Willingness to pay to protect cold water corals.
An economic argument for inclusive ocean governance

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Running Head: Protection of cold-water corals

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Abstract

There is increasing pressure to utilize currently unused resources in the deep sea, raising questions regarding ecosystem service tradeoffs in these often unknown areas. We assess these tradeoffs in relation to protection of cold-water coral reefs versus economic activities such as fisheries and petroleum, using a choice experiment, carried out in Norway and Ireland. Surveys are applied using both discursive approaches and internet-based settings, yet nonetheless providing some similar results. This economic cross-country comparison that gives voice to the public's view on protection of deep-sea habitats indicates that the general public in Norway and Ireland show substantial willingness to protect cold water corals as habitat for fish. This result is obtained despite possible conflict with extractive and

consumptive economic activities in the deep sea. The Norwegian respondents show greater existence values linked to cold water coral than do the Irish respondents, and the latter are less willing to trade off industrial activities than the former. Nonetheless, the findings support conservation of cold water corals, and more generally ocean environments that provide habitat for fish, which the current deep sea governance systems are not adequately designed or sufficiently well-structured for securing.

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Introduction

Cold water corals represent high biodiversity ecosystems that occur in deep water, mostly far from shore and with limited possibilities for observation, making them less visible to public and scientific scrutiny, and vulnerable to exploitation, overuse and degradation (Ramirez-Llodra et al. 2011). At the same time, extractive uses of the ocean represent important economic activities generating revenue and providing employment in coastal regions that often are highly dependent on these industries. Also deeper, open ocean areas are receiving growing interest in an effort to expand blue growth (Danovaro et al. 2017). Scientific and economic analysis of the ocean has increasingly focused on the vulnerability of deep sea ecosystems, including cold water corals, arising from commercial uses of the ocean, particularly deep sea fishing and oil and gas extraction (Roberts et al. 2006; Wattage et al. 2011; Folkersen et al. 2018). In response to these concerns the scientific community and stakeholders have called for more effective governance, improved funding and action in relation to key threats to cold water corals, such as bottom trawling and dredging, oil and gas exploration and climate change (Roberts et al. 2006; Barbier et al. 2014). Marine protected

areas (MPAs) have been suggested and in some places implemented to safeguard cold water coral reefs and habitat (Roberts 2002). Indeed, a number of such reserves have been established in recent years (Armstrong et al. 2014; Lagasse et al. 2015) and ambitious goals identified more generally in the Convention of Biological Diversity (CBD 2011), to secure protection of 10% of marine and coastal areas by 2020. Yet, important questions remain regarding the scientific, technical and socio-economic needs underpinning their deployment (Watson et al. 2016), and large areas still exist where our knowledge of the ocean floor is limited, with cold water coral areas still remaining unprotected, raising questions regarding further conservation efforts (Armstrong et al. 2014). Calls have therefore been made to generate more economic data on the costs, benefits, funding arrangements, typology of values and governance associated with marine protection (Barbier et al. 2014). Marine spatial uses are dynamic and multidimensional and involve a wide variety of stakeholders often with conflicting interests and value, some of which oppose the use of MPAs. Thus, political acceptance of MPAs is often problematic and may involve controversial economic trade-offs. Policy makers recognize that successful deployment of MPAs requires information on the economic value of goods and services associated with marine habitats, and the extent to which stakeholders are willing to forego developmental gains for conservation benefits. Policy makers have a responsibility to balance conservation policy with fisheries policy (De Santo 2013). According to the Law of the Sea Convention, nation states have a duty under the public trust doctrine to protect the corpus of marine resources on behalf of its citizens. This typically includes all biological marine resources such as marine habitat, not just fish. It has been argued that the Common Fisheries Policy (CFP) makes it difficult for EU member states to fulfill their responsibilities to conserve marine habitat under the public trust doctrine on behalf of their citizenry (Mellett et al. 2011). And while the voices of stakeholders with vested interests in ocean governance have often been heard (Levin et al. 2009), the public's

view of the role of marine habitats in supporting marine life (Armstrong & Falk-Petersen 2008), particularly in the deep sea, has not been widely investigated. Indeed, a number of studies suggest that more could be done to engage the public in marine conservation (Jefferson et al. 2015; Thaler and Shiffman 2015).

Research on cold water coral valuation is limited to a handful papers (LaRiviere et al. 2014; Sandorf et al. 2016; Aanesen et al. 2015; Sandorf et al. 2016; Wattage et al. 2011), while studies on tropical coral reefs are much more common (for an overview, see Brander et al. (2007)), and show high end values compared to all other biomes, despite most studies focusing solely on recreational values (de Groot et al. 2012). Little is known about the public's willingness to trade off conservation measures against competing uses of the open ocean. This limits the consideration of broader public interests in policy decision-making regarding the ocean (Young et al. 2007). We argue that the public are legitimate parties that need to be involved in questions regarding marine stewardship and governance. The public perceive themselves as stakeholders with rights, responsibilities and obligations to safeguard marine ecosystems (Häussermann & Försterra 2007; De Santo 2013). They derive welfare from direct and non-use of deep sea marine resources, are willing to pay for policies to protect marine habitats and the ecosystem services they provide (Jobstvogt et al. 2014). Furthermore, the public funds marine conservation and research through general taxation, support to NGOs concerned with marine conservation and management, and play an increasingly active role in marine conservation activities and governance (Cigliano et al. 2015).

