Willingness to pay to protect cold-water coral

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Abstract

There is increasing pressure to use currently untapped resources in the deep sea, raising questions regarding ecosystem service trade-offs in these often unknown areas. We assessed the trade-offs between protection of cold-water coral reefs and economic activities, such as fisheries and petroleum extraction, through a survey of a representative sample of the populations of Norway and Ireland. Choice-experiment surveys were conducted in workshop settings and through the internet . Both survey approaches provided some similar results, such as preferences for protection. Our cross-country comparison showed the general public in Norway and Ireland was willing, despite possible conflict with extractive and consumptive economic activities in the deep sea, to protect cold-water corals as habitat for fish. On average, people are willing to pay NOK 341 and NOK 424 for a small and large increase in protected areas respectively, and NOK 880 if the area is important habitat for fish, everything else equal. However, there is large variation across individuals and countries. . Norwegian respondents valued pure existence of cold-water corals more than the Irish respondents, and the latter were less willing to trade off industrial activities than the former. Nonetheless, the findings support conservation of cold-water corals and more generally of ocean environments that provide habitat for fish, which the current deep sea governance systems are not adequately designed or sufficiently well-structured to secure.

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. Deeper, open ocean areas are receiving growing interest in an effort to expand blue growth (Danovaro et al. 2017). Scientific and economic analyses of the ocean increasingly focus 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 and improved funding and action relative 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) may safeguard cold-water coral reefs and habitat (Roberts 2002). A number of such reserves have been established in recent years (Armstrong et al. 2014; Lagasse et al. 2015) and ambitious goals identified (CBD 2011) to secure protection of 10% of marine and coastal areas by 2020. Yet, important questions remain regarding the scientific, technical, and socioeconomic needs underpinning their deployment (Watson et al. 2016), and large areas still exist where knowledge of the ocean floor is limited. Cold-water coral areas still remain 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 stakeholders oppose establishment 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. Common Fisheries Policy may make 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 although the voices of stakeholders with vested interests in ocean governance are often 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. A number of studies suggest 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), whereas studies on tropical coral reefs are much more common (Brander et al. 2007) and show high-end values compared with 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 ocean policy making (Young et al. 2007). We argue that the public are legitimate parties who 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 nonuse of deep-sea marine resources and 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 taxes and support of nongovernmental organizations 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 emphasize the importance of nonuse values associated with different marine species and marine protected areas, in addition to use values (McVittie & Moran 2010; Börger & Hattam 2017). Central in nonuse values are existence values (i.e., an individual values that a resource exists, independent of actual or prospective use, and 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 areas 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 nonuse values. These methods have been used extensively to estimate values, evaluate trade-offs, and provide advice 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 nonuse-values literature concerned focuses primarily on rare and charismatic species (Börger & Hattam 2017), fish (Campbell et al. 2012), and other biodiversity (McVittie & Moran 2010). We are unaware of any investigations of nonuse values or trade-offs involving restrictions linked to

the role of marine habitats in supporting other species. McVittie and Moran (2010) used choice experiments to evaluate nonuse values and trade-offs among biodiversity, environmental benefits, and restrictions on resource extraction related to U.K.'s marine conservation bill. However, in common with much of the stated- preference literature, they were unable to clearly distinguish between use value and nonuse value motives or to demonstrate public support for policies that involved restricting resource extraction. We used choice experiments because they allow for the valuation of specific characteristics of a nonmarket good, which enabled us to identify nonuse-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.

We had 3 primary aims to determine public preferences for cold-water coral protection in Norway and Ireland; evaluate public trade-offs between cold-water coral conservation and competing commercial uses of the ocean; and investigate existence values associated with deep-sea habitats. We also sought to determine how public preferences challenge current management of deep-sea environments. We aimed to input social science, and specifically economics, into the conservation discussion related to the deep sea, playing what Bennett et al. (2017) call a "descriptive role" by identifying the public's preferences and valuation of cold-water coral ecosystem services in a broad sense and a generative role by pointing to existing governance shortcomings and needs for change if these conservation preferences are to be incorporated. We aimed to 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 2 countries, social and economic circumstances and cultural differences may play a role in public preferences for development

and conservation in the marine environment and thus allow us to better assess the generality of our results.

We applied the choice-experiment method across countries and by using 2 survey types. Though the survey results we used have been not been published previously, results of 2 other Norwegian internet surveys and surveys conducted in a workshop setting (hereafter workshop survey) have been published (LaRiviere et al. 2014; Sandorf et al. 2016; Aanesen et al. 2015; Sandorf, et al. 2016). These articles focus on information effects, discursive approaches, and comparisons between approaches. Our contribution here is the comparison of the country results and results of the 2 survey types, which gives the conservation-related results more weight when discussing management issues. We also investigated the motivations behind the valuation results.

