges for the  
626 incorporation of ecosystem service assessments and valuation into marine planning (Börger et al.,  
627 2014a). The gaps identified here indicate where future monitoring effort is needed if ecosystem  
628 services are to be incorporated into marine management for the Dogger Bank.

629 The absence of appropriate information for the citizens' jury also affected the ability of members of  
630 the public to discuss the uses and benefits of the Dogger Bank, and how the Dogger Bank should be  
631 managed. Despite providing participants with background information and experts to question, they  
632 still felt they had insufficient information to make informed decisions. Follow-up sessions are  
633 needed with the same participants to allow them to reflect on the information they have received  
634 and allow further discussion, as well as additional workshops with different participants (e.g.  
635 Abelson et al., 2003). This would enrich the data from the citizens' jury and provide increased  
636 confidence in the results.

637 Improving the effectiveness of complementary studies requires not only improvement in the input  
638 data used in the different methods, but also increased generation of data from the application of  
639 different methods. Additional economic valuation, through DCE surveys or other methods, is needed  
640 to cover a wider range of ecosystem services. For example, Martinez-Lopez et al. (2014) draw on  
641 seven monetary valuation studies covering nine ecosystem services. This suggests an opportunity for  
642 benefit transfer, however, benefit transfer may present challenges for integration, if the data are  
643 being used for a purpose that is different to that for which the data were originally collected.

644 Alternatively, the outcomes of complementarity studies such as this could be used to focus future  
645 ecosystem service assessments and valuations of the same study site. This would enable  
646 complementarities or divergences emerging from the first cycle to inform the next. For example, the  
647 preferences highlighted by DCE and the citizens' jury could be used to focus future ecological  
648 assessments and modelling efforts. Any divergences apparent between methods could form the  
649 focus of deliberations in a future study or inform economic valuations such as DCEs.

#### 650 **4.3.4 Mismatches between scenarios used**

651 Future scenarios were incorporated into each of the three methods used in this study. A mismatch is  
652 apparent, however, in the time-frames used. The ecological assessments considered changes to  
653 2050, a relatively short time-frame for ecological change, while the DCE and the citizens' jury  
654 explored change in the near future (undefined in the citizens' jury and over the next five years for  
655 the DCE). This mismatch results from the very different time-frames suitable for the different  
656 approaches. While for ecological assessments a five year time frame is in most cases too short for  
657 any change to become apparent, a 50 year period is far too long for workshop or survey participants  
658 to be able to assess. Furthermore, preferences are unlikely to be stable over such a long period  
659 meaning resulting preference data may be too uncertain for use in long-term environmental  
660 management.

661 This mismatch is not necessarily a problem and is potentially a strength of mixed-method  
662 approaches. The implications of current actions needed to achieve future ecological outcomes and  
663 the trade-offs they imply can be more easily evaluated through mixed-method approaches. In  
664 addition, if accompanied by biological/ecological monitoring and updated assessments of societal  
665 and individual preferences, management could be adapted to better achieve desired goals. This  
666 would ensure ecosystem management is responsive not only to environmental change but also to  
667 changing preferences or societal demand.

668

669

## 670 **5 Conclusion: better supporting marine management**

671 Growing use of the marine environment demands careful spatial planning (Douvere, 2008; Douvere  
672 and Ehler, 2009). The integration of findings from different ecosystem service assessment and  
673 valuation approaches can highlight complexities relating to management outcomes (e.g. for the  
674 Dogger Bank in relation to fishing) that would not become apparent using a single method approach.  
675 The combination of an ecological assessment (describing the supply of ecosystem services) with a  
676 DCE and a citizens' jury (that assess ecosystem service demand) identified areas where mismatches  
677 may occur between ecosystem service supply and demand in the future. This study has also  
678 highlighted potentially contentious issues (e.g. fisheries management) that will require careful  
679 consideration if societal demands are to be balanced with conservation needs.

680 There will always be trade-offs between improving approaches to ecosystem service assessments  
681 and having the resources to cover all relevant aspects of such assessments. Including an integration  
682 stage at the end of ecosystem service assessments may allow researchers and funders to obtain  
683 greater understanding from their data. It may therefore prove a powerful tool for supporting  
684 environmental management decisions. As shown in this case study, mixed methods approaches can  
685 (and probably most likely will) generate mixed messages. Where those mixed messages are  
686 understood as challenges or used to focus ecosystem management, the full potential of mixed  
687 methods approaches can be utilised, offering more than single method approaches can deliver.

688

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697

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