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Managing coastal area resources by stated choice experiments

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ABSTRACT

In many coastal regions, oil spills can be considered as one of the most important and certainly the most noticeable forms of marine pollution. Efficient contingency management responding to oil spills on waters, which aims at minimizing pollution effects on coastal resources, turns out to be critically important. Such a decision making highly depends on the importance attributed to different coastal economic and ecological resources. Economic uses can, in principal, be addressed by standard measures such as value added. However, there is a missing of market in the real world for natural goods. Coastal resources such as waters and beach cannot be directly measured in money terms, which increases the risk of being neglected in a decision making process. This paper evaluates these natural goods of coastal environment in a hypothetical market by employing stated choice experiments. Oil spill management practice in German North Sea is used as an example. Results from a pilot survey show that during a combat process, beach and eider ducks are of key concerns for households. An environmental friendly combat option has to be a minor cost for households. Moreover, households with less children, higher monthly income and a membership of environmental organization are more likely to state that they are willing to pay for combat option to prevent coastal resources from an oil pollution. Despite that choice experiments require knowledge of designing questionnaire and statistical skills to deal with discrete choices and conducting a survey is time consumed, the results have important implications for oil spill contingency management. Overall, such a stated preference method can offer useful information for decision makers to consider coastal resources into a decision making process and can further contribute to finding a cost-effective oil preventive measure, also has a wide application potential in the field of Integrated Coastal Zone Management (ICZM).

1. Introduction

In practice to reduce greenhouse gas emission, offshore wind energy (OWE) conversion has recently been started to operate in coastal oceans and seas surrounding Europe. For example, the German government has set the substantial target of installation of 20,000–25,000 MW of offshore capacity by 2030 (Kannen, 2005). Despite many ideal characteristics of OWE, the mere existence, however, increases the risk of oil spill due to ship collision. In the German Bight, the position of many planned wind farms in vicinity of transport routes with the highest density of ship movement in the world such as the German Bight Western Approach has created an elevated problem awareness both in the public as well as by authorities. Most concern derives from the risk of oil spills in the aftermath of collision events. Oil spills can be considered as one of the most important and certainly the most noticeable forms of marine pollution. Increased risk of accidental spills together with the lessons made with oil pollution in the recent past has led to a re-evaluation of existing oil spill contingency management in Germany and many other countries (Insel and Halligkonferenz, 2008). Management improvement can generally be divided into two problem areas that are related to short-term operational issues and long-term preparedness. Operational decision making during an imminent spill is always a difficult task, not only due to the complex dynamics of the physical system in the coastal zone, but it also involves assessment and balancing of various ecological and economic values of coastal areas under risk (Liu and Wirtz, 2005). Preparedness includes prevention measures as well as additional human and technical resources. These facilities should enable a highly efficient protection of environmental goods against pollution. In the case of OWE farms in Germany, it has been proposed to invest in further facilities for oil spill contingency management. This way is going to adapt the means for protection of sensible coastal areas to the new risks. For solving both problems (e.g. short- and long-term planning), one needs to assess the specific benefits of different combat strategies. Costs of increased

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preparedness have to be compared by the total benefit for the environment, ideally in monetary terms. While, during operational decision making, defence of one specific habitat has to be compared to its consequence not to protect another habitat.

Evaluating combat strategies and preparedness is directly linked to the evaluation of the environmental goods that are subject to potential oil spills. However, there is still limited information available about monetary benefits of coastal habitats to society (Spurgeon, 1999; Ojeda et al., 2008; Stål et al., 2008). Yet little is known about how much households are willing to pay for a set of environmental goods prevented from oil pollution. Therefore, more guidance is required related to the relative importance of environmental impacts caused by oil pollution.