Method

Choice experiment

There are several ways to elicit welfare loss from environmental degradation. Surveys examining people's preferences for environmental goods, usually by asking respondents to state preferences for increased conservation and protection, either ask direct questions about willingness to pay a certain amount for such protection or ask indirect select trade-offs between mutually exclusive alternatives). 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 (details in Supporting Information) asked respondents to choose between three alternatives for protection of cold-water corals; each alternative was described by four attributes. Two alternatives describe increased protection of cold-water corals, and one specified the status quo situation concerning this protection. To avoid a biased survey, which can lead to confounded parameters, the attributes we chose 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, such as fisheries and oil exploration and extraction. These attributes allowed us to assess the general public's preferences in relation to conservation versus development and allowed an assessment of both use and nonuse values, the latter expressed by the size attribute. Finally, there was the cost attribute, indicating how much people would have to pay if they preferred increased coral protection. We informed respondents that increased protective measures depended on public support and funding in the shape of a tax increase and used five nominal values to indicate the size of the cost. The cost attribute enabled us to estimate respondents' marginal utility of money and facilitated the estimation of WTP. The attributes and levels the attributes could have (Table 1) were combined into 12 choice tasks. Figure 1 is 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 preexisting preferences for all types of goods and services, the deliberative-monetary-valuation literature stresses that people need information, time to think, and the chance to deliberate with others to reasonably respond to monetary-valuation surveys (Lo & Spash 2013). These are reasonable arguments, and we implemented two of the three surveys in valuation workshops (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 4 steps were presentation about cold-water corals, quiz about cold-water corals, presentation about the choice experiment, and choice experiment. The valuation workshops included a deliberative valuation stage after the choice experiment (Fig. 1). In the valuation workshops a moderator gave 2 power-point presentations – one concerning cold-water corals and the other concerning the choice cards.

In the internet survey presentations were replaced with videos designed to give the same information and the same visual cues as for the workshop presentations. Some results of the 2 workshop surveys required further investigation in order to explain possible motivations behind these results. Therefore, in the internet survey, we examined more closely the respondents' stances regarding habitat protection. This was done by asking additional follow-up questions that distinguished between a number of plausible reasons for the responses and included questions about nonuse values, potential use values, values pertaining to protecting fish for consumption and for the existence value of fish, and more general protection of cold-water corals.

Each workshop included 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 through 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 prerecruited panel. The two valuation workshop surveys had 105 (Norway) and 139 (Ireland) respondents, and the internet survey had 302 respondents (546 total respondents). The valuation workshop participants were representative regarding gender and age in the municipalities in which they were implemented. The internet survey was representative with respect to gender, age, and geography for the Norwegian

population. The survey applied in all cases followed the protocol of the Norwegian Centre for Research Data for research involving human subjects.

Results

The distributions of WTP varied in the sample (Table 2). Details on the specification and estimation of the model are in Supporting Information. The means of the WTP distributions for small and large increases in cold-water coral protection were relatively large and significant. However, large SDs indicated significant heterogeneity with respect to these attributes. A large share of respondents was not willing to pay to increase protection for protection's sake, which means they might need to be compensated to protect cold-water corals. People were willing to pay more for a large increase relative to a small increase in protection. Mean WTP for protecting areas important to industry was not significant. However, there were large and significant standard deviations that indicated people were split with respect to this issue. People had the highest mean WTP for protecting areas that are important habitat for fish. However, unlike the other attributes, the vast majority of people had positive WTP. These results are reflected in the individual specific WTP estimates (Figure 2).

When we combined different sources of preference data, here 3 different data sets, we needed to consider the possibility of unobserved differences between them. It is possible that there were factors outside of what we could observe (i.e., attributes of the alternatives) that influenced the choices respondents made in the choice experiment. To consider such factors, we estimated a relative-scale parameter, which implies we normalized the variance for one group and estimated the variance for the other groups relative to this baseline. This is a simple and effective way to control for some such unobserved effects.

Respondents in the Irish workshop and Norwegian internet survey had a significantly lower scale parameter (significance tested against 1), which suggests unobserved factors for these two samples affected choices relatively more than those in the Norwegian workshop sample.

To explore differences and similarities that might exist between countries, we derived mean, individual, and specific estimates and plotted them (Figure 2). The individual specific estimates showed where an individual is likely to lie on the estimated WTP distributions. Respondents 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 (positive values for habitat in far-right panel of Figure 2).

