Conservation Biology

Contributed Paper

Valuing high-seas ecosystem conservation

Bui Bich Xuan,[1,2] Claire W. Armstrong,[1] Isaac Ankamah-Yeboah,[3,4] Stephen Hynes,[3] and Katherine Needham[5]

[1]UiT The Arctic University of Norway, Tromsø, Norway
[2]Nha Trang University, Nha Trang, Vietnam
[3]Socio-Economic Marine Research Unit (SEMRU), Whitaker Institute, National University of Ireland, Galway, Ireland
[4]Department of Agricultural Economics and Agribusiness, College of Basic and Applied Sciences, University of Ghana, Legon-Accra, Ghana
[5]Institute of Biodiversity, Animal Health & Comparative Medicine, University of Glasgow, Glasgow, UK

Abstract: The high seas provide a variety of ecosystem services that benefit society. There have, however, been few attempts to quantify the human welfare impacts of changes to the delivery of these benefits. We assessed the values of several key ecosystem service benefits derived from protecting ecosystems in the high seas of the Flemish Cap through choice experiments conducted in Canada, Norway, and Scotland. Rather than solely eliciting public willingness to pay, we also explored the determinants of variance in the estimates of willingness to pay. We aimed to determine how much respondents were willing to pay for high-seas ecosystems conservation, which factors influence individuals' willingness to pay, and whether individuals in Canada had a higher willingness to pay relative to those living in Norway and Scotland. This latter point captures distance-decay effects. On average, the public placed positive value on conserving high-seas ecosystems and on developing economic activities related to the exploitation and exploration of marine resources, despite a lack of awareness and familiarity with these environments. Distance-decay effects on willingness to pay were not clear. Scots had the highest willingness to pay and the Norwegians the lowest willingness to pay for all attributes, with the only exception being willingness to pay for a large increase in new jobs, in which case Canadians' willingness to pay was higher than Scots'. The public's willingness to pay was influenced by sociodemographic characteristics and their perceptions of high-seas ecosystems. Our results provide evidence of the impacts of high-seas governance on human welfare and that improved governance could increase the value people place on high-seas ecosystems and the services they produce.

Keywords: Canada, ecosystem services, Norway, Scotland, willingness to pay

Resumen: La alta mar proporciona una variedad de servicios ambientales que benefician a la sociedad. Sin embargo, ha habido pocos intentos por cuantificar los impactos al bienestar humano ocasionados por los cambios en la entrega de estos beneficios. Analizamos los valores de varios beneficios importantes de los servicios ambientales derivados de la protección al ecosistema en la alta mar del Cabo Flamenco por medio de experimentos de elección realizados en Canadá, Noruega y Escocia. En lugar de sólo suscitar la voluntad pública para pagar, también exploramos las determinantes de la varianza en las estimaciones de la voluntad para pagar. Nuestro objetivo fue determinar cuánto están dispuestos a pagar los respondientes por la conservación de los ecosistemas de alta mar, cuáles factores influyen sobre la voluntad para pagar de cada individuo y si los individuos en Canadá tenían una mayor voluntad para pagar que aquellos individuos que viven en Noruega y en Escocia. Este último punto captura los efectos de la descomposición por distancia. En promedio, el público le colocó un valor positivo a la conservación de los ecosistemas de alta mar y al desarrollo de actividades económicas relacionadas con la explotación y la exploración de los recursos marinos, a pesar de la falta de conocimiento y familiaridad con estos ambientes. Los efectos de la descomposición por distancia sobre la voluntad para pagar no estuvieron claros. Los escoceses tuvieron la mayor voluntad para pagar y los noruegos la menor voluntad para pagar por todos los

***Article impact statement**: The public is willing to pay for the conservation of remote environments that they have little direct use for or experience with.*

Paper submitted May 8, 2020; revised manuscript accepted January 29, 2021.