1.1. Why choice experiments (CEs)

Due to a missing market, quantification in monetary terms is hard, implying a risk of their negligence during decision making. A large class of stated preference methods appropriate to support environmental risk management have been tested during the last decade (Schläpfer, 2008). Most often, a contingent valuation method (CVM), has been chosen to estimate consumer's willingness to pay for non-market goods including environmental risk management (Baral et al., 2008). However, it is difficult to distinguish the value of each attribute of multi-attribute goods using CVM. For instance, the damage to natural resources caused by an oil spill includes a variety of effects on coastal waters, beach, birds and so on. CVM can estimate the total value of protection from oil spills, but it cannot identify the value of avoiding each effect. Choice Experiment (CE) as an alternative stated preference technique is capable of distinguishing the value of each attribute of multi-attribute goods. CE is a structured technique where respondents have to choose their most preferred alternative from a set of alternatives. For environmental studies, CEs have recently been applied in forest (Rolfe et al., 2000; Horne et al., 2003; Lehtonen et al., 2003), wetland (Kuriyama, 1998; Carlsson et al., 2003), fishery (Wattage et al., 2005), waste management (Garrod and Willis, 1998; Guikema, 2005), water supply (Haider and Rasid, 2002; Hanley et al., 2005), hunting (Boxall et al., 1996; Bullock et al., 1998) and renewable energy (Álvarez-Farizo and Hanley, 2002). Although the number of CEs studies continues to increase, to our knowledge none has addressed oil spill contingency management at present.

The general flow of procedures of applying the CEs is shown in Fig. 1. The first step is the preparation of the survey. This includes the identification of the valuation problem and making preliminary decisions about the survey formats such as telephone survey, mail survey and in-person interview. Next comes a survey design including the design of the questionnaire, the pretest of the survey, modification of the questionnaire followed by its implementation. The final step is the processing and analysis of the data and the communication of results, preferably according to emerging standards of an integrated resource use management.

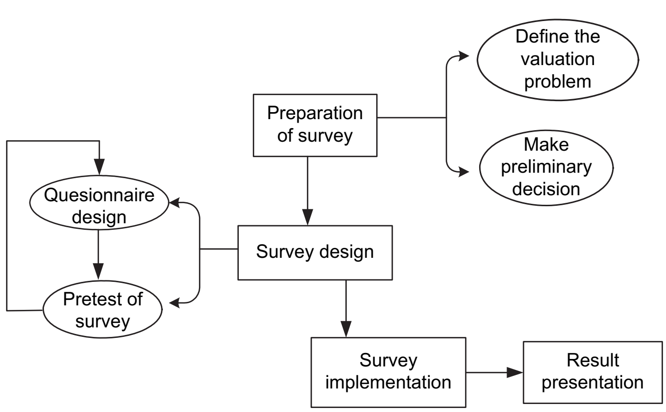

Fig. 1. Steps of the choice experiments.

1.2. Outline

The study proceeds as follows. In Section 2 the basis of the choice experiments: random utility theory, Logit model, and welfare estimation are described in detail. Section 3 develops a survey to elicit how much households are willing to pay for specific combat management scenario. Different levels of benefits and prices are specified in a number of experiments in order to provide a necessary variation with which the marginal utility of each benefit can be estimated. Section 4 presents analyzed results of the choice experiments followed by exploration of its potential application and limitations in an oil spill contingency management. Finally, Section 5 summarizes major findings of the study.

2. Methodology

2.1. Random utility theory

The random utility theory underlying the CEs technique provides the theoretical underpinning for integrating choice behaviour with economic valuation (Turner et al., 1998). Within the choice selection approach, the random utility theory postulates that an individual's utility $u(y,q,\varepsilon)$ corresponding to a change of an environmental item depends on individual's characteristics, here for simplicity reduced to income y, and the non-market item itself, which is to be valued and denoted by q (Hanemann and Kanninen, 1996). The other key component is a stochastic part ε, which is unobserved by analysts. Suppose that an individual is confronted with the possibility of obtaining a change in a good q from q_0 to q_1 with $q_1 > q_0$. If the individual views this as an improvement, $u(y,q_1,\varepsilon) > u(y,q_0,\varepsilon)$ holds. The individual is told that this change will cost \$$A$. The answer is "yes" only if $u(y-A,q_1,\varepsilon) > u(y,q_0,\varepsilon)$, and "no" otherwise. Hence,

$$Pr\{response\ is\ \text{“yes”}\} = Pr\{u(y-A,q_1,\varepsilon) > u(y,q_0,\varepsilon)\} \tag{1}$$

Let C^* be the respondent's maximum WTP for the change from q_0 to q_1. From a compensating view, C^* satisfies,

$$u\left(y-C^*,q_1,\varepsilon\right) = u(y,q_0,\varepsilon) \tag{2}$$

Thus, the respondent answers "yes" if the stated price A is less than that C^*, and "no" otherwise. ε itself is a random variable for the investigator. Let $G_c(A)$ be the cumulative distribution function of C^*, then:

$$Pr\{response\ is\ \text{“yes”}\} = 1 - G_c(A) \tag{3}$$

According to the economic theory, a person's maximum willingness to pay for an item has both upper and lower bounds (Hanemann, 1984). In terms of the response probability formula, the constraints are given by,

$$\begin{cases} Pr\{response\ is\ \text{“yes”}\} = 0 & A \geq y \\ Pr\{response\ is\ \text{“yes”}\} = 1 & A = 0 \end{cases} \tag{4}$$

2.2. A linear Logit model

As mentioned previously, a random utility of a choice alternative includes a measurable (explainable) part as well as a random part.