The habitat aspect of cold-water corals trumped both peoples' preferences for commercial activities (e.g., oil and gas extraction and fisheries) and nonuse values of coral reefs (expressed by size attribute), except for the Norwegian valuation workshop sample, where respondents showed substantial WTP for the coral reefs themselves.

Respondents were split with respect to whether they were willing to pay to protect areas that are important for commercial activities (Fig. 2). For example, those with a positive WTP were willing to pay to protect cold-water corals at the expense of industry. However, about half the respondents had a negative WTP to protect areas that are important for commercial activities; thus, they emphasized allowing commercial activities even if it they were to result in not increasing the protection of cold-water corals.

Answers given to the additional questions on the internet survey were consistent with our findings from the Norwegian valuation workshop survey: positive WTP for habitat and positive WTP for the commercial attributes. Cold-water coral protection was not motivated by habitat preservation in support of commercial fish species, or possible future values; instead, it was based on preferences for general environmental protection and for the habitat

that the coral provides for fish. Principal motivations for cold-water coral protection, by 63% of respondents, focused on the role of habitat support for marine species independent of extractive human use. Although we found differences in WTP between the surveys (Figure 1), the main findings were robust and consistent across all surveys regardless of setting, timing, and survey mode, which strengthened their reliability.

Discussion

Two firm conclusions can be drawn from this work. First, the Irish and Norwegian public expressed a clear WTP to conserve cold water coral in the deep sea as long as the 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 was a common finding across all three surveys. A number of researchers have used stated-preference methods to investigate nonuse values associated with marine resources (Börger & Hattam 2017; Campbell et al. 2012; McVittie & Moran 2010). However, departing from these studies, we have shown a clear link between nonuse-value motives and policy support for marine habitat conservation, even if it 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 potentially conflicting preferences of different stakeholders and, given the increasing uncertainties in the deep sea, to what extent should the precautionary principle and no-take zones be implemented in protected-area design (De Santo 2013). In answering the former our data presents the perspective of public stakeholders from the two countries. Our results from Norway showed respondents were willing to pay for the existence value of cold-

water coral reef structures themselves although the Irish respondents were not. The Irish did nonetheless strongly value cold-water coral existence as a habitat for fish, as was also the case in Norway (respondents endorsed its conservation on the grounds of being essential habitat). Clearly, public stakeholders in both countries support protective measures motivated by nonuse 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 regarding the latter question related to trade-offs between cold-water coral protection and commercial uses were 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 attributes representing commercial activities and fish habitat were also willing to forego commercial activity in favor of cold-water coral habitat to safeguard the well-being of marine fish species. However, this was by no means a universal finding; half the respondents had a negative WTP to protect areas important for commercial activities. This implies these respondents were not willing to protect more coral areas if this meant hindering commercial activities, such as fisheries and oil exploration and exploitation. The number of cold-water coral protected areas has been growing, and this may affect WTP to increase protection further. Furthermore, wider market conditions may affect WTP. However, the final internet survey was conducted following the oil-price collapse in 2015, which had a negative financial effect on parts of the Norwegian population. Though this could imply people had less money to spend on conservation initiatives, the main findings remained robust.

If the public preferences we identified were included in deep-sea management, it would require incorporation of trade-offs between ecosystem services (market and non-market and consumptive and nonconsumptive), underlining a broader ecosystem-based management than is currently found in ocean governance. Though an ecosystem focus has 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 because national ministries and directorates are notoriously sectorial and environmental jurisdictions are 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 governance and policy would require reform in support of integrated ocean management that incorporates trade-offs between ecosystem services and values and that 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 is also reflected in the Convention on Biological Diversity goal of protection of 10% of marine and coastal areas worldwide, a goal that seems increasingly possible (Jantke et al. 2018) and that 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 nonuse-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) found 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 nonuse value), but were not able to separate these 2 distinct types of value or explain how they might influence WTP. We built on Aanesen et al. (2015) and investigated the underlying motivations behind the public valuation of protection of cold-water corals, illustrating that it lies outside of the realm of commodities and market-based

values, and identified 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 understanding of the socioecological links is vital for securing conservation (Hughes et al. 2017). What is interesting regarding the cold-water coral surveys, as compared with assessments of tropical corals, was the broad public support for nonuse values of cold-water corals and for securing supporting services for fish. Taking the general publics' preferences into account could be expected to lead to greater protection of marine ecosystems, even those most humans will never experience in situ.

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Supporting Information

The econometric model (Appendix S1) and the survey (Appendix S2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Table 1. Attributes describing economic and environmental aspects of coral conservation alternatives, their status quo level (the first line) and levels used in the hypothetical alternatives for increased conservation.