Conservation Biology, Volume 35, No. 5, 1405–1416

DOI: 10.1111/cobi.13720

atributos, siendo la única excepción la voluntad para pagar por un incremento de trabajos nuevos, en cuyo caso, la voluntad de los canadienses fue más alta que la de los escoceses. La voluntad del público para pagar estuvo influenciada por las características sociodemográficas y su percepción de los ecosistemas de alta mar. Nuestros resultados proporcionan una evidencia de los impactos que tiene la gestión de alta mar sobre el bienestar humano y que la gestión mejorada podría incrementar el valor que las personas le ponen a los ecosistemas de alta mar y a los servicios que producen.

Palabras Clave: Canadá. Escocia, Noruega, servicios ambientales, voluntad para pagar

Introduction

Almost 60% of the seas and oceans lie in areas beyond national jurisdiction, an area often referred to as the high seas (White & Costello, 2014). Until relatively recently, high-seas environments were still thought to retain little or even no life due to their remote and inhospitable conditions. Yet, these environments are now known to include some of the richest biodiversity areas on the planet and sustain major ecosystem services (ESs) that are crucial for life on Earth (Gjerde, 2006). The high seas provide society not only with provisioning services but also with supporting, regulating, and cultural services that can be valued economically within categories of use and nonuse value, where the latter (i.e., existence and bequest values) are identified values of conservation of high-seas ecosystems (Armstrong et al., 2012).

High seas are often described as a free for all involving a tragedy of the global commons because no single nation has sole responsibility for their management (White & Costello, 2014). Despite the growth in international bodies (e.g., United Nations International Seabed Authority, Regional Fisheries Management Organizations, and the International Maritime Organization) and international conventions (e.g., Convention on Biological Diversity and Convention on Migratory Species) that govern human activities associated with high seas, their ecosystems are facing risks resulting from anthropogenic activities (Armstrong et al., 2019a). Temperature change, ocean acidification, fishing, pollution, and oil and gas activities have negative impacts on deep-seas ESs, where biodiversity, habitat, and fish and shellfish are most at risk. Due to the largely sectorally divided governance of the high seas (Freestone et al., 2014), the evolution of legal systems has not kept up with scientific and technological advances or the expansion of the human footprint on the oceans (Gjerde, 2006). Indeed, there are ongoing international legal processes, such as the Biodiversity Beyond National Jurisdiction (BBNJ), that raise a number of questions regarding high-seas stakeholders and the sharing of benefits from these environments (Leary, 2019; Tiller & Nyman, 2018).

Though a growing body of research in recent years indicates the importance to humankind of the high-seas ESs, there have been very few attempts to characterize and quantify the economic values of services from these ecosystems (but see Sumaila et al., 2007, 2015; White & Costello, 2014). Despite the recommendations for greater high-seas conservation (Smith & Jabour, 2018; White & Costello, 2014), little is known about public support for high-seas conservation policies at an international scale. However, there exist several studies evaluating ESs in deep-sea areas within national jurisdictions that are nonetheless remote and have similar characteristics to the high-seas environments. Results of these studies show the public is willing to pay to prevent losses in marine species richness in national deep seas (e.g., Aanesen et al., 2015; Jobstvogt et al., 2014; Ressurreição et al., 2011). The lack of information related to quantification and valuation of the economic contributions of high-seas ecosystems means their loss would often not, or not appropriately, be taken into account in planning or designing the regulations for high-seas governance (Gjerde, 2006). This highlights the importance of providing more relevant evidence of economic values of conserving habitats and wildlife in the high seas, as a foundation for informing regulations to improve high-seas governance (Jobstvogt et al., 2014). However, one major challenge of valuing high-seas ESs is the public's unfamiliarity with these environments (Jobstvogt et al., 2014). Discrete choice experiment (DCE)—a stated preference method is often used in ESs valuation despite the challenge of valuing unfamiliar environmental goods (i.e., obtaining informed willingness-to-pay [WTP] estimates) (Aanesen et al., 2015). To overcome this challenge, Aanesen et al. (2015) implemented a DCE in a series of valuation workshops in which the sampled participants completed choice tasks individually and learned about the good to be valued at the same time. This made the survey valid but induced possible sample bias due to self-selection, knowledge acquisition, and social desirability effect (Aanesen et al., 2015). Alternatively, internet-based surveys can be used to value unfamiliar public goods if extra care is taken in relation to survey-response speeding behavior, reminding people about their budget constraints, payment and policy consequentiality issues, and providing information (Sandorf et al., 2016).