Several recent studies have emphasised the importance of non-use values associated with different marine species and marine protected areas (McVittie & Moran 2010; Börger & Hattam 2017). Central in non-use values are existence values which refer to circumstances where an individual values that a resource exists, independently of any actual or prospective use, and where that individual would feel a 'loss' if the resource were to disappear (Freeman

1993). The main beneficiaries of existence values associated with the deep sea are probably the general public. Valuing deep sea marine habitats is particularly challenging because researchers cannot rely on observed behavior. Instead, they have to use stated preference methods such as contingent valuation or choice experiments to elicit non-use values. These methods have seen extensive use to estimate values, evaluate trade-offs and advise on policy formulation of protected area policy in coastal and temperate regions and tropical coral reefs globally (McVittie & Moran 2010, Jobstvogt et al. 2014, Börger & Hattam 2017). The literature concerned with non-use values has focused on rare and charismatic species (Börger & Hattam 2017), fish (Campbell et al. 2012) and biodiversity (McVittie & Moran 2010), but we are not aware of any studies that investigate non-use values or trade-offs involving restrictions linked to the role of marine habitats in supporting other species. McVittie and Moran (2010) used choice experiments in an attempt to evaluate non-use values and trade-offs between biodiversity, environmental benefits and restrictions on resource extraction concerned with the UK's marine conservation bill. However, in common with much of the stated preference literature they were not able to clearly distinguish between use value and non-use value motives, or to demonstrate public support for policies that involved restricting resource extraction. We used choice experiments in this study because they allow for the valuation of specific characteristics of a non-market good which enables us to identify non-use value motivations and trade-offs between conservation and extractive activities.. Choice experiments could thus provide critical information to policy makers about a range of potential values associated with cold water corals.

The study has three main aims. First, to determine public preferences for cold water coral protection in Norway and Ireland, second to evaluate public tradeoffs between cold water coral conservation and competing commercial uses of the ocean, and third to investigate

existence values associated with deep sea habitats. Finally, the study points to how the public preferences identified challenge current management of deep-sea environments.

Our study provides social science, and specifically economic, input, into the conservation science discussion related to the deep sea, playing what Bennett et al. (2017) coin a *descriptive role*, in identifying the public's preferences and valuation of cold water coral ecosystem services in a broad sense, and a *generative role* in pointing to existing governance shortcomings and needs for change if these conservation preferences are to be incorporated. We contribute to the deep-sea conservation debate by deriving willingness-to-pay (WTP) measures associated with extending the protection of cold-water corals in Ireland and Norway. Though the natural circumstances of cold water coral and marine industry presence is somewhat similar in the two countries, social and economic circumstances, as well as cultural differences may play a role in public preferences for development and conservation in the marine environment allowing us to better assess the generality of our results.

We apply the choice experiment method across countries and survey modes. Though the surveys presented here are previously unpublished, two other Norwegian internet and workshop surveys have been presented earlier (LaRiviere et al. 2014; Sandorf et al. 2016; Aanesen et al. 2015; Sandorf, et al. 2016), focusing on information effects, discursive approaches, and comparisons between approaches. The contribution of this current paper, is the combined country and methodological comparison, giving the conservation related results more weight when discussing management issues. In addition we investigate the motivations behind the valuation results. Indeed, the results are highly robust, showing that the general public, both in Norway and Ireland, have strong preferences for conservation of cold water corals, especially focusing on the ecological aspect of corals, namely as habitat for fish. Hence, our results are not idiosyncrasies of some national preference, but can be argued to be a more general representation of public preferences for cold water corals.

Method: The choice experiment

There are several ways to elicit welfare loss from environmental degradation. Surveys asking people to state their preferences for environmental goods, usually by increased conservation and protection, either ask "directly" if they are willing to pay a certain amount for such protection, or include a payment mechanism in more subtle ways. The former is known as the contingent valuation method, and encompasses a variety of ways of asking people directly what they are willing to pay for an environmental good. The latter, among which the choice experiment is the most commonly applied, includes monetary payment as one of several characteristics (attributes) describing an environmental good.

The choice experiment we implemented (see Appendix 1-3 for more detail) asked respondents to choose between three alternatives for protection of cold water corals, where each alternative is described by four attributes. Two alternatives describe increased protection of cold water corals, and one specifies the status quo situation concerning this protection. To avoid a biased survey, which in turn may lead to confounded parameters, in deciding the attributes we emphasized a balance between economic and ecological concerns. The ecological concerns were formulated in terms of cold water coral as habitat for fish, and the mere existence of such coral, expressed as size of coral area protected. The economic concerns were formulated in terms of lost opportunities for commercial activities like fisheries and oil exploration and exploitation. These attributes allow us to assess the general public's preferences in relation to conservation versus development, They open for an assessment of both use and non-use values, the latter expressed by the size attribute. Finally, there is the cost attribute, indicating how much people have to pay if they prefer increased coral protection. We informed respondents that increased protective measures depended on

public support and funding in the shape of a tax increase, and five nominal values were used to indicate the size of the cost. The cost attribute enables us to estimate respondents' marginal utility of money and facilitates the estimation of willingness-to-pay (WTP). The attributes and levels were combined into 12 choice tasks. In Table 1 we list the attributes and the levels that they can take, and in Figure 1 we show a sample choice card from the survey.

Cold-water corals are unknown ecosystems to most people, which complicates eliciting preferences for their protection and conservation. Recognizing that people do not necessarily have pre-existing preferences for all types of goods and services, the Deliberative Monetary Valuation literature stresses that people need information, time to think and the possibility to deliberate with others, in order to reasonably respond to monetary valuation surveys (Lo & Spash 2013). These are reasonable arguments, and we implemented two of the three surveys in a valuation workshop fashion (Hensher et al. 2011). The third survey was internet based. Independent of survey mode, each of the three surveys included the same steps, with a few notable exceptions. The five steps were: i) presentation about cold water corals, ii) a quiz about cold water corals, iii) presentation about the choice experiment, iv) the choice experiment. The valuation workshops included a deliberative valuation stage after the choice experiment. In the valuation workshops a moderator held two power-point presentations – one concerning cold-water corals and one concerning the choice cards. In the internet survey this was replaced with videos designed to give the exact same information and the same visual cues as for the workshop presentations.

Each workshop included between 15-20 individuals, and we implemented 6 and 7 identical valuation workshops in Norway and Ireland, respectively We used a professional survey company to recruit all respondents using a stratified random sampling approach. Respondents in the valuation workshops were recruited from the general population, and in the internet survey they were recruited from a probability based pre-recruited panel. The two valuation

workshop surveys had 105 (Norway) and 139 (Ireland) respondents, while the web-survey had 302 respondents, yielding a total of 546 respondents. The valuation workshop participants are representative regarding gender and age in the municipalities in which they were implemented. The internet-survey is representative with respect to gender, age and geography for the Norwegian population.

Results

In Table 2 we show the estimated mean and standard deviation of the willingness-to-pay (WTP) distributions. The distributions show how WTP varies in the sample (details on the specification and estimation of the model can be found in Appendix 1 and 3). First, we notice that the means of the WTP distributions for small and large increases in cold-water coral protection are relatively large and significant. However, the large standard deviations indicate that we have significant heterogeneity with respect to these attributes. This suggests that a large share of respondents are not willing to pay to increase protection for protection's sake, and indeed might need to be compensated. Note that people are willing to pay more for a large increase relative to a small increase. This is consistent with economic theory stating that more is preferred to less and that WTP is increasing in the scope of the project. Interestingly, we see that mean WTP for protecting areas that are important to industry is insignificant. However, we do observe large and significant standard deviations, which indicates that people are split with respect to this issue. Turning our attention to the habitat attribute, we see that people have the highest mean WTP for protecting areas that are important habitat for fish. However, unlike the other attributes, the vast majority of people have positive willingness-to-pay. These results are reflected in the individual specific WTP estimates shown in Figure 2.

When we combine different sources of preference data, here 3 different datasets, we need to consider the possibility that there are unobserved differences between them. It is possible that there are factors outside of what we can observe, i.e. the attributes of the alternatives, that influence the choices respondents make in the choice experiment. To consider such factors we estimate a relative scale parameter, which implies that we normalize the variance for one group and estimate the variance for the other groups relative to this baseline. This is a simple and effective way to control for some such unobserved effects. We see that respondents in the Irish workshop and Norwegian internet survey have a significantly lower scale parameter (significance is tested against 1), which suggests that unobserved factors for these two samples affect choices relatively more than those in the Norwegian workshop sample.

To explore differences and similarities that might exist between countries we have derived the mean individual specific estimates and plotted them in Figure 2 (see Equation 6 in Appendix A). The individual specific estimates show where an individual is likely to lie on the WTP distributions estimated above. Several findings are worthy of attention. First, people expressed a clear WTP to conserve cold water corals in all three surveys regardless of survey timing, country surveyed or survey mode, given that cold water coral is important habitat for fish. This is indicated by the positive values for habitat in the far right panel of Figure 2.

Second, the habitat aspect of cold water corals trumps both peoples' preferences for commercial activities (like oil/gas and fisheries) and non-use values of coral reefs (expressed by the size attribute), except for the Norwegian valuation workshop sample who show substantial WTP for the coral reefs themselves. The very significant WTP for the habitat attribute means that people care for the well-being of fish. One could argue that this might be for "selfish" reasons, i.e. because it enables larger harvests in the future. However, the fact that the commercial attributes are insignificant implies that people do not care whether industries are hampered by protection.

Third, our observations tentatively suggests that the public are willing to make trade-offs between competing uses of the ocean. We see from the distribution of individual specific WTP in Figure 2 that people are split with respect to whether they are willing to pay to protect areas that are important for commercial activities. For example, those with a positive willingness-to-pay, are willing to pay to protect cold-water corals at the expense of industry. However, about half the respondents have a negative willingness-to-pay to protect areas that are important for commercial activities. This indicates that they put emphasis on allowing commercial activities even if it results in not increasing the protection of cold water corals.

The categorical and consistent emphasis prioritizing the habitat attribute found in the two workshop surveys required further investigation in order to explain possible motivations behind this result. In the internet survey we therefore examine more closely why the public take such an unambiguous stance regarding habitat protection. This is done by asking follow-up questions that distinguish between a number of plausible reasons for cold water coral habitat protection, including non-use values, potential use values, values pertaining to protecting fish for consumption and for the existence value of fish, and finally more general protection of cold water corals. The answers given confirm our findings from the Norwegian valuation workshop survey (i.e. positive WTP for habitat combined with positive WTP for the commercial attributes). Cold water coral protection is not motivated by habitat preservation in support of commercial fish species, or possible future values, but is instead based on preferences for general environmental protection and for the habitat that the coral provides for fish. Indeed, principal motivations for cold water coral protection, by 63% of respondents, focus on the role of habitat support for marine species independent of extractive human use. Although we find differences in WTP between the surveys (Figure 1), the main findings are robust and consistent across all surveys regardless of setting, timing and survey mode, which strengthens their reliability.

Discussion

Two firm conclusions can be drawn from this work. We find that the Irish and Norwegian public expressed a clear WTP to conserve cold water coral in the deep sea, as long as this coral is an important habitat for fish. Second, our findings suggest a strong public endorsement of ecological considerations whereby priority is afforded to the role of cold water coral in supporting the well-being of fish. This can be interpreted as a WTP for the existence value of fish and is a common finding across all three surveys. A number of studies have used stated preference methods to investigate non-use values associated with marine resources (Börger & Hattam 2017; Campbell et al. 2012; McVittie & Moran 2010). However, departing from these studies we make a new contribution by providing a clear link between non-use value motives and policy support for marine habitat conservation, even if this involves restrictions on resource extraction in the form of no take zones.

Two important questions for policy makers concerned with protected area design are how to respond to the conflicting needs of different stakeholders, and given the increasing uncertainties in the deep sea, the extent to which the precautionary principle and no-take zones should be implemented in protected area design (De Santo 2013). In answering the former, our data conveys the perspective of public stakeholders from the two countries. Our results from Norway show that respondents are willing to pay for the existence value of cold water coral reef structures themselves although the Irish are not. The Irish do nonetheless strongly value their existence as a habitat for fish, as was also the case in Norway, endorsing its conservation on the grounds of being essential habitat. In answering the first question, clearly public stakeholders in both countries support protective measures motivated by non-use values for conservation of habitat to support fish. This perspective representing the

general public as a constituent stakeholder needs to be included in the future of protected area design.

Our findings with respect to tradeoffs between cold water coral protection and commercial uses are more tentative. Respondents displayed greater ambiguity when confronted with clear conflicts between protection of cold water corals versus commercial activities in the deep sea. Respondents with a positive WTP for the attributes representing commercial activities and fish habitat are willing to forego commercial activity in favor of cold water coral habitat in order to safeguard the well-being of marine fish species. However, this was by no means a universal finding, as about half the respondents have a negative willingness-to-pay to protect areas that are important for commercial activities. This implies that these respondents are not willing to protect more coral areas if this means hindering commercial activities like fisheries and oil exploration and exploitation. A qualification that should be mentioned is that the number of cold water coral protected areas have been growing, and clearly this may also impact on the willingness to pay to increase protection further. Furthermore, wider market conditions may affect willingness-to-pay. However, the final internet survey was conducted following the oil-price collapse in 2015, involving a tightening of the budget constraint for parts of the Norwegian population. Though this could imply that people had less money to spend on conservation initiatives, the main findings remain robust.

If public preferences as identified in this study were to be included in deep sea management, it would require incorporation of tradeoffs between ecosystem services both market and non-market, as well as consumptive and non-consumptive, underlining a broader ecosystem-based management than currently found in ocean governance. Though an ecosystem focus has definitely entered the realm of fisheries management in many countries (Worm et al. 2009), a full incorporation of a wider set of ecosystem services represents a challenge to statutory authorities governing deep-sea marine resources. This since national ministries and

directorates are notoriously sectorial, with environmental jurisdictions being largely independent from ministerial portfolios concerned with extractive industries (Salomon and Dross 2018). In many countries, there is poor integration between fisheries and conservation policies (Mellet et al 2011), though increasingly connections between habitats and fisheries are shaping protection, both inside and outside national jurisdictions (Gullage, Devillers et al. 2017). Nonetheless, inclusion of broader public preferences in deep sea ocean governance and policy would require reform in support of integrated ocean management which incorporates tradeoffs between ecosystem services and values, and which better reflects public interests in marine environmental public goods and governance. This fits well with the broad scientific effort to secure biodiversity conservation across large marine spatial areas and across jurisdictions (Weaver & Johnson 2012). It can also be seen reflected in the CBD goal of protection for 10% of marine and coastal areas worldwide, a goal which seems increasingly possible (Jantke et al. 2018), and which includes some cold water coral protection (Armstrong et al. 2014, Gullage et al. 2017). Though our surveys relate to national Exclusive Economic Zones, they add potential non-use value arguments to the use-value arguments used to for instance promote high seas area closures (Sumaila et al. 2007; White & Costello 2014).

Aanesen et al. (2015) find that the Norwegian public are willing to pay to protect cold water coral habitat to secure fish as a food source (a use value) and because they care about the existence of fish (a non-use value), but were not able to separate these two distinct types of value or explain how they might influence willingness-to-pay. We build on Aanesen et al. (2015) and investigate the underlying motivations behind the public valuation of cold water coral protection, illustrating that it lies outside of the realm of commodities and market based values, and identify that the public is willing to pay to protect environments that they have little direct use or experience of. Research on tropical corals has lead to a realization that the

understanding of the socio-ecological links are vital for securing conservation (Hughes et al. 2017). What is interesting regarding the cold water coral surveys as compared to tropical coral assessments, is the broad public support in relation to non-use values, not only for cold water corals, but even more in the sense of securing supporting services for fish. Taking the general publics' preferences into account, as identified in this study, could be expected to lead to greater protection of marine habitats, and even ones that most humans will never experience *in situ*.

Appendix 1 Econometric model

The analysis of choice experiment data is based on random utility theory and assumes that an individual's choice among competing alternatives can be described by a random utility model (McFadden 1974). Choice experiments have their theoretical basis in welfare economics, random utility theory and Lancastrian consumer theory (Lancaster 1966; McFadden 1974), which makes them ideally suited to estimate the values people place on non-marketed goods and services resulting from policy change. When a respondent chooses between the different protection alternatives, she reveals information on her preferences for increased protection in addition to marginal utilities for changes in each of the attributes. To introduce notation, we assume the utility that individual *n* receives from choosing alternative *i* in choice situation *t* can be described by the linear-in-the-parameters additive indirect utility function depicted in Equation 1.

$$\mathrm{U}_{nit} = -\alpha \mathrm{C}_{nit} + \beta \mathrm{X}_{nit} + \varepsilon_{nit} \qquad (1)$$

where α and β are parameters to be estimated for the cost, C_{nit}, and non-cost, X_{nit}, attributes of the alternatives, respectively, and ε_{nit} an unobserved error-term. We let the cost-parameter enter with a negative sign since economic theory suggests that people have a positive marginal utility of money. The purpose of the present study is to explore differences and similarities of willingness-to-pay (WTP) across surveys and countries. As such, we find it useful to make a simple transformation of the indirect utility function such that the estimated parameters can be interpreted directly as WTP (Scarpa et al 2008; Train & Weeks 2005). Specifically, we define $\omega = -\beta/\alpha$, i.e. willingness-to-pay, which is the negative ratio of the non-cost to the cost attribute, and write the transformed indirect utility function as follows:

$$\mathrm{U}_{nit} = -\alpha(\mathrm{C}_{nit} - \omega \mathrm{X}_{nit}) + \varepsilon_{nit} \qquad (2)$$

What we observe, as researchers, are the levels of the attributes comprising the alternatives, and an indicator for the chosen alternative. If we assume that an individual chooses the utility maximizing alternative, and that the error-term follows a type I extreme value distribution with variance $s^2\pi^2/6$, then we can estimate the indirect utility function up to a probability using the multinomial logit model (MNL).

$$\Pr(i_{nt}|\alpha, \omega, \mathrm{C}_{nit}, \mathrm{X}_{nit}) = \frac{\exp(-\lambda\alpha[\mathrm{C}_{nit} - \omega \mathrm{X}_{nit}])}{\sum_{j \in J} \exp(-\lambda\alpha[\mathrm{C}_{njt} - \omega \mathrm{X}_{njt}])} \qquad (3)$$

where *J* is the complete set of all alternatives and λ a scale parameter. To identify the model, we need to normalize the variance of the error-term. We divide through by s^2, which leads to the inclusion of λ, which is inversely related to the variance of the error term. For example, as the variance approaches infinity, λ limits to zero and the probability in Equation 3 approaches

1/*J*. Standard practice is to set the scale parameter equal to unity. This implies that all unobserved factors are the same for all individuals. It is unlikely that this is the case when we combine different sources of preference data or attempt to compare results from different surveys done at different times in different countries (Adamowicz et al. 1994). To facilitate comparison between datasets, we consider relative differences between the datasets by normalizing the variance for one dataset to unity and estimate the variance of the other datasets relative to the normalized one (Adamowicz et al. 1994; Swait & Louviere 1993). We use the following specification for the scale parameter:

$$\lambda_n = \frac{\lambda_{\mathrm{W}}\mathrm{I}_{\mathrm{W}}+\lambda_{\mathrm{I}}\mathrm{I}_{\mathrm{I}}+\lambda_{\mathrm{IR}}\mathrm{I}_{\mathrm{IR}}}{\lambda_{\mathrm{W}}} \qquad (4)$$

where the I's are indicators of whether a respondent was in the Norwegian valuation workshop, W, Norwegian internet panel, I, or the Irish valuation workshop, IR; and the λ's are the relative scale parameters with λ_{W} set to unity. The MNL, outlined above, is the workhorse in discrete choice modeling, but is limited by its inability to describe preference heterogeneity, i.e. the idea that different people have different preferences. To overcome this limitation, and thus allow for preference heterogeneity, we use a random parameter logit model (also called a mixed logit model). This extension of the MNL allows for heterogeneity by letting the researcher specify different distributions for preferences in the sample, or in our case: different distributions for willingness-to-pay. Let Θ be a vector of random parameters, and Ω the means and variances of these parameter distributions, then the unconditional probability of the sequence of choices, $y_n = \langle i_1, i_2, \dots, i_{niT} \rangle$, can be expressed as the integral over the logit formula for all possible values of α and ω.

$$\Pr(y_n|\mathrm{C}_n, \mathrm{X}_n, \Omega) = \int \prod_{t=1}^{T} \Pr(i_{nt}|\alpha, \omega, \mathrm{C}_{nit}, \mathrm{X}_{nit}) f(\Theta_n|\Omega) d(\Theta_n) \qquad (5)$$

This integral does not have a closed-form solution, but is approximated using simulation (Train 2009). To explore how willingness-to-pay varies across surveys and people, we use Bayes' rule to derive the conditional parameter distributions, here: conditional willingness-to-pay distributions (Train 2009). The conditional estimates are conditional on the sequence of choices made by the respondent, and as such they are individual specific. The mean of a conditional distribution gives an indication as to where a given respondent lies on the WTP distribution (Hess 2010). We show the formula for calculating conditional willingness-to-pay in Equation 6 and refer the interested reader to Train (2009) for a more in-depth discussion.

$$\omega_{n \vee y_n} = \frac{\int \omega \prod_{t=1}^{T} \Pr(i_{nt}|\alpha, \omega, C_{nit}, X_{nit}) f(\Theta_n|\Omega) d(\Theta_n)}{\Pr(y_n|C_n, X_n, \Omega)} \qquad (6)$$

All models were estimated using Ox 7.1 (Doornik 2007). We let the cost parameter follow a log-normal distribution with sign change and all non-cost parameters follow normal distributions. To allow for possible correlations between our distributions and other unobserved effects (Hess and Train 2017), we estimated the full correlation structure between our parameter distributions, i.e. all off-diagonal elements of the lower-triangular Cholesky matrix. The integrals were simulated using 2000 scrambled Halton draws per individual (Bhat 2003). To increase our certainty of reaching a global maximum, we generated and tested a large number of starting values and ran several of the best fitting vectors of starting values to convergence.

Appendix 2 The choice experiment

The attributes used to describe the alternatives were identified in a thorough literature review and interviews with experts, before refinement using focus groups (Aanesen et al. 2015). The

attributes finally included were i) the size of the protected area, ii) whether the proposed protected area would be located in areas important for industry (i.e. oil and gas, and commercial fishing), iii) the importance of cold water corals as habitat for fish, and iv) the private cost of increased protection. Increasing the size of the protected area involved a moderate (5000 km^2) or large (10000 km^2) increase, and protection could potentially restrict commercial activities in the form of oil and gas exploitation and bottom trawling in some areas. These attributes allow us to assess the general public's preferences in relation to conservation versus development, and can potentially provide policy makers with input regarding hard choices in the areas considered. They open for an assessment of both use and non-use values, the latter of which often are not present on the table when assessing area protection.

In addition, respondents were made aware that the amount of fish can vary from one cold water coral area to another, and that our knowledge of the importance of this habitat for fish is limited. Finally, we informed respondents that increased protective measures depended on public support and funding in the shape of a tax increase, which provides us with an estimate of respondents' marginal utility of money and facilitates the estimation of willingness-to-pay (WTP).

In addition, the workshops included a treatment where half the respondents received the score on a quiz they took about cold water corals, which was included in all surveys, prior to the choice experiment. This treatment had only minor effect on survey results and does not affect the conclusions presented in this paper. Finally, after the choice experiment in the valuation workshops, participants took part in a deliberative valuation exercise. As it took place after the initial survey, this has no consequence for the results presented here. Note that the internet survey was conducted last, following the oil-price collapse in 2015, involving a tightening of the budget constraint for parts of the Norwegian population. This implies that people have less

money to spend on conservation initiatives and could lead to a downward shift in estimated willingness-to-pay. Furthermore, this survey included a set of follow-up questions after the choice cards to better understand the type of values the respondents were relating to.

Appendix 3 Hypothetical bias

Without a coercive payment mechanism, stated preference surveys remain prone to hypothetical bias, which involves people stating that they are willing to pay more than they would be in reality. Hence, choice experiment surveys do not come without problems, of which the hypothetical character of the payment is the most important. Although several refinements have been suggested and are now standard procedures in the implementation of stated preference surveys, they are inherently prone to hypothetical bias, i.e. people give answers that deviate from what they would have given in a market situation. In spite of the inherent hypothetical bias, stated preference surveys are widely applied to provide estimates for the value of non-market goods and services, and tests indicate that the bias is not unambiguously large and on the positive side. A method to avoid bias that has proved effective in the contingent valuation literature is the use of cheap-talk scripts (Cummings and Taylor 1999). A cheap-talk script involves explicitly explaining to respondents people's propensity to overstate WTP in hypothetical situations and reminding them of their budget constraint, i.e. that what they choose to pay for environmental protection cannot be used for other goods. Given the indirect elicitation in a discrete choice experiment, as used here, we only reminded respondents about their budget constraint. Another way to avoid hypothetical bias is to make the survey incentive compatible, i.e. respondents have an own interest in truthfully responding to the valuation question (Johnston et al. 2017). Vossler et al. (2012) derive a set of conditions under which binary discrete choice experiments are theoretically incentive compatible, and show that a necessary, but not sufficient, condition for theoretical

incentive compatibility is that the survey is 'consequential'. This means that i) the respondent cares about the outcome of the valuation scenario, and ii) believes that their choice can possibly influence the decision made by policy makers (Vossler et al. 2012). The current surveys were formulated with three alternatives and are therefore not generally incentive compatible (Collins & Vossler 2009; Vossler et al. 2012). However, the alternatives were framed around hypothetical increases in cold-water coral protection and respondents were informed that the results would be shared with policy makers, and that the focus on cold-water coral was chosen because policy makers had requested knowledge about people's attitudes towards cold-water coral protection for future conservation policies. Hence, to increase the reliability of our elicitation format we made sure to remind people of their budget constraints and emphasize the consequentiality of the survey.

Appendix 4 Experimental design

Given the nature of cold-water corals, we were unable to obtain reliable priors to use when generating the design. To overcome this, we generated a design based on the assumption of zero priors and the multinomial logit model, and used this design in a pilot study. The results from the pilot study gave us a set of initial priors, which we used to update the design. To accommodate our uncertainty with respect to how good these priors were, we treated them as normally distributed Bayesian priors with means equal to the multinomial logit estimates and standard deviations of 0.2 – 0.5 of the mean. We used 10 000 Halton draws to simulate the distribution and efficiency was determined based on minimizing the median Db – error. The updated design was tested in a second pilot study and again the results were used to refine the design prior to implementation of the main study.

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Table 1. Attributes and levels of the choice experiment

Attributes:	**Size of Protected Area (km^2)**	**Protected area attractive for industry?**	**Protected area important habitat for fish?**	**Additional cost of protection**
Reference level	2.500	Partly	Partly	0
Level 1	5.000	Attractive for fisheries	Not important	100
Level 2	10.000	Attractive for oil and gas	Important	200
Level 3		Attractive for fisheries and oil and gas		500
Level 4		Unattractive for fisheries and oil and gas		1000

Table 2. Results from the random parameter logit model in willingness-to-pay space with full correlation among the random variables.

	Mean	Std. Err.	SD	Std. Err
Size – Small	0.3414***	0.1412	1.9318***	0.0345
Size – Large	0.4244***	0.1641	2.3311***	0.0381
Industry - Oil and Gas	-0.0006	0.0429	0.5199***	0.0526
Industry – Fisheries	0.0271	0.0396	0.3630***	0.0392
Habitat	0.8801***	0.0695	0.8367***	0.0423
Cost/Scale	-1.4107***	0.1695	1.1848***	0.0803
Scale – Workshop – Norway	1	fixed	-	-
Scale – Internet	0.6572***	0.1032	-	-
Scale - Workshop - Ireland	0.6849**	0.1294	-	-
Log Likelihood	-4638.281			
Rho Sq.	0.351			
AIC	9334.561			
BIC	9531.377			
K	29			
N	6547			

***' 1 %, '**' 5%, '*' 10% significance levels. Standard errors are adjusted and robust. The estimates for the non-cost attributes can be interpreted directly as WTP. However, note that they are scaled by NOK 1 000. For example, the unconditional mean of the WTP distribution for Size - Small is NOK 341,40. The test for significance of the scale parameters is against 1.