Consider a choice with index j, the discrete utility of a consumer i choosing choice j is,

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{5}$$

where V_{ij} represents the measurable part of the utility U_{ij} and ε_{ij} captures the unexplainable proportion. The observed utility V_{ij}, as in the following application, is formally a function of all attributes of the choice j and of the respondent i. A common specification of this function is linear in parameters,

$$V = \beta X \tag{6}$$

where β is a vector of parameters to be estimated through the maximum likelihood method. The vector X contains discrete levels of observable attributes related to environmental goods, costs and individual's socio-economic characteristics. Selection of one choice over another implies that the utility held by that choice is greater than the utility of the other. The probability of choosing alternative j is:

$$Pr\{j\ is\ selected\} = Pr\{U_{ij} > U_{ik} \quad \forall j \neq k\} \tag{7}$$

In a multinomial Logit model the random part ε_{ij} is assumed to be independently and identically distributed (IID). Thus, the probability of a choice j from a choice set consisting of p choices has a closed form depending on the matrix of formalized utilities (Malhotra, 1984)

$$Pr\{j\ is\ selected\} = \frac{\exp(V_{ij})}{\sum_{k=1}^{p} \exp(V_{ik})} \tag{8}$$

2.3. Welfare estimation

The maximal WTP (i.e. C_j^*) for option j, is defined as the payment that just makes an individual indifferent between the choice j and status quo choice k. Algebraically, it can be expressed as:

$$V\left(X_j, C_j^*, S_i\right) = V(X_k, C_k = 0, S_i) \tag{9}$$

C_j denotes the cost of choice j. X_j and X_k are environmental attributes related to choice j and k, respectively. S_i is a vector of demographic factors represented by respond i. Hence, a marginal WTP (mWTP) value of a change within a single attribute m can be represented as a ratio of coefficients as follows,

$$mWTP_m = -\frac{\beta_m}{\beta_c} \tag{10}$$

where β_m is the coefficient of attribute m and β_c is the coefficient of the monetary attribute. This part-worth formula provides effectively the marginal rate of substitution between cost change and the attribute in question (Bennett and Blamey, 2001). In addition, a relative difference of willingness to pay (ΔWTP) associated with all changes in environmental goods between two choices' profiles reads,

$$\Delta WTP_{jk} = -\left(\frac{\sum \beta_m (X_{mj} - X_{mk})}{\beta_c}\right) \tag{11}$$

ΔWTP quantifies the variation in environmental items in money terms as represented by two different choices. It is here used to elicit preferences for different environmental scenarios relevant for a management option.

3. An application to oil spill combat options

To assess values that Germans might hold for coastal resources prevented from oil pollution, a questionnaire was designed and followed by a pilot survey. The questionnaire (see Appendix for a brief information of questionnaire) can be divided into three parts: attitudinal and behaviour, evaluation and demographic parts. Through a set of questions in the first part, respondents are warmed up and the third part will record respondents' socio-economic characteristics. The evaluation part designing CEs in a context of a hypothetical oil accident at the German Bight, 2010, consists of a number of attributes. Generally, employing combat may decrease coastal pollution and increase response costs on the other hand. To address these benefits and costs, five key attributes are employed as indicators of combat management. These attributes include three different types of natural goods, the oil collection ratio during the combat and finally, yearly payments required for the using of combat facilities. For simplicity, only coastal waters, beaches and eider ducks are concerned as main natural goods suffering from oil spills. All but one attribute (e.g. the payment) are assigned with 2 levels, respectively. The payment attribute was spilt into 4 levels. The combinations of these levels were used to build choice profiles to be presented to the respondents. Selected attributes and levels are presented in Table 1 forming an array of 64 (4×2^4) possible profiles. To create choice sets in an efficient way, an orthogonal experiment design process was used to select 8 out of 64 profiles. These eight profiles together with a status quo represent 8 choice sets. Each choice set consists of two combat options, the status quo together with an alternative option. For an example choice set see Appendix. From a pretest of the questionnaire, we found, in order not to frustrate volunteers addressed by our study, firstly the length of questionnaire should be kept as short as possible; secondly, the

Table 1
Attributes and levels used in the choice experiments.