We, therefore, investigated public preferences and estimated their WTP for future policies to protect high-seas ecosystems in the Flemish Cap in the North Atlantic. This was undertaken in Norway, Scotland, and Canada with the DCE method. Rather than eliciting only public WTP, we went a step further to explore the determinants of the variance in these

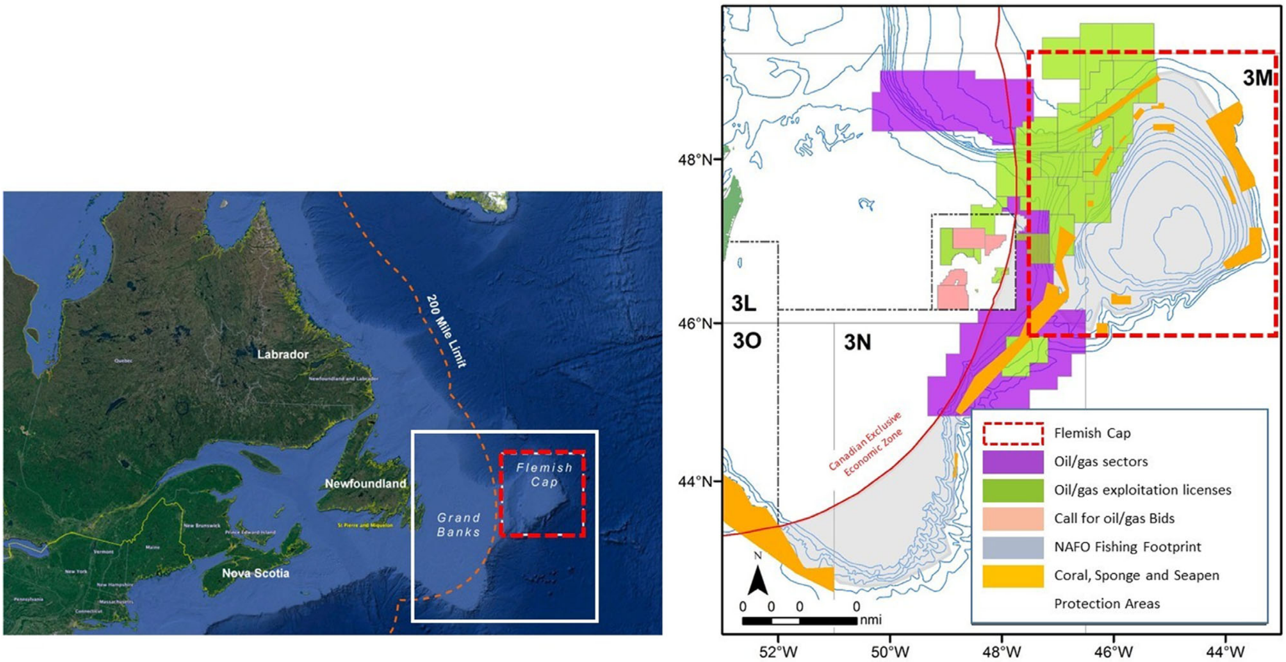

Figure 1. Location of study area and distribution of sectoral activities and management zones (source Grehan et al. [2018])

estimates. Specifically, we aimed to determine how much respondents were willing to pay for conserving high-seas ecosystems, which factors influenced the individual WTP for high-seas ecosystems conservation and to what extent, and whether an individual residing in Canada had a higher WTP for high-seas ecosystems conservation compared with those living in Norway and Scotland. This latter question captures distance-decay effects. Canada is closer to the Flemish Cap than Norway and Scotland and has jurisdiction over the seabed of the Flemish Cap; hence, we expected Canadians would have more knowledge of the Flemish Cap regarding the advantages associated with exploration and exploitation activities, as well as the benefits provided by enhanced marine protection. For example, fish stocks in Canadian territorial waters could be increased due to dispersal effects. Answering these research questions increases understanding of the impacts of high-seas governance on human welfare, as well as the potential increased values of high-seas ecosystems due to improving governance of the high seas.