	Size of protected area (km^2)	Attraction of protected for industry	Importance of protected as fish habitat	Additional cost of protection (X)
	2.500	partly	partly	0
	5.000	attractive for fisheries	not important	100
	10.000	attractive for oil and gas	important	200
		attractive for fisheries and oil and gas		500
		unattractive for fisheries and oil and gas		1000

Table 2. Mean Willingness to pay, standard error of the mean, standard deviation and standard error of the standard deviation for each non-cost attribute in 1000 NOK, mean marginal utility of cost, and relative scale parameter for Irish survey and Norwegian internet survey.[a]

Attribute[b]	Mean[c]	SE[d]	SD[c]	SE[d]
Size of protected area				
small	0.3414***	0.1412	1.9318***	0.0345
large	0.4244***	0.1641	2.3311***	0.0381
Industry				
oil and Gas	-0.0006	0.0429	0.5199***	0.0526
fisheries	0.0271	0.0396	0.3630***	0.0392
Habitat for fish	0.8801***	0.0695	0.8367***	0.0423
Cost	-1.4107***	0.1695	1.1848***	0.0803
Survey scale				
workshop Norway	1	fixed	-	-
internet Norway	0.6572***	0.1032	-	-
– workshop Ireland	0.6849**	0.1294	-	-
Log likelihood	-4638.281			
ρ^2	0.351			
AIC	9334.561			
BIC	9531.377			
K	29			
N	6547			

[a]The test for significance of the scale parameters is relative to 1.

[b]Abbreviations: AIC = Akaike Information Criteria; BIC = Bayesian Information Criteria; *K* = Number of estimated parameters; *N*= Number of choice observations, .

[c]Statistical significance: ***, 1 %; **, 5%; *, 10%.

[d]Adjusted and robust.

Figure 1. Sample choice cards used in the (left) valuation workshop and (right) online survey.

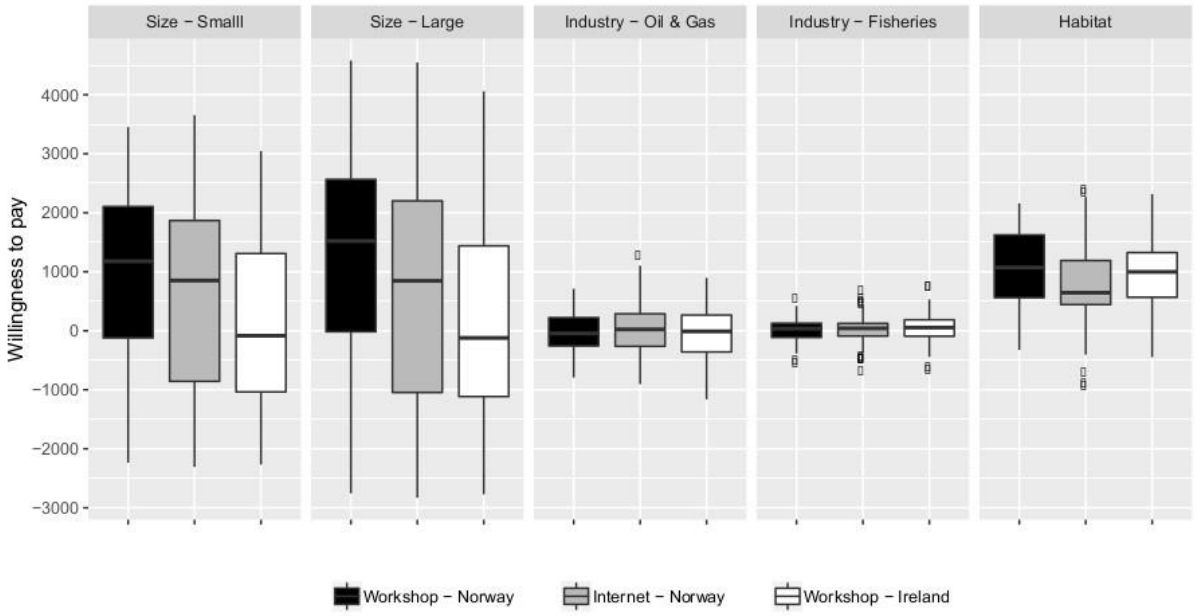

Figure 2. Distribution of mean conditional willingness to pay for each of the conservation attributes for each discrete choice experiment (black lines, median; upper and lower end of bars, 75th and 25th percentiles respectively; whiskers are equal to 1.5 times the interquartile range; black circles, extreme values; size, size of the protected area; industry, area is important to the industry; habitat, area is important habitat for fish). Y-axis is willingness to pay in Norwegian Krone for a change in the conservation attributes.