Attribute	Level	
Coastal waters	200 km^2	avoided from oil pollution
	130 km^2	
Beaches	80 km	avoided from oil pollution
	30 km	
Eider ducks	15,000	birds avoided from oil pollution
	5000	
Collect ratio	50%	of spilled oil to be collected by combat vessels
	25%	
Yearly payment	€150	
	€50	
	€20	
	€0	

Table 2
Results for the survey with a basic binary Logit model.

Variable	Coefficient	|Z| statistic
Constant	−2.56[e]	1.99
Water	5.36E−3	1.22
Beach	1.19E−2[f]	1.85
Duck	1.17E−4[d]	3.69
Collect	2.07E−2[f]	1.69
Payment	−1.69E−2[d]	6.33
Child[a]	−4.96E−1[d]	2.57
Income[b]	4.52E−1[e]	1.99
Member[c]	1.70[d]	2.75

$\log L = -142.67$
$\chi^2(8) = 77.23$ (significant at 0.00000 level)
$\rho^2 = 0.213$

[a] Continuous variable indicating the number of children in a household.
[b] Category variable represents the household monthly income; 1 = less than €2000; 2 = €2001–4000; 3 = €4001–6000; 4 = €6001–8000; 5 = more than €8000.
[c] Dummy variable set equals 1 if respondent is a member of any environmental organization; 0 otherwise.
[d] Statistically significant at the 1% level.
[e] Statistically significant at the 5% level.
[f] Statistically significant at 10% level.

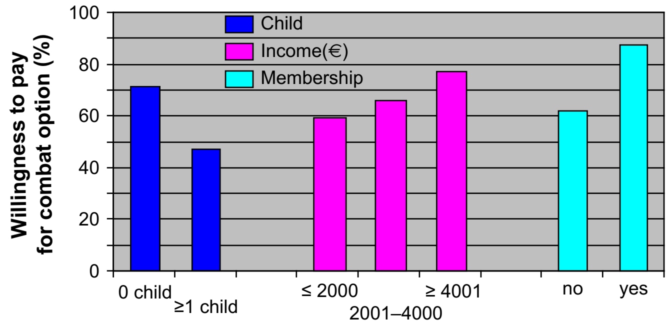

Fig. 2. Effects of demographic characteristics of household on choice.

number of profiles to be compared in each choice set should not exceed 3 and the total number of choice sets is limited up to 10; thirdly, a graphical design should help respondents to understand questions at first glance.

4. Results and discussions

For the experiment reported here, a pilot survey within Oldenburg University, Germany was conducted by the working group IMPULSE in 2005. Totally 80 people including students and staffs are randomly contacted in the campus. However, only 35 respondents completed the survey (i.e. response rate is 43%). Each respondent answered 8 choice sets, giving a total of 280 observations among which costly combat option is chosen 182 times. These results may be explained that either respondents concern natural resources in coastal environment deeply or yearly payments set in the alternative combat option are conceived as relatively low, or both. Information from attitudinal and behaviour questions indicated that while Germans were aware of oil spill issues in general, there was little to suggest that they had specific knowledge and concern about oil spill contingency management. A binary Logit model calculation in which significant demographic characteristics are included is performed by the software of Eviews®. The Logit model outcomes are presented in Table 2. All signs of attributes in the model are expected a priori indicating whether utility has been

Table 3
Part-worth of environmentally related attributes.

Attributes	Part-worth
Water	$-\beta_{water}/\beta_{payment} = €0.32/km^2$
Beach	$-\beta_{beaches}/\beta_{payment} = €0.70/km$
Duck	$-\beta_{duck}/\beta_{payment} = €6.92E-3/bird$
Collect	$-\beta_{oil}/\beta_{payment} = €1.22/tons$

increased or decreased. All attributes except water are statistically significant in the model at conventional levels. The overall fit of the model as measured by McFadden's ρ^2 also meets standards for probabilistic discrete choice models (Ben-Akiva and Lerman, 1985).

The coefficients reveal that households with less children, higher monthly income and a membership of environmental organization are more likely to prefer the alternative, more costly combat option. As shown in Fig. 2, 71% households without children are willing to pay for the combat option, while only 47% households with one or more children choose the alternative combat option. Also the percentage of households saying "yes" for the alternative option increases as monthly income increases or if the respondent is a member of any environmental organization.

Part-worthies can be generated for the continuous variables: waters, beaches, birds, oil collection as shown in Table 3.

For example, the part-worth for beach reflects that each unit (1 km) increase in the length of beaches prevented from oil spill has a marginal value of €0.70 per household per year. The model can also be used to estimate value differences between any two profiles used in this study. For the two profiles presented in Table A2 of Appendix, the differential WTP equals,

$$\begin{aligned}\Delta WTP &= \frac{-[\beta_{water}\Delta water + \beta_{beach}\Delta beach + \beta_{bird}\Delta bird + \beta_{oil}\Delta oil]}{\beta_{payments}} \\ &= \frac{-1}{-0.0169}[0.00536 \times (200-130) + 0.0119 \\ &\quad \times (80-30) + 0.000117 \times (15{,}000-5000) + 0.0207 \\ &\quad \times (50-25)] \\ &= €157.3/household/year\end{aligned}$$

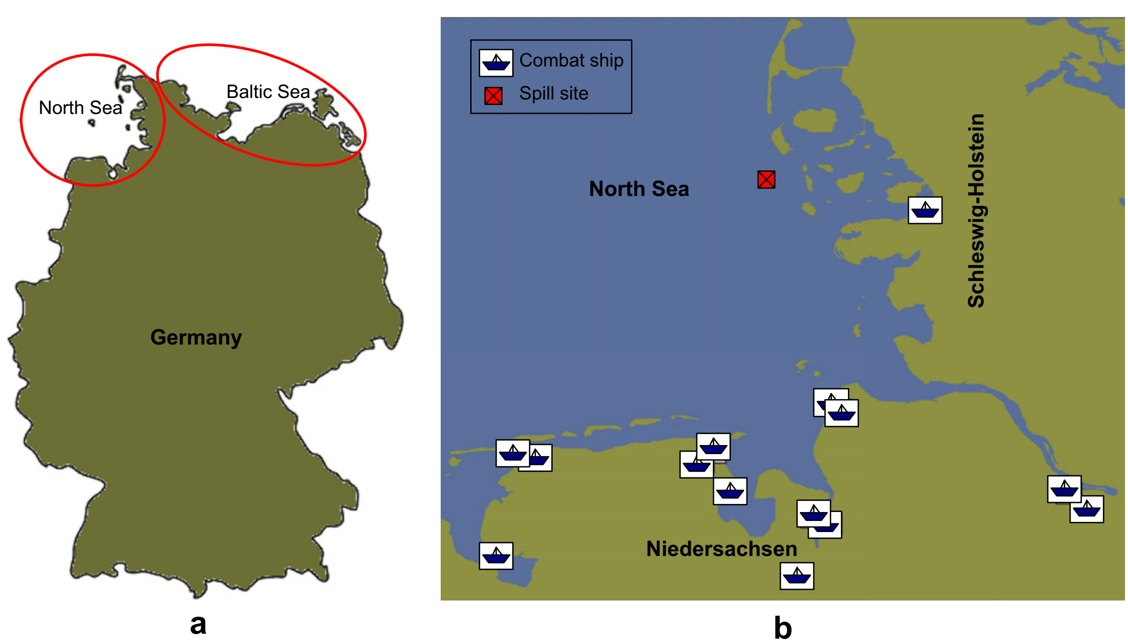

Fig. A1. German coastal areas and oil spills. (A) Coastal regions in Germany; (B) A hypothetical oil spill (amount: 70 tons; site: 54°32.5′N; 8°17.24′E).

Often, decision makers are forced to make responses immediately when facing an oil spill. In such instances, using CEs may cost time, especially when a larger sample is surveyed. Moreover, CEs require knowledge about designing of questionnaire and statistical skills to deal with discrete choices. Therefore, such a method is suggested to be conducted *ex ante* to collect possible information for future use.

It is impossible to directly ask people's WTP for one specific combat option, since they are unfamiliar with oil spill contingency management. Hence, attributes as indicators of combat management should be determined carefully to help people to identify the difference between combat alternatives. Generally, they should be well known to people and their quality or quantity changes are plausible and well understood (Boxall et al., 1996).

According to a general aim of integrated coastal zone management (ICZM), environmental impacts should be introduced with a relative importance into a decision making process. Here, CEs taking economic values of environmental resources into account, break the environmental impacts in multiple dimensions down to a single dimension, a monetary value (Braeuer, 2003). The Cost Benefit Analysis (CBA) and the Multi-criteria analysis (MCA) are two widely used decision making tools in the approval of environmental management. Preferences elicited from CEs can be used in those analyses to help decision makers to find optimal combat option. For example, in the CBA they support the calculation of the Net Present Value (NPV) associated with combat management and may help to find a more cost-effective combat management; they also constrain the weights of the importance between environmental resources used in the multi-criteria analysis. Undoubtedly, CEs will have a wide application potential in the field of ICZM, as demonstrated by former studies (Haekan and Bjoern, 2000; Brown et al., 2001; Wattage et al., 2005) and the case of oil spill management in this paper.

5. Conclusions

This paper describes and presents an empirical example of stated choice experiments for oil spill combat options with different levels of management attributes. It is not only designed to support ongoing discussions about the level of preparedness of coastal spill combat facilities, but also aims at analysing management preferences hold by the public. Future studies have to involve a broader spectrum of stakeholders, which could infer even more robust statistics. Although our study is only a pilot survey involving a small number of households, which could lead to a biased result, it reveals how environmental and monetary attributes and household's characteristics influence the support for different options. First, environmental attributes including beach, bird and oil collection ratio are proved to generate a significantly higher impact on the utility for the household than the attribute of sea water quality. Second, significant impact of the yearly extra payment on the utility of household implies that an environmentally friendly combat option has to be a minor cost for the household. Third, it is pointed out that households with less children, higher monthly income and a membership of environmental organization are more likely to prefer a more costly but environmental friendly scenario. The existence of such demographic trends, however, puts severe constraints on the applicability of the choice experiments as one has to address a larger group of respondents than in our study in order to avoid a bias.

Overall, the coastal resources suffering from oil pollution can be measured appropriately by using the method of choice experiments. Results of the study have revealed that CEs provide essential information for evaluating combat option for oil spill management, also have a wide application potential in the field of integrated coastal zone management.

Acknowledgements

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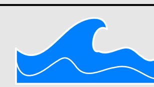
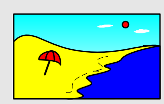
Appendix. Brief information of questionnaire

Coastal regions in Germany are in North where it borders the North and Baltic Seas (Fig. A1). Although many efforts and obvious improvements in prevention measures have been underway since 1970s, oil spill accidents still occurred at irregular intervals. For example, around 244 tons of fuel oil were released through the damaged tanker "Pallas" into the coastal waters in the German North Sea area, 1998. On January 1993 Heweliusz, a Polish ferry which sank in the Baltic of Germany leaked 80 tons of oil.

Now we suppose that an oil spill could happen at the site where the Pallas occurred in 2010. Totally there are 100 tons of fuel oil are released as shown in Fig. A1. Compared with doing nothing, a response strategy of using available combat vessels distributed along the German North Sea often succeeds to prevent more coastal waters, beaches and birds from being polluted by the spilled oil. Both benefits and costs of using a combat strategy are described in Table A1. In the following Section, 8 cards will be presented. In each card, you will be asked to choose one out of two alternatives. An example is given in Table A2.

Table A1. Characteristics of using combat strategy and descriptions.

Characteristics of using combat strategy

Saved coastal waters (km^2) during the combat

Saved beaches in km during the combat

Saved eider ducks during the combat

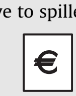
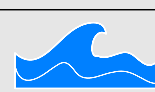
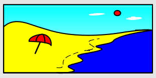
Collected oil relative to spilled oil during the combat

Yearly extra payments to each household for using an effective response strategy

Table A2. A sample choice set from the questionnaire is presented in the choice experiments. Pictograms represent the attributes including sea waters, beaches, birds (eider ducks), oil removal and payment, respectively.

Attributes	Combat options	
	Alternative A	Alternative B
	200 km^2	130 km^2

(*continued*)

Attributes	Combat options	
	Alternative A	Alternative B
	80 km	30 km
	15,000 birds	5000 birds
	50%	25%
	€50	€0
I would prefer	☐	☐

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