Figure 1. Sample choice cards - Valuation workshop to the left and online survey to the right

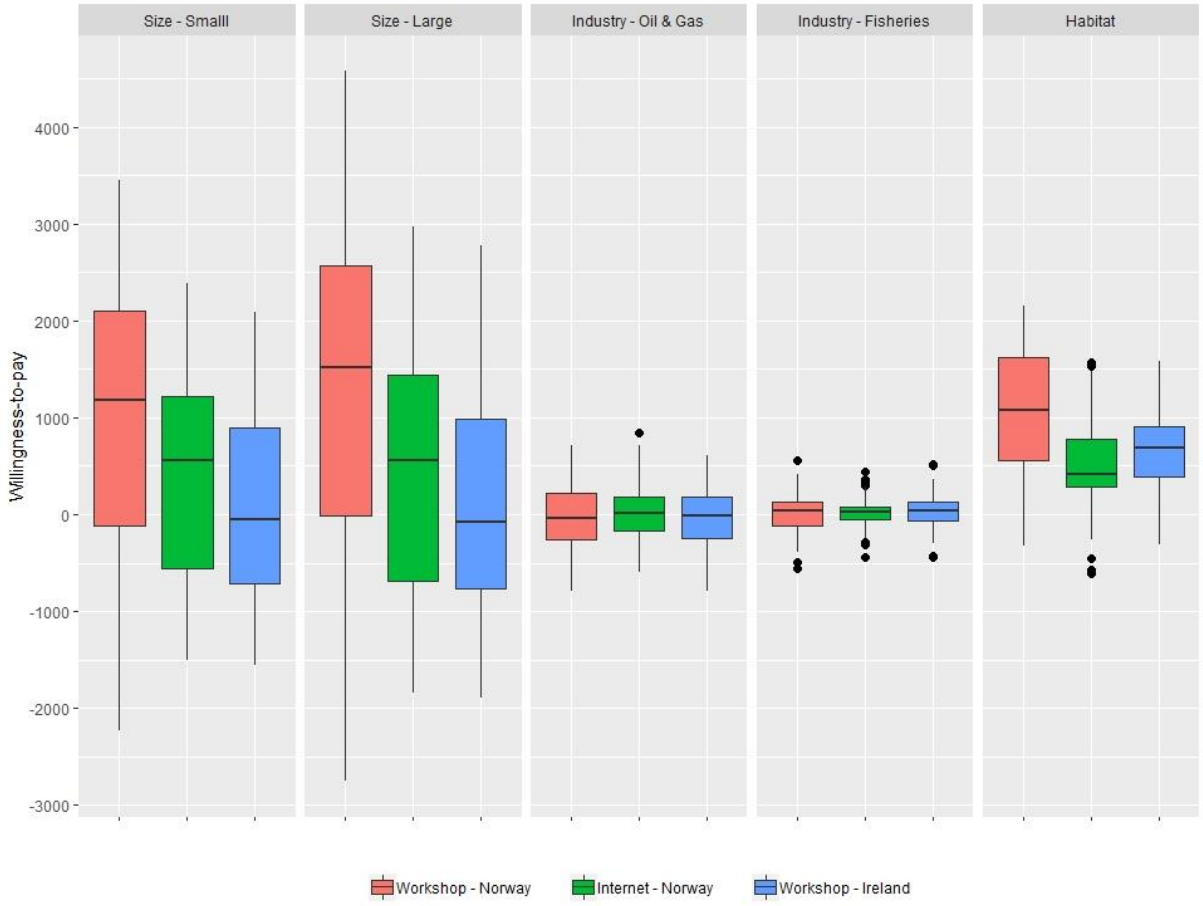

Figure 2. The distribution of conditional willingness-to-pay from the three surveys. The estimates are adjusted for relative scale differences. The black line shows the median, the upper and lower end of the box the 75th and 25th percentiles, the lines extending from the boxes are equal to 1.5 times the interquartile range, and values more extreme than this are plotted as individual outliers.

Figure legends

Figure 1. Sample choice cards - Valuation workshop to the left and internet survey to the right.

Figure 2. The distribution of conditional willingness-to-pay from the three surveys. The estimates are adjusted for relative scale differences. The black line shows the median, the upper and lower end of the box the 75^{th} and 25^{th} percentiles, the lines extending from the boxes are equal to 1.5 times the interquartile range, and values more extreme than this are plotted as individual outliers.