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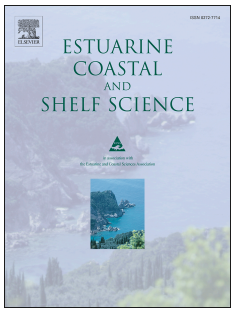

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PII: S0272-7714(17)30010-0

DOI: 10.1016/j.ecss.2017.03.009

Reference: YECSS 5415

To appear in: *Estuarine, Coastal and Shelf Science*

Received Date: 4 January 2017

Revised Date: 19 February 2017

Accepted Date: 4 March 2017

Please cite this article as: Börger, T., Böhnke-Henrichs, A., Hattam, C., Piwowarczyk, J., Schasfoort, F., Austen, M.C., The role of interdisciplinary collaboration for stated preference methods to value marine environmental goods and ecosystem services, *Estuarine, Coastal and Shelf Science* (2017), doi: 10.1016/j.ecss.2017.03.009.

The role of interdisciplinary collaboration for stated preference methods to value marine environmental goods and ecosystem services

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Abstract: With the increasing use of environmental valuation methods in coastal, marine and deep-sea settings, there is a growing need for the collaboration of natural scientists and environmental economists. Stated preference valuation methods in particular need to be based on sound natural science information and translate such information to be used in social surveys. This paper uses three applications to make explicit the flow of information between different disciplines in the preparation and implementation of stated preference studies. One approach for facilitating this flow is to increase knowledge and understanding of natural scientists on these methods. To address this, this paper highlights key opportunities and pitfalls and demonstrates those in the context of three case studies. It therefore provides guidance on stated preference valuation for natural scientists rather than for economists.

Keywords: Marine ecosystems, environmental valuation, stated preference methods, discrete choice experiments

1. Introduction

A rising demand for cost-benefit analyses of coastal and marine management measures, driven by national and international legislation, has recently been stimulating increasing efforts in environmental valuation in this field (Hanley et al. 2015, Börger et al. 2014a). Efficient use of public funds for marine environmental policy requires the assessment of costs and benefits of management measures (Oinonen et al. 2016, Scharin et al. 2016). Such management measures are a response to an increasing number of directly and indirectly human-induced stressors, such as climate change, fishing, maritime transport, land-based pollution and tourism. These stressors are leading to changes in the state of the marine environment and consequently impact human welfare (Halpern et al. 2015, Wolanski and Elliott 2015). Beyond their direct and indirect influence on economic activity, such as the production of goods and services, there are a variety of impacts that are not directly accounted for in observable market transactions. Their value (for use in environmental cost-benefit analyses) cannot be assessed through the analysis of market data, necessitating the use of non-market valuation techniques. These can be divided into two main groups: revealed preference and stated preference (SP) methods. Other methods exist, such as cost-based approaches and value transfer (Johnston and Rosenberger 2010), but as they do not employ survey methods, they are beyond the remit of this paper. Revealed preference methods, such as the travel cost method (e.g. Whitehead et al. 2008, Söderqvist et al. 2005, Bhat 2003) or hedonic pricing (e.g. Gopalakrishnan et al. 2011, Samarasinghe and Sharp 2010), use available data on market transactions or individual behaviour to infer the value of non-market goods. These methods are limited to the assessment of use values. Total economic value, potentially consisting of use and non-use value, can only be assessed by means of SP methods. The two most prominent of the latter are the contingent valuation method (CVM) (Carson and Hanemann 2005, Mitchell and Carson 1989) and discrete choice experiments (DCE) (Louviere et al. 2000).

In recent years, there has been an increase in the application of SP valuation studies in coastal locations (e.g. Hynes et al. 2013, Taylor and Longo 2010, Hanley et al. 2003), the intertidal zone (e.g.

Nunes et al. 2009, Bulte et al. 2005) and offshore resources (e.g. Brouwer et al. 2016, Aanesen et al. 2015, Börger et al. 2015, Jobstvogt et al. 2014a, Norton and Hynes 2014, Wattage et al. 2011, Glenn et al. 2010, Liu and Wirtz 2010, McVittie and Moran 2010, Eggert and Olsson 2009). Nevertheless, the number of high-quality primary valuation studies in the marine realm remains low compared to terrestrial environments as can be seen in the existing valuation databases such as that of the Marine Ecosystem Services Partnership (MSEP)[1] or the Environmental Valuation Reference Inventory (EVRI)[2].

The stimulation for further marine valuation already exists due to increasing activity within marine policy and management domains (for example, the EU Marine Strategy Framework Directive (2008/56/EC), the development of marine plans and growing interest in the promotion of the blue economy (Spalding 2016)). To ensure that environmental valuation is robust, of high quality, and useable in the decision-making process, what needs to be fostered is increased collaboration between natural scientists and environmental economists. This requires contributions from different disciplines at different stages of the valuation process. On a practical level, the valuation of environmental goods and ecosystem services entails four steps (Freeman 2002): (1) determining (and quantifying) the size of the environmental change to be valued and its effect on ecosystem structure and function; (2) determining (and quantifying) the impact of these effects on the provision of ecosystem services to humans; (3) assessing changes in human welfare in monetary terms, i.e. valuation; and (4) aggregating individual valuations over the affected population. While steps (3) and (4) have received considerable attention from environmental economists and relevant manuals are available (e.g. Johnston et al. forthcoming, Kanninen 2006, Champ et al. 2003, Bateman et al. 2002, Haab and McConnell 2002), there is no standardised way to translate natural science information into a valuation scenario in steps (1) and (2). It is evident that these steps depend heavily on the specific survey topic. Interdisciplinary teams are indispensable to ensure that the links

[1] www.marineecosystemservices.org

[2] www.evri.ca

between environmental changes and ecosystem services affected are presented to survey respondents in a correct, succinct and understandable, yet neutral and non-leading way. This involves a trade-off between the provision of more detail to increase ecological accuracy and realism of the environmental changes to be valued and the risk of overburdening respondents on a cognitive level. Against this backdrop, this paper explores how natural science knowledge and data can be best translated for the use in SP studies by making the information flow in this interdisciplinary type of research explicit. One approach for facilitating this information flow is to increase the understanding of natural scientists of practical SP environmental valuation. In addition, while biases and procedural problems still challenge valuation practitioners (Hoyos 2010, Venkatachalam 2004, Mitchell and Carson 1989), the application of CVM and DCE in the marine environment has its own recognised set of difficulties (Hanley et al. 2015). Therefore, key opportunities and pitfalls in the use of SP valuation in the marine environment are highlighted by means of three recently conducted valuation surveys in Poland, the Netherlands and the UK in the framework of the EU FP7 project VECTORS (www.marine-vectors.eu). Consequently this paper is intentionally aimed predominantly at a natural science readership rather than environmental economists. This focus will enable the former to better assess the quality of existing valuation studies and generally to improve the translation of environmental information for valuation purposes. Using the three applications of the DCE approach as examples, this paper examines the approach and its application to value ecological changes in the coastal and marine environment and thereby intends to raise awareness amongst natural scientists for the particular requirements of interdisciplinary research around environmental valuation.

2. Using stated preferences to value non-market environmental goods

2.1. Introduction to the concept of value in economics and stated preference methods

In economics, value can be expressed through exchange, and as such is instrumental and anthropocentric (Freeman 2002, Turner 1999). Instrumental (as opposed to intrinsic) values relate to

77 individual preferences and needs. Something has value to the extent that it satisfies existing human
78 preferences. Value can be thought of as the value of the good as a whole, which underpins the
79 conceptualisation in the CVM, or made up of the value of the different characteristics of the good,
80 which is the foundation of the DCE approach. Values are relative in the sense that the value of good
81 A relates and is comparable to the value of good B (Turner 1999). Consequently, in economics value
82 is usually assessed by employing the concept of willingness to pay (WTP), which implies a
83 comparison between the value of a good and money. This concept attempts to assess welfare
84 changes by quantifying how much of an individual's current income or wealth he is willing to trade
85 for the provision of a good or service (or to prevent the cessation or reduction of this provision). An
86 alternative to this is the concept of willingness to accept (WTA) compensation to go without an
87 improvement or to endure deterioration of environmental quality. The majority of practical
88 applications, however, employ the WTP concept. In other words, what is the amount of money
89 forgone that leaves an individual exactly as well off, in terms of welfare, as before a positive change
90 in environmental quality occurred? This establishes a substitution relationship between the
91 provision of environmental quality and money. WTP can therefore be interpreted as an indicator of
92 the change in welfare that this individual expects from the change in provision or quality expressed
93 in monetary terms.

94 When goods or services are traded in markets, market data can usually be used to infer WTP
95 and hence the value of the goods in question.[3] For the case of non-market goods this is not possible,
96 but SP valuation methods can be used to assess how much people *would* be willing to pay if there
97 was a market for these goods. While the beginnings of the CVM go back to the middle of the 20th

[3] Note that there is a difference between WTP and market prices in that the amount a person is willing to pay for a good might be more than she actually needs to pay in the market, i.e. the market price. Valuation is therefore concerned with WTP, which is associated with the concept of consumer surplus (Bateman et al. 2002, Morse-Jones et al. 2011). However, in well-functioning markets (and only there), market prices are usually a good approximation of WTP.

century (Randall et al. 1974, Davis 1963, Ciriacy-Wantrup 1947), DCE originate in the 1980s in marketing and transport research (Louviere 1988, Louviere and Woodworth 1983) with first applications in the environmental field appearing in the 1990s (Hanley et al. 1998, Boxall et al. 1996, Adamowicz et al. 1994). Both methods are survey-based and present respondents with hypothetical environmental management measures, the 'valuation scenario'. These scenarios detail a proposed, hypothetical environmental management project, which will lead to changes in specific aspects of a non-market good or service. It is further specified that the proposed management measures can only be implemented at a certain cost, which will have to be incurred by the potential beneficiaries of the resulting changes, typically the households surveyed. As part of the valuation scenario, a payment vehicle, the specific way respondents are asked to contribute to support the proposed scenario, has to be specified. Typically coercive payment vehicles, such as taxes or fees are preferable to voluntary vehicles such as donations (Carson and Groves 2007, Mitchell and Carson 1989). The payment vehicle also determines the frequency and duration of the hypothetical payments. In DCE, both the changing aspects of the ecosystem and the payment vehicle details are expressed in the choice attributes that describe a certain choice option. As an example, Figure 1 displays the valuation scenario used in one of the DCEs examined in this paper (the Dogger Bank survey; Section 3.1) introducing all choice attributes ('Diversity of species', 'Protection of porpoises, seals and seabirds' and 'Invasive species' and the need to pay for this programme and the payment vehicle, an 'Additional tax'). Subsequently, respondents are presented with the valuation task. In the CVM this is usually a single question directly eliciting the WTP for a change in environmental quality proposed in the valuation scenario. Common formats of the elicitation question are the dichotomous-choice question, in which respondents are simply prompted to indicate whether they are willing to pay a certain amount for the proposed environmental change. This format has been shown to make truthful responding in the best interest of the respondent (and hence more likely to occur) if the WTP response really influences the chance of the proposed scenario to be implemented or not (Carson and Groves 2007). Another format often used is the payment card approach, in which

124 they are asked to state their maximum WTP on a list of monetary amounts (or intervals) (Cameron
125 and Huppert 1989).
126
127 ***- Figure 1 -***
128
129 While the CVM assesses the value of the entirety of attributes of a good in monetary terms,
130 the DCE conceptualises a good as consisting of a number of attributes which all contribute to its
131 value. As two of these attributes are usually environmental quality and the price of the good, the
132 comparison with money is less direct in the DCE. Therefore, DCE are somewhat more flexible than
133 the CVM because instead of eliciting the WTP for the hypothetical management measures they
134 present respondents with a series of choices between two or more specifications of measures. These
135 choice options are described in terms of a set of attributes, the levels of which vary across options.
136 Each option displays how the management measure leads to different quantities or quality levels of
137 the specific non-market goods described (i.e. the choice attributes) at different costs. Respondents
138 are then asked to indicate their most preferred option. Typically a respondent answers several such
139 choice tasks with varying levels of the choice attributes. The use of the cost attribute allows for the
140 computation of respondents' WTP for changes in the non-monetary choice attributes. As an example,
141 Figure 2 displays the choice card from one of the case studies. Respondents are asked to state their
142 preferred alternative between the current ('Plan A') and two hypothetical management plans ('Plan
143 B' and 'Plan C') (Section 3.1).
144
145 ***- Figure 2 -***
146
147 In both CVM and DCE, if the survey sample is representative of the whole population affected
148 by the proposed environmental management measures, estimated mean WTP in the sample can be
149 multiplied with the total number of households affected. This yields the total value of the change

under study, which in welfare economics is referred to as the social value of this change. Both approaches assume that respondents have clear and stable preferences regarding the goods and services provided so that they can express their WTP (in CVM) or indicate their preferred choice alternative(s) (in DCE) during the survey interview. In turn, respondents need to have all the necessary information to complete this task. However, an increasing number of studies have shown that preferences are often formed during the valuation interview (e.g. Kingsley and Brown 2010, Holmes and Boyle 2005). Consequently, the way information is presented and what information is provided is crucial if respondents are to accurately express their WTP or preferences. This is especially important when the good to be valued is unfamiliar to respondents, which is often the case in applications to coastal or marine environmental goods (Aanesen et al. 2015; McVittie and Moran 2010).

2.2. Stated preference valuation in practice

Considerable research has gone into the different steps of developing a survey questionnaire, preparing and administering the survey, and analysing collected data. In addition to a vast literature in this field (Carson 2012a, Hoyos 2010), a number of manuals and textbooks are available (e.g. Johnston et al. forthcoming, Kanninen 2006, Champ et al. 2003, Bateman et al. 2002). The development of the valuation scenario and survey questionnaire is often informed by policy requirements (Hanley et al. 2015), consultation with the scientific literature and natural scientists with expertise in the area under study, and semi-structured interviews and focus groups with members of the general public (Figure 3). The latter two help the researchers gauge the level of concern, knowledge and understanding that potential survey respondents have for the specific topic. It also helps identify suitable cost levels that can be incorporated into the choice exercise and the payment scenario. The former helps identify how the proposed measures will be financed, the responsible institution and the payment vehicle. The choice of an appropriate payment vehicle requires substantial consideration to maximise the level of realism of the scenario and to help

176 respondents relate the proposed changes to their household budget. The last crucial component of
177 questionnaire construction is the experimental design. In the case of the CVM, the experimental
178 design involves the selection of payment amounts for the dichotomous-choice format or the
179 specification of a payment card. For DCE, the experimental design is the combination of attribute
180 levels and costs into choice alternative that appear on the choice cards (e.g. Figure 2). In practical
181 applications the number of all possible attribute combinations is typically too large to present them
182 to respondents. Efficient experimental designs generate that combination of attribute levels in a
183 limited number of choice occasions, which is able to produce accurate estimates of the model
184 parameters in the analysis stage of the DCE while taking into account a number of additional criteria,
185 such as balancing the occurrence of each attribute level (Johnson et al. 2006, 2013, Street et al. 2005,
186 Ferrini and Scarpa 2007).
187
188 ***- Figure 3 -***
189
190 Figure 3 illustrates the further survey process. Preliminary questionnaires are tested in waves
191 of pilot surveys using face-to-face interviews or the mode to be applied in the main survey (e.g.
192 postal, e-mail or online). This is an essential iterative process in which the scenario and
193 questionnaire are refined based on insights from pilot interviews, and the importance of this stage
194 should not be underestimated. During this stage, repeated meetings with natural scientists are
195 typically necessary regarding the use of factual information and its clear and concise, yet
196 understandable, representation in the survey materials (e.g. the use of illustrative materials, such as
197 photos, charts, graphs or maps in the questionnaire to support respondent comprehension). For
198 DCEs, typically the pilot surveys produce choice data that can be used to further inform the
199 experimental design (Scarpa and Rose 2008). The development of a survey and a questionnaire can
200 take up considerable amounts of time; a year or 18 months is not uncommon in academic
201 applications, whereas valuation studies for consulting purposes can be conducted in as little as six

202 months. With the fully developed questionnaire and an experimental design the main survey can be
203 conducted and resulting choice data analysed. The three case study surveys reported below were
204 developed and conducted following this procedure.
205

206 **3. Translating and presenting natural science knowledge in SP surveys**

207 In the framework of the VECTORS project, three stated preference surveys were conducted to value
208 changes in the provision of goods and services from selected marine ecosystems. These case studies
209 cover two European regional seas, the North and Baltic Seas, and both coastal and offshore sites.
210 These case studies illustrate the practical steps and considerations necessary to use SP surveys to
211 value changes in the marine environment. To reach this point, Figure 3 indicates that understanding
212 and quantifying these environmental changes requires close cooperation between environmental
213 economists and natural scientists, such as marine biologists and ecologists. However, there is
214 frequently a mismatch between the types of data and knowledge available to natural scientists and
215 the type of information required for a valuation survey. Therefore, this section first sketches out the
216 practical implementation of valuation surveys in the case studies. It subsequently uses these cases to
217 highlight the challenges of translating natural science information into SP surveys and links these
218 challenges to relevant procedural issues and ongoing research on SP methods.[4] This discussion is
219 structured into three parts: (1) valuation scenarios, (2) endpoints of environmental change to be
220 valued and (3) the importance of letting policy and management issues guide survey development.
221 The use of realistic and believable scenarios based on accurate natural scientific evidence is an
222 essential requirement to obtain valid valuation estimates. While substantial methodological research
223 on these approaches in environmental economics focuses on removing or minimising biases in the

[4] General overviews of methodological issues under study for stated preference valuations can be found in Hoyos (2010), Venkatachalam (2004) and Mitchell and Carson (1989). Continuing methodological controversies are discussed by Carson (2012b), Hausman (2012) and Kling et al. (2012).

survey responses and resulting WTP estimates (Rakotonarivo et al. 2016), the subsequent discussion emphasises the role of cooperation between the natural sciences and economics in this effort.

3.1. Stated preference valuation in the marine environment – The cases

3.1.1. Conservation benefits on the Dogger Bank (North Sea)

The Dogger Bank is a shallow sea area in the southern North Sea traversing the exclusive economic zones of Denmark, Germany, the Netherlands and the UK. Due to its shallowness the area is characterised by high primary production, which supports substantial fish assemblages (Sell and Kröncke 2013). Consequently, the Dogger Bank has long been an important fishing ground. In recent years the site has also been used for natural gas and aggregate extraction (JNCC 2011). More recently, plans for Europe's largest wind farm have been developed for the Dogger Bank (Forewind 2010). The valuation scenario for this DCE survey was framed around ongoing negotiations between stakeholders about a management plan for the Dogger Bank, a requirement of its recent designation as a candidate special area of conservation (cSAC) under the EU Habitats and Species Directive (92/43/EEC) (Burdon et al. in press, Hattam et al. 2015b). The valuation scenario introduced to respondents focused on the regulation of the two main commercial activities on the site – commercial fishing and wind farm development. Respondents were informed that by introducing different regulations regarding permissible fishing gear and construction of the wind farm, several aspects of the local ecosystem would be affected. These aspects are captured in the resulting choice attributes, which were general species diversity, protection of some charismatic species (porpoises, seals and seabirds), restrictions of the spread of invasive species and an annual household tax (Table 1). While ecosystem service categories were not directly used as attributes, the idea of capturing diversity of species as a regulating service and the protection of particular species as a cultural service guided attribute selection. As the survey was to be conducted in the UK, all described changes refer to the UK section of the Dogger Bank area. The survey was conducted online in December 2013 with respondents sampled across the UK. In total, 1,022 completed questionnaires

were obtained (Table 1), 973 of which were used for analysis. Survey preparation took approximately one year and drew upon continual interaction between members of the survey team (two natural scientists and three environmental economists) and multiple interactions with members of the public: 29 semi-structured in-person interviews in the Southwest and Northeast of England, 19 test interviews using a draft questionnaire and finally an online pilot survey ($n = 60$). WTP estimates and further details can be found in Börger et al. (2014b).

- Table 1 -

3.1.2. Climate change impacts in the Dutch Wadden Sea (North Sea)

The Dutch Wadden Sea is an intertidal zone in the south eastern part of the North Sea enclosed by the Frisian Islands. It comprises deep basins, tidal gullies, sand and mudflats and saltmarshes (Wang et al. 2012), which accommodate several habitats and a variety of species, including shellfish, birds, fish and seals. This distinctive ecological system makes the Wadden Sea area attractive for tourism and recreation, with activities concentrated on the five Dutch Wadden Sea islands and alongside some parts of the mainland coast. With approximately 2.15 million visitors and a turnover of around €450 million per year, tourism is one of the most important economic sectors of this region (Stenden Instituut Service Management 2010, Statistics Netherlands 2010). Changing ecosystems may impact the Wadden Sea area and the tourism industry it sustains. Two challenges that the Wadden Sea may encounter are: (1) mud flats may disappear, which may substantially influence the ecological system potentially threatening the habitat of several species, such as birds and seals (van Goor et al. 2003, Wang et al. 2012); and (2) growing sea transport and rising temperatures will facilitate more introductions of southern warm water species, such as the invasive pacific oyster *Crassostrea gigas*, into the area (Ravel and Olden 2008).

A DCE survey was conducted to assess the values held by tourists to the Wadden Sea for the prevention of these impacts. Choice attributes were selected to reflect the changing conditions, such

as the presence of beach and sea, nature and an open view (Sijtsma et al. 2012, Raad voor de Wadden 2008). Five climate change related attributes, which potentially impact the value of the Wadden Sea to tourists, were chosen: (1) changes in the abundance of the 'Pacific Oyster' that may limit recreation possibilities on the mud flats; (2) numbers of 'Birds' and (3) numbers of 'Seals' as charismatic species; (4) 'Wind turbines' as a landscape feature that may affect the open view of the sea; and (5) a tourist tax, which was selected as the most realistic payment vehicle (Table 1). This selection was based on three indicators: (1) the importance of the attribute for tourists, (2) the potential impact of climate change on the attributes and (3) the lack of a proven management strategy that may reduce the potential impact. Beach width seemed to be another relevant indicator. However, the Netherlands already have a successful sand nourishment strategy, which will reduce the potential impact (Giardino et al. 2011). Hence this characteristic was not included.

Attribute levels were based on the present situation and potential future changes resulting from the International Panel on Climate Change (IPCC) emission scenarios A1F1 (high CO_2 emissions) and B1 (lower CO_2 emissions) (Nakićenović et al. 2000). Due to limited literature regarding the extent of the potential impacts on the Wadden Sea (Markham et al. 2016), expert judgment was used to derive attribute levels reflecting the possible future impacts on the selected attributes. Assumptions were made on the potential vectors of change based on the climate change scenarios resulting from a literature review. This review was subsequently checked by eight experts and practitioners in the field including ecologists, policy makers, tourism experts and a morphologist. After several semi-structured interviews with amongst others environmental economists, ecologists, geologists, sociologists and Wadden Sea experts a draft questionnaire was set up. This questionnaire was tested during two pilot surveys with residents ($n = 50$) and tourists ($n = 25$) on the Wadden Island Ameland (Table 1). After both pilots the feedback was included in the questionnaire. The attribute levels of the payment vehicle were also set based on these tests. The final questionnaire consisted of six choice cards including a test choice card and an introduction of the different attributes. After the set of choice tasks a question was included to identify protest respondents. Between April and May

2012 a combination of 550 face-to-face and take-home interviews were undertaken in Ameland. The sample consisted of 121 German and 429 Dutch tourists.

3.1.3. Ecosystem benefits of seagrass in the Gulf of Gdańsk (Baltic Sea)

The Gulf of Gdańsk in Northern Poland is part of the Southern Baltic Sea. This shallow and sheltered sea has witnessed a sharp decline in seagrass (*Zostera marina*) from the 1950s, but recently there have been measures to protect and recover the seagrass meadows (Boström et al. 2003, Jankowska et al. 2014). This DCE was concerned with benefits resulting from seagrass restoration. Choice attributes were a reduction of the amount of filamentous algae (*Ectocarpus* and *pilyaella*) in the water and on the shore (ecosystem service: biological control), access to seagrass meadows for boaters and divers (opportunities for recreation and tourism) and improved water clarity through water purification (waste treatment/water purification). The cost attribute was specified as a waste water treatment fee that all households in the region would have to pay (Table 1). The preparation of this survey took just under one year and comprised regular interactions between members of the survey team (two economists and three seagrass ecologists) and between the survey team and the public, including: 19 semi-structured interviews with residents in the Gdańsk area, three focus group meetings as well as two face-to-face pilot surveys with $n = 50$ completed interviews each (Table 1). After each of these steps, the survey questions, valuation scenario and attribute description were modified based on findings. In the main survey, 500 interviews were completed face-to-face with residents in the coastal areas of the Pomeranian Province in Northern Poland between November 2013 and January 2014. Börger and Piwowarczyk (2016) provide detailed WTP estimates and additional results.

3.2. Valuation scenarios

The effect of scenario realism has been assessed in several studies (e.g. Cameron et al. 2011, Kataria et al. 2012). The extent to which respondents believe the presented status quo and proposed

328 change and their level of agreement with them have been demonstrated to affected the elicited
329 preferences. To ensure that lay respondents understand the survey task and can accurately state
330 their preferences, valuation scenarios, the provision of information on the environmental change to
331 be valued, how it will be caused (i.e. the management measure) and what its consequences will be,
332 therefore need to be presented in an understandable way. This can be problematic for marine
333 settings as the marine environment has been shown to be perceived as remote and unfamiliar (Rose
334 et al. 2008, Steel et al. 2005). While it is crucial to present realistic scenarios of change to ensure
335 respondents interpret scenarios as credible and to induce them to take the (hypothetical) valuation
336 task seriously it is equally important to simplify ecological relationships to ensure they are
337 understood. Scenarios which are hardly credible will result in random stated choices and
338 consequently uninformative WTP estimates. The valuation scenario must demonstrate how the
339 environmental changes under study will affect the welfare of the interviewed population. Practically
340 this means repeated interactions between specialists on the environmental change of interest,
341 survey designers, other members of the valuation team and members of the target survey
342 population (e.g. members of the public in the three cases presented here). For example, in the Dutch
343 case, the different ecosystem impacts had to be made specific to the Wadden Sea (Table 2). This
344 required ecological, climate-related and morphological expert knowledge, including a pilot survey to
345 examine the understanding of the scenarios by the general public. Experts of Pacific oysters
346 indicated the possible spreading of this invasive species, while mud flat walking agencies could add
347 information on the impact of this spread for tourists. Another example of expert input into scenario
348 design concerned the possibility of replanting of seagrass in the Polish survey. While participants of
349 the preparatory focus groups believed that active replanting of seagrass was the easiest mitigation
350 strategy, expert interviews revealed that such initiatives have so far proved to be technically
351 unsuccessful. As a result of this information the restoration scenario included in the survey
352 questionnaire clearly explains why seagrass planting is not the solution.

Once a preliminary questionnaire has been developed, multiple rounds of questionnaire testing commence. This can be undertaken in many ways, including through interviews, focus groups and self-completion activities. One of the approaches used in the development of the Dogger Bank survey was the use of think-aloud interviews whereby respondents were asked to vocalise their thoughts are they completed the questionnaire. This enabled the survey development team to detect unclear wording and overly complex attribute description (Ryan et al. 2009, Schkade and Payne 1994). By gaining insight into how respondents take up and process the information presented, refinements of the questionnaire were undertaken with the aim of increasing respondent engagement and the stating of informed preferences. This process of testing and refinement should be employed routinely, especially when remote and unfamiliar goods are to be valued.

Realistic, credible and understandable valuation scenarios are also required to help mitigate a procedural problem that continues to trouble SP surveys: Protest responses (Venkatachalam 2004; Meyerhoff and Liebe 2008). In the CVM some respondents might state a WTP of zero not because they truly expect no change in welfare but because they want to express protest, dissatisfaction or anger regarding the valuation scenario, the payment vehicle, the institution responsible for the proposed measures or the valuation survey as a whole. This type of respondent has to be identified so that only true zero WTP statements are used for welfare analysis. In DCE studies, protest respondents might be those who prefer the no-cost status quo in all choice occasions even though they would in fact experience a change in welfare from the proposed changes. Attitudinal follow-up questions are used to distinguish these respondents from those who choose the no-cost option because they truly do not value the described changes. In the Wadden Sea study, for example, all respondents consistently choosing the status quo were asked why they were not willing to pay to avoid environmental changes in the Wadden Sea. Most of these respondents stated that the Wadden Sea needs to be protected by law or that such measures should be paid out of current taxes. This indicates that their choices of the status quo do not mean that they do not value the

management measures, but simply that they did not want to pay even though they would value the proposed changes. Based on these answers 33 respondents were discarded from the survey sample.

- Table 2 -

3.3. Endpoints of valuation scenarios: Definition and range of choice attributes

Valuation scenarios need to clearly specify the endpoints of the proposed environmental change. Such endpoints are described in terms of the different ways through which the environmental changes will affect societal welfare. In CVM scenarios, typically only a one-off change from a current status or business-as-usual scenario to a future change scenario covering all possible impacts is presented. In DCE, the different impacts may find expression in the choice attributes which can be varied and valued independently based on the collected choice data. Determining realistic ranges for each attribute and ensuring that combinations of different attribute levels are ecologically meaningful are crucial to the interpretability of valuation results.

A helpful tool to specify choice attributes and their ranges proved to be the ecosystem service framework, which facilitates the translation of ecosystem changes to services and eventually benefits that affect human welfare (de Groot et al. 2010). Böhnke-Henrichs et al. (2013) call for valuation studies to clearly describe which ecosystem service categories are being valued and "how much of a particular service has been valued" (p. 144). However, ecosystem service categories may have a greater role than just as a communication tool in the valuation scenario. They can also help guide the development of choice attributes by the researchers, as applied in both the Polish and the Dogger Bank case studies (Table 2). If indicators for ecosystem service change exist (e.g. Hattam et al. 2015a, Liquete et al. 2013), such metrics can be used in the valuation scenario. This allows the changes in the marine environment to clearly map to the values elicited in the survey. In the case of the Gulf of Gdańsk survey, the ecosystem service framework was used to structure preparatory focus group discussions (Table 2). The emphasis on all channels through which seagrass potentially

affects individual welfare proved helpful in guiding participants' discussions of the role of this ecosystem. Consequently, the use of clear-cut ecosystem service categories as choice attributes was retained in the main survey. While ecosystem service categories guided the initial considerations about the choice attributes to be used in the Dogger Bank survey, they were not used in the final survey due to a lack of required ecosystem data at the appropriate spatial scale for the ecosystem services in the case study area and lack of familiarity with these services by the respondents (e.g. waste remediation, carbon sequestration and gene pool protection).

The selection of choice attributes, however, is always influenced by both the scientific evidence and the perception of respondents. In the Polish survey, ecological expert knowledge was necessary to translate the quantitative – but still relatively scarce – information about projected filamentous algae abundance into spatial terms meaningful to respondents. In a series of work meetings, economists and seagrass ecologists developed the description of the attribute and its levels, which were then tested on members of the public and subsequently refined. Focus groups can serve to detect potential interaction effects between attributes which should be taken into account in the experimental design (Hoyos 2010). While clarification from a natural science perspective is needed about which services are delivered jointly by the same ecological processes (e.g. carbon sequestration and bioremediation of waste) and hence cannot be independently varied, the perception of respondents on service interactions also needs to be assessed. It is possible that the value of a benefit from a certain service depends on the level of another service. This information needs also to be incorporated into the experimental design of the DCE. For example, participants in the Polish focus groups explicitly discussed which seagrass ecosystem services they perceive as related and being provided jointly. Since no relationships between the three attributes were perceived, they were varied independently in the experimental design used in the main survey.

3.4. The importance of policy and management in survey design and evaluation

Supporting natural science knowledge is required to facilitate the use of value estimates and particularly environmental cost-benefit analysis (informed by valuation) in policy and management (Scharin et al. 2016). Natural science knowledge provides the context for result interpretation but also makes valuation outputs useful beyond the specific context of the study. As stated, a well-designed survey not only improves the credibility of the scenario for respondents, ensuring scenario realism, but is also more likely to elicit credible values. The presentation of SP valuation findings by interdisciplinary teams is necessary as it has been shown that decision-makers have limited knowledge about the economic aspect of these valuation techniques in particular (Guo and Kildow 2015). The use of interdisciplinary language to present results may therefore help to remedy this situation and facilitate the take-up of these values by policy- and decision-makers. Values assessed through SP surveys provide indications about the societal desirability of environmental change, but natural scientific knowledge is needed to devise the management measures that will lead to these changes.

Guo and Kildow (2015) emphasise that valuation studies need to address specific environmental management problems if they are to be relevant for policy-making. This idea has guided the Dogger Bank study, which looked at the specific need to develop a management plan for the area. This study's scenario was entirely based on ongoing negotiations about a management plan for the Dogger Bank cSAC under the EU Habitats and Birds Directive. Different attribute levels represented the anticipated outcomes of different management measures proposed by the stakeholders involved in these negotiations. Similarly the Gdańsk study was framed by the need for management to support local implementation of local targets for the EU Marine Strategy Framework Directive. In the Wadden Sea study scenarios were linked to global rather than national or local policy by using official IPCC scenarios from which to derive the anticipated environmental change in the study area (Table 2). This step attempts to close the gap between SP valuation and policy-making (Guo and Kildow 2015) and address the lack of uptake of valuation results by decision-makers (Laurans et al. 2013, Billé et al. 2012).

4. Discussion and conclusions

The above discussions illustrate how valuation studies can incorporate natural science knowledge to improve scenario realism, attribute definition and valuation surveys and findings for policy and management. This is achieved through the establishment of the causal links between the applications of certain environmental management measure(s), the impact on ecosystems, the resulting effects on human welfare and associated values. Establishing these links and conducting policy-driven valuation is essential if the needs of marine legislation and policy, such as the EU Marine Strategy Framework Directive or for marine planning are to be met (Börger et al. 2014a).

Despite the use of state-of-the-art survey development techniques in the above studies, the presentation of information about the marine environment remains challenging. Self-reported knowledge of respondents about the survey topic is often gathered in such surveys and commonly shown to be low. For example, in the Dogger Bank survey, while approximately half of the respondents stated they had heard of the Dogger Bank, 80.3% of these had done so in the shipping weather forecast on national radio. After completing the choice tasks, 57.2% of respondents indicated that they did not have enough information about the Dogger Bank to know what the proposed measures are worth to them. Looking beyond the three case studies, this share is equally high (56.2%) in a similar survey about ecological and amenity impacts of an offshore windfarm in Northwest England (Börger et al. 2015) and higher in the Gulf of Gdańsk survey (63.0%). In a valuation study of deep-sea ecosystem services in Scotland, 63.0% of respondents indicated they knew only half or less of the presented information (Jobstvogt et al. 2014a). In the Dogger Bank study, 59.6% of respondents stated they had known none of the information presented. These numbers demonstrate that providing respondents with accurate, succinct and neutral information about the good to be valued is crucial and yet still challenging. Many DCE studies, but particularly those valuing offshore environmental goods, such as Börger et al. (2014b), Jobstvogt et al. (2014a) or Wattage et al. (2011), have to reduce complexity of information and also the number of choice

attributes to keep the survey manageable for respondents. Methodological research has recently been studying how exactly respondents receive and process information in stated preference surveys (Czajkowski et al. 2014, LaRiviere et al. 2014). Given the low level of prior knowledge regarding many marine ecosystems, this is an important field for further research.

To further facilitate the presentation of ecological information in SP surveys, the use of ecosystem principles has been proposed (Jobstvogt et al. 2014b), which systematically extracts expert knowledge on ecosystem processes to express these in a set of comprehensive principles in a survey setting. Other research on SP surveys has pointed out the role of using maps, both as overview maps and individualised maps, to facilitate the respondent's understanding of the environmental good and its exact location or spatial distribution (Johnston et al. 2016). Another area of research that has consequences for nature of natural science information to be included and the way how it can be presented concerns survey modes. While face-to-face surveys are regarded as the 'gold standard' (Arrow et al. 1993) and allow for presentation of complex information and even additional explanations from the interviewer, other modes are usually employed to save costs and time.[5] Online surveys (Olsen 2009) are comparably cheap and allow access to a wide range of respondents (in countries where there is a high level of internet penetration in the population) but are also vulnerable to "professional respondents" who regularly take surveys and might rush through the questionnaire and might not be easy to identify (Börger 2016). As an alternative, some studies valuing hard-to-understand or remote environmental goods employ workshops to collect data (Aanesen et al. 2015, Christie and Rayment 2012). This approach increases survey costs and limits the geographical reach of the survey sample, but it facilitates the provision of complex ecological information and offers more room for deliberation and contemplation before WTP or choices are stated. It is important that social and natural scientists work cooperatively on the

[5] It should be noted that the presentation of choice cards needs to be randomised, which is difficult in face-to-face interviews. While computer-assisted personal interviewing (CAPI) is a way to solve this problem, this mode also increase survey costs compared to traditional paper-and-pencil surveys.

504 preparation and implementation of valuation surveys to ensure that the information provided and
505 the materials used are in line with the particular requirements of the survey mode.

506 Many changes in the marine environment cannot be described in quantitative terms due to
507 the lack of relevant data at appropriate spatial and/or temporal scales. Indicators of ecosystem
508 services and their changes as developed by e.g. Hattam et al. (2015a) will play an important role in
509 overcoming this challenge, as may ecological and ecosystem modelling outputs (Hyder et al. 2015,
510 Peck et al. in press). Some degree of uncertainty therefore exists around ecosystem change and
511 responses to ecosystem management. How this uncertainty is presented in SP surveys remains a
512 challenge and is an under-researched issue. Although natural science information is often associated
513 with uncertainty, valuation surveys often present respondents with future changes that occur with
514 certainty. This mismatch would not be problematic if preferences were unaffected by this, but it has
515 been shown that presenting environmental change in valuation scenarios as certain or uncertain
516 affects elicited preferences (Roberts et al. 2008). Consequently, better communication of
517 uncertainty about future environmental states in surveys and understanding its effect on values is an
518 important field of research. This requires better information from natural scientists about the extent
519 and the type of uncertainty related to a particular environmental change.

520 In addition, ecological expertise is usually required for value transfer to ensure that elicited
521 values from one site are only applied to other sites which are ecologically equivalent in
522 characteristics (Richardson et al. 2015, Johnston and Rosenberger 2010). Value transfer is analogous
523 to the process by which a marine ecologist might infer that the marine species in one location where
524 sampling has been undertaken will be similar to those in another location because they share key
525 environmental characteristics. The pitfalls for an economist using value transfer with limited data
526 availability are familiar to those faced by the natural scientists. Can it be reasonably assumed that
527 the two sites are sufficiently similar in the characteristics that affect economic choices to be certain
528 that value transfer is a valid process? However, this technique is developing rapidly (e.g. Czajkowski
529 et al. 2017, Bateman et al. 2011), and the involvement of natural scientists in the design of the three

530 case studies and the use of ecosystem service categories guiding the selection of choice attributes
531 could further facilitate the use of the elicited values in value transfer. The values could, therefore,
532 support management decisions in these other locations. For example, in the Polish seagrass study
533 values for the reduction of algae abundance and improved water clarity can be transferred to other
534 sites independent of their link to seagrass beds, but ecologists and biologists are required in this
535 transfer to ensure the equivalence of ecological conditions between the study site and the transfer
536 site.

537 Several conclusions can be drawn from the above discussion of challenges of SP valuation in
538 marine and coastal settings. First, interdisciplinary teams are a necessity, consisting at least of
539 marine scientists (particularly biologists and ecologists), environmental economists and survey
540 methodology experts. Furthermore, the handling of DCE data and the related field of choice
541 modelling (also relevant to applications to health and transport policy) have seen rapid progress in
542 recent years and methods are now available to extract increasingly detailed information from choice
543 data (Hensher et al. 2015, Train 2009). Second, the ecosystem service approach should be more
544 extensively applied in valuation studies as a way of describing the consequences of change in the
545 marine environment and guiding the selection of choice attributes as highlighted in the Dogger Bank
546 and Gulf of Gdańsk cases. Future research is needed to strengthen this link between what is being
547 valued and established ecosystem service categories so that ecosystem service values can be used to
548 support marine planning and general marine management. This is also necessary if valuation outputs
549 are to be used as input to larger ecosystem or bioeconomic models that consider multiple ecosystem
550 services (e.g. Punt et al. 2009, Hyder et al. 2015). Third, defining best practice for questionnaire
551 development for SP surveys is challenging. While there are detailed manuals available for the
552 development of an appropriate survey instrument, some trade-off between clarity and realism
553 within the survey and the potential overburdening of respondents with information will always exist.
554 Against this background, the cases in this paper show that (and how) natural scientists can
555 contribute to different steps throughout a SP study. The cases also highlight that close collaboration

556 between natural scientists and environmental economists adds a further layer of complexity to
557 survey preparation and implementation and therefore requires time during survey development but
558 results in greater survey quality. For the natural scientists who are willing to contribute to
559 interdisciplinary SP valuation the reward is that their research can directly support policy
560 development and management decisions in the marine and coastal environment.
561

562 **Acknowledgements**

563 This study was funded by the European Community's Seventh Framework Programme (FP7/2007 –
564 2013) within the Ocean of Tomorrow call under Grant Agreement No.266445 for the project Vectors
565 of Change in Oceans and Seas Marine Life, Impact on Economic Sectors (VECTORS).
566

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851 revealed and stated preference data. Marine Resource Economics, 23 (2), 119-135.
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Table 1: Choice attributes and main characteristics of the three case study surveys

	Case study		
	Dogger Bank	**Wadden Sea**	**Gulf of Gdańsk**
Attributes	- General species diversity	- Changes in the abundance of the Pacific oyster	- Reduction of the amount of filamentous algae
	- Protection of porpoises, seals and seabirds	- Numbers of birds	- Access to seagrass areas
	- Spread of invasive species	- Numbers of seals	- Improved water clarity
		- Presence of wind turbines	
Payment vehicle	Household tax	Tourist tax	Waste water fee
Survey mode	Online	Face-to-face	Face-to-face
Sample size	1,022	550	500
Questionnaire preparation and testing	Semi-structured interviews (*n=29*)	Resident pilot survey (*n=50*)	Focus groups (three meetings)
	Test interviews using think-aloud protocol (*n=19*)	Tourist pilot survey (n=25)	Semi-structured interviews (*n=19*)
	Online pilot survey (*n=60*)		Two face-to-face pilot surveys (*n=50* each)

Table 2: Matching natural science knowledge with information requirements for SP surveys

Type of natural science information	How are different types of information matched in case studies		
	Dogger Bank	**Wadden Sea**	**Gulf of Gdańsk**
Expert knowledge on environmental change	- Translation into choice attributes guided by ecosystem service and benefit categories	- Experts' indication of potential changes in IPCC emission scenarios translated into choice attributes	- Ecosystem services provided by seagrass used to select the choice attributes, and to discuss the importance of seagrass meadows with focus groups participants
Scenarios of environmental and ecosystem change	- Translation of effects of management discussed in stakeholder negotiations	- Breakdown of IPCC scenarios to local conditions	- Definition of possible protection and restoration initiatives and assessment of their effectiveness
Assessment of biophysical indicators	n/a	n/a	- Translation of information about algae abundance into approximate spatial patterns of distribution - Translation of the optical properties of the water into improvements in water clarity
Ecosystem modelling	n/a	- Outputs from ecosystem and ecological models indicated potential changes in the ecosystem	- Used to define the potential distribution of *Zostera marina* beds

Notes: IPCC – International Panel on Climate Change; n/a – not applied

Regulating fishing activities and changing windfarm design could determine the state of Dogger Bank habitat and the ecological functions Dogger Bank is able to perform.

In the next set of questions, we want to explore your opinions about the potential outcomes of the Dogger Bank management plan and the costs of monitoring and enforcing the plan:

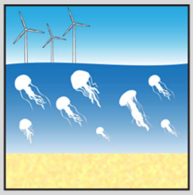
Diversity of species 	**Reducing or removing trawling in some parts of the Dogger Bank will:** • **increase the diversity of fish, invertebrates and other marine species** • **Enhance the natural functions provided by the Dogger Bank (contributing to the regulation of climate, maintenance of clean water and support of fish populations).**
Protection of porpoises, seals and seabirds 	**The Dogger Bank provides a natural home for porpoises and seals, and is a feeding ground for seabirds.** • **These animals and birds are sometimes accidentally caught in fishing nets.** • **The use of harmful nets will be regulated or forbidden on some parts of the Dogger Bank meaning these animals will be better protected.** • **Fishing vessels will not be banned from the whole area**
Invasive species 	**The construction of wind turbines on the Dogger Bank provides space for invasive species, increasing their ability to spread elsewhere.** • **They may affect the survival of species normally found there.** • **The higher the numbers of turbines and the closer they are, the greater the likelihood of invasive species becoming established.**
Additional tax 	**Monitoring and enforcing the Dogger Bank management plan will be costly. The government therefore needs to raise additional funds through taxes.** • **The tax is payable by all households in the UK for the next 5 years.** • **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.**

Figure 1: Valuation scenario, including choice attributes and payment vehicle, of the Dogger Bank study

Please choose the one you prefer by selecting the button in the appropriate box.

Description	Dogger Bank Management Plan A "no change"	Dogger Bank Management Plan B	Dogger Bank Management Plan C
Diversity of species 	**No change** in species diversity	**25% increase** in species diversity	**10% increase** in species diversity
Protection of porpoises, seals and seabirds 	Porpoises, seals and seabirds **Not Protected**	Porpoises, seals and seabirds **Protected on 50% of area**	Porpoises, seals and seabirds **Not Protected**
Invasive species 	**Restricted spread** of invasive species	**Wide spread** of invasive species	**Wide spread** of invasive species
Additional tax 	Additional tax **£0** per household per year	Additional tax **£20** per household per year	Additional tax **£5** per household per year
Please select your answer here:	○	○	○

Figure 2: Choice card used in the Dogger Bank survey (from Börger et al. 2014b)

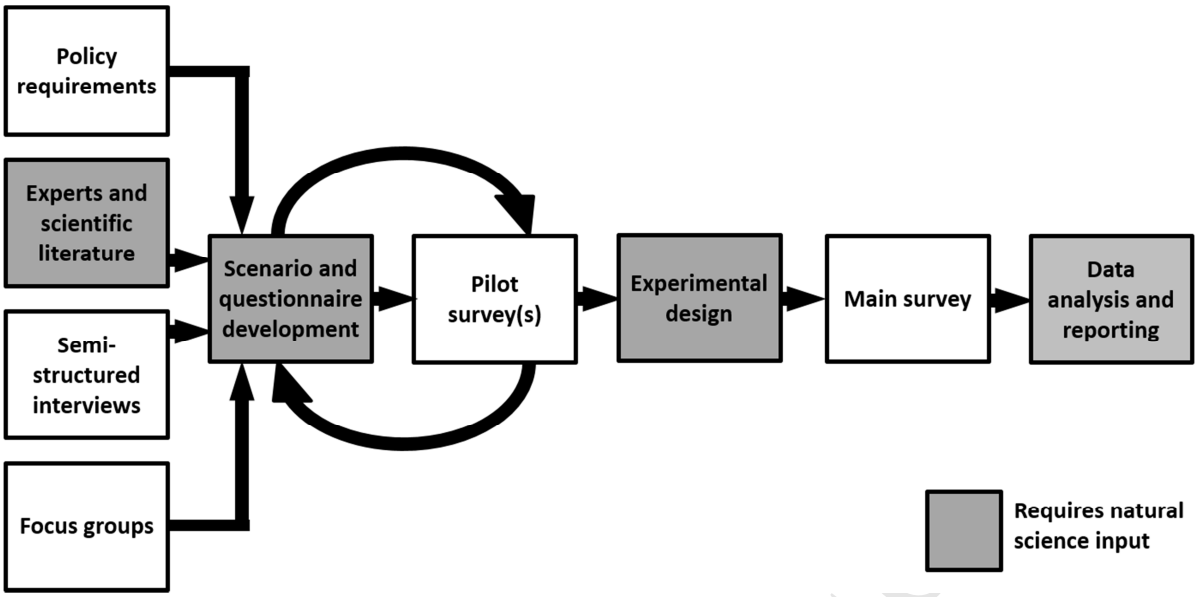


Figure 3: Typical preparatory steps of a SP survey and input requirements from the natural sciences and survey methodology