METHODS

Study area

The Flemish Cap (Figure 1) is an oceanic bank about 600 km to the east of Newfoundland in an area beyond national jurisdiction and in the Northwest Atlantic Fisheries Organization (NAFO) regulatory area. It has high ecological productivity that supports abundant fish populations and provides a variety of ESs (Grehan et al., 2018). Flemish Cap was historically a productive fishing ground supporting various fisheries, such as Greenland halibut (*Reinhardtius hippoglossoides*), American plaice (*Hippoglossoides platessoides*), cod (*Gadus morhua*), redfish (*Sebastes* spp.), grenadier (*Macrourus berglax*), yellowtail flounder (*Limanda ferruginea*), capelin (*Mallotus villosus*), skate (*Dipturus laevis*), shrimp (*Pandalus borealis*), squid (*Illex* spp.), and so on (Grehan et al., 2018). Many commercial and noncommercial species have declined substantially as a consequence of overexploitation, habitat degradation, and climate change (Howell & Casas, 2017; Pérez-Rodríguez et al., 2012).

Currently, the main human activities in the region are fisheries, shipping, undersea cable routes, scientific research, and hydrocarbon exploration (Grehan et al., 2018) (Figure 1). Yet, there is no integrated spatial management plan for the Flemish Cap and only 1 active fishing sector management plan, the NAFO management plan. There are potential opportunities in the Flemish Cap for growth in marine activities in existing and potential economic sectors, such as increased oil and gas exploitation, bioprospecting, and new fisheries (Grehan et al., 2018). The development of such economic activities could generate more jobs internationally but could also lead to negative effects on ecosystems in the area.

Discrete choice experiment

We used DCE to elicit the public's preferences for protecting the environment in the Flemish Cap. Respondents were presented with a sequence of hypothetical choice tasks, each containing a set of competing policy alternatives described by several attributes taking on a finite number of levels. When respondents selected their preferred alternative that was assumed to maximize their utility, they implicitly revealed their trade-offs between the levels of the attributes in all the alternatives presented in the choice task. Based on the choice responses, we estimated the utility function up to a probability and derived welfare measures, such as the public's marginal WTP a higher tax rate to obtain an improvement in the environmental quality of the high seas. Survey questions and choice tasks are in Appendix S3. Each choice task included 3 alternatives: a status quo (SQ), with current attribute levels of provision, and the 2 experimentally designed alternatives (with current and improved attribute levels of provision).

Of the 5 attributes (Table 1) that appeared in each choice task (shown in Appendix S3), 3 were associated with the environmental aspects (health of fish stocks, amount of marine litter, and size of marine protected area [MPA]), 1 was associated with economic development (marine economy jobs), and 1 was related to the cost of the proposed policy in the form of an annual income tax increase, expressed in currency units corresponding to each country where the survey was conducted.

Survey design and sampling

The surveys were implemented online by the market research company YouGov, which drew from a registered online panel of respondents in Canada, Norway, and Scotland in October and November of 2019. YouGov has a panel management system that defines quotas based on representation by gender, age, and geography. Their system sent out random invitations to respondents in their panel until the quotas were satisfied. Response rates varied, but the company expected response rates to be minimum 30%. Details of survey design and sampling are in the Appendix S1. The surveys were approved by the research ethics committee at the University of Edinburgh and by the Norwegian Centre of Research Data.

Models

To identify the sociodemographic, attitudinal, and spatial determinants of WTP for high-seas ecosystems protection, we applied a 2-stage approach that may increase the explanatory power of welfare estimates (Campbell, 2007; Scarpa et al., 2011; Yao et al., 2014). This modeling approach was employed because a regression on conditional mean WTP is better suited to explore systematic effects of the explanatory variables on WTP variation than exploring these effects on random parameters as in a hybrid choice modeling approach (Yao et al., 2014; Zawojska et al., 2019). First, a model allowing for preference heterogeneity, a mixed logit (MXL) model, was used to estimate individual WTP values (Hensher et al., 2015). Next, these individual WTP estimates were regressed on determinants of WTP for high-seas ecosystems protection.

Mixed logit model

The MXL is a highly flexible model that can approximate any random utility model and overcomes the limitations of the standard logit model (Train, 2009). The MXL model can be expressed as follows:

$$U_{nit} = \beta_n X_{nit} + \left(\eta_{nit} + \varepsilon_{nit}\right), \quad (1)$$

where U_{nit} is the utility of individual n obtained from choosing alternative i in choice situation t; X_{njt} is a vector of observed variables related to the attributes; β_n is a vector of parameters associated with the attributes representing the individual's tastes; η_{nit} is a random term with 0 mean whose distribution over individuals and alternatives depends on underlying parameters and observed data associated with alternative i and individual n; and ε_{njt} is a random term with 0 mean that is independent and identically distributed (iid) over alternatives and depends on neither underlying parameters nor data (Hensher et al., 2015).

To allow for heterogeneous preferences among respondents, all noncost attribute parameters were specified as random following a normal distribution. After evaluating the results from the various specifications of distributional assumptions, we found the assumption of a normal distribution of noncost random parameters to fit our data well. An assumption of a log-normally distributed cost parameter resulted in unrealistic (very high) WTPs. Hence, the cost parameter and the alternative-specific constant (ASC) in the model were assumed to be fixed across respondents. Additionally, the fixed cost parameter assisted in the computation of WTP values.

Linear regression of WTPs

To determine the factors influencing WTP for protecting high-seas ecosystems, we used the standard ordinary-least-squares (OLS) regression and a panel random effect (RE) regression. In the MXL model, the noncost attribute variables were dummy coded with the reference level being the SQ level. The estimated results (see Appendix S2) showed that the population mean WTP was largest for the highest improved level related to each noncost attribute. Therefore, we selected the individual WTP corresponding to the highest improved level for each of the 4 attributes (so-called attribute level) and used them as dependent variables in the OLS regression to explore the determinants of the attribute-level WTP. We then regressed these 4 attribute-level values (i.e., that were pooled and used as the dependent variable) on individual characteristic covariates in the form of a 4-period panel

Table 1. Variables used in models of public preferences for high-seas ecosystem conservation.

Variable	*Description*	*Level* code*	*Levels description*
Attributes and their levels			
health	percentage of commercial stocks at functioning stock levels	1, health1 2, health23, health3	low (<40) moderate (40–80)high (>80)
litter	density of marine litter (number of items of litter per km^2 [Canada and Norway] and mile^2 [Scotland])	1, litter1 2, litter23, litter3	Canada and Norway poor (4–6) moderate (2–3) good (0–1) Scotland: poor (5–8) moderate (2–4) good (0–1)
area	size of protected area as percentage of the area of the Flemish Cap	1, area1 2, area2 3, area34, area4	2125 3035
job	number of marine economy jobs created from sea-based commercial activities in the area	1, job1 2, job23, job3	no employment change +100 +200
cost	additional costs (unit currency per person per year)		Canada (CAD): 0 (for status quo [SQ] option only), 10, 20, 40, 60, 80, 110 Norway (NOK): 0 (for SQ option only), 100, 150, 300, 450, 650, 850 Scotland (£): 0 (for SQ option only), 5, 10, 20, 30, 40, 60
Individual characteristics and attitudes			
gender		1, female 2, male	female male
age		1, age >66 2, age 36–65 3, age 18–35	66+ years 36–65 years 18–35 years
NGO	member of environmental organization	1, no2, yes	
education		1, high school and below2, tertiary degree	
country		1, Canada 2, Norway3, Scotland	
awareness	Have you heard of the Flemish Cap's deep seas and wildlife previously?	1, no2, yes	
perceived deep-sea condition	Thinking about the deep sea in the North West Atlantic, how would you rate its condition?	1, condition1 2, condition2 3, condition3 4, condition4 5, condition56, condition6	don't know very poor fairly poor neither good nor poor fairly goodvery good
personal effect	Do you think that changes to Flemish Cap's deep seas and wildlife affect you, personally?	1, effect1 2, effect2 3, effect34, effect4	don't know not effect on me some effect on memajor effect on me
perceived deep-sea manage-ment	How well do you think Flemish Cap deep-sea areas are managed?	1, management1 2, management2 3, management34, management4	don't know/don't care poorly fairly wellwell
confi-dence in the choice made	Thinking back over the choice cards you have just gone through, how confident are you in the choices you made?	1, confidence1 2, confidence2 3, confidence3 4, confidence45, confidence5	not very confident somewhat confident fairly confident confidentvery confident

**Levels of the cost attribute used in 3 surveys (in national currency) adjusted for differences in income levels between the countries based on the purchasing power parity index of 1.245, 10.142, and 0.7 for Canada, Norway, and Scotland, respectively (1, reference level) (data from OECD [2018]).*

to account for the fact that these conditional mean estimates were correlated for the same respondent.

The linear regression model was as follows:

$$WTP_{na} = \alpha + \gamma A_{na} + \theta S_n + (\nu_n + \varepsilon_{na}), \quad (2)$$

where WTP_{na} is willingness to pay for attribute-level a for respondent n; α is an intercept term capturing the average WTP for the concerned attribute level in the case of OLS, whereas for the RE, it captures the average WTP for the reference attribute level; A_{na} is a vector of indicator variables for k minus 1 attribute level (i.e., specified for the RE regression); S_n is a vector of covariates; γ and θ are vectors of parameters to be estimated; $(\nu_n + \varepsilon_{na})$ is the error term, where ν_n is the individual-specific error term (i.e., specified for the RE regression) and ε_{na} is the usual error term with properties of zero mean, serially uncorrelated (across a), and homoscedasticity.

A summary of the explanatory variables used in the linear regression model is in the second part of Table 1. In addition to the sociodemographic variables, the attitudinal variables that described the respondents' awareness of the Flemish Cap, their perception regarding the current status and management of the Flemish Cap, the perceived personal effects on the respondent when the Flemish Cap ecosystems change, and the confidence of respondents when they made their choices were included as regressors to explain the variation in individual WTP of the sample of respondents. The response scale for these variables included a don't know or don't care option (Table 1), allowing an indefinite statement of the attitude. When analyzing the data, we treated don't know or don't care responses as the outermost level followed by the definite negative category, as suggested by Zawojska et al. (2019). Respondents' locations (e.g., nationality) were also included in order to capture the distance-decay effect on individual WTP variation. The explanatory variables in this model were all dummy coded. We used a p value $\leq$5% level to determine significant results.

RESULTS

Sample description

The gender and age distribution in the Norwegian sample was very close to the national statistics, although we had a lower share in the oldest group (over 65 years) (Table 2). The gender and age distribution of the Scottish sample was reasonably close to the national gender and age distribution; men and the oldest group were slightly undersampled compared with the national average. For the Canadian sample, age categories were somewhat different from the actual population; the age range 18–35 was slightly oversampled and the oldest age category was undersampled (Table 2). Across all 3 countries, there was an oversampling of those with a tertiary education, which included vocational and higher education (university or college level) qualifications.

Logistic model estimation

A sample of 501, 503, and 503 respondents from Canada, Norway, and Scotland were surveyed. However, subsamples used for model estimations excluded protest bidders who were defined as respondents selecting the SQ option in all 8 choice tasks and stating in the follow-up questions one of the following: "The government should pay from existing revenue," "I do not believe any protection management scheme would be implemented," or "I object to paying for marine ecosystem protection." This left a usable sample size of 491, 465, and 498 respondents from Canada, Norway, and Scotland, respectively. Our samples were skewed toward more tertiary educated individual, possibly due to more educated people being more likely to participate in online surveys and also to have more knowledge of the subject matter. Respondents with high education levels are more likely to be associated with high purchasing power, which in turn may lead to high WTP. To control for the skewness of our sample, we ran the MXL models with population weights corresponding to education to determine the 3 nationalities' public preferences for protecting the Flemish Cap ecosystems. The models were estimated in NLOGIT 6.0 with 3000 modified Latin hypercube sampling random draws because Halton draws are highly correlated in higher dimensions; hence, they should not be used with more than 4–5 random parameters (Czajkowski & Budziński, 2019). Based on the unconditional parameter estimates from the 3 weighted MXL models, we simulated the mean WTP for each change from the SQ, which is the ratio of the noncost parameter over the cost parameter. Because all noncost parameters were normally distributed and the cost parameter was fixed, the WTP values had normal distributions (Tables 3 & 4).

There was significant preference heterogeneity (as shown by the significance of the SD estimates) for all attributes in the 3 samples (Table 3). On average, respondents in the 3 countries were price sensitive, ceteris paribus, identified by the negative sign of the cost parameter. The negative and significant ASC parameters for the Canadian sample, which was not significant for the Norwegian and Scottish samples, implied that Canadians, on average, would like to move from the current level of management of the Flemish Cap, all else being equal. Generally, respondents in the 3 countries put greater values on higher levels of all noncost attributes, except for the job attribute, where only the Canadians preferred more jobs, whereas this was not the case for Norwegians and Scots. This implies that the public's utility increased when moving to a higher level of improved sustainable management of Flemish Cap ecosystems, although

Table 2. Sample and population[a] characteristics in a survey of public preferences for high-seas ecosystem conservation in Canada, Norway, and Scotland.

	Canada		*Norway*		*Scotland*	
Characteristic	*sample*	*population*	*sample*	*population*	*sample*	*population*
Gender						
male	49.1	49.7	50.1	50.4	46.7	48.7
Age						
18–35	30.7	26.2	30.8	30.5	26.8	27.6
36–65	55.7	51.5	51.3	49.1	52.7	49.1
66 and above	13.6	22.4	17.9	20.5	20.5	23.3
Education tertiary degree	65.7	53.0	65.8	37.2	74.8	35.7
Income (€)[b]						
<23,297	51.4		14.4		42.0	
23,297–46,592	28.7		62.8		40.0	
46,593–69,888	6.9		17.0		11.6	
69,889–93,184	7.9		2.9		3.2	
>93,184	5.0		2.9		3.2	
Member of environmental organization	4.2		8.8		4.4	
Awareness heard of Flemish Cap deep sea	24.2		20.3		16.3	
Perceived deep-sea condition						
very poor	3.6		2.8		3.6	
fairly poor	27.0		24.3		28.6	
neither good nor poor	26.8		27.2		22.9	
fairly good	21.0		19.5		17.5	
very good	5.4		2.2		1.6	
don't know	16.4		24.1		25.8	
Personal effect						
no effect on me	15.2		19.1		21.7	
some effect on me	55.9		49.1		51.3	
major effect on me	13.4		12.1		9.7	
don't know	15.4		19.7		17.3	
Perceived deep-sea management						
Poor	19.0		13.3		13.7	
Fair	21.4		25.8		23.1	
Good	14.6		22.1		7.9	
don't know	43.5		36.6		53.1	
don't care	1.6		2.2		2.2	
Confidence in choice made						
not very confident	8.2		20.5		16.3	
somewhat confident	35.9		22.3		40.8	
fairly confident	35.1		35.2		28.8	
confident	13.4		14.5		10.5	
very confident	7.4		7.5		3.6	

[a] *Population data are from Statistics Canada (2018), Statistics Norway (2018), and the National Records of Scotland (2018).*
[b] *Reported income levels in 3 surveys (in national currency) were adjusted for differences in income levels among countries based on the purchasing power parity index of 1.245, 10.142, and 0.7 for Canada, Norway, and Scotland, respectively (data from OECD [2018]).*

Norwegians, on average, did not show significant differences in utility regarding the small and medium increases in MPA size (25% and 30%) compared with the current MPA size (21%).

We observed a clearer pattern of public stated preferences toward policy aiming to protect Flemish Cap ecosystems, though with some notable substantial variations (Table 4). On average, the public in the 3 countries was willing to pay for improvements compared with the SQ policy, except the Norwegians in relation to MPA sizes of 25% and 30%, suggesting sensitivity to the scope of conservation. The WTP values were higher for the attributes reduction in marine litter density and improvement of health of fish stock than for other attributes. In relation to the job attribute, the mean and median WTPs indicated that respondents in Canada were willing to pay more for a larger number of new jobs, whereas Norwegian and Scottish respondents showed contrasting preferences by being willing to pay less for more jobs. We found that respondents in Scotland had the highest WTP for the proposed management scenarios, followed by the Canadians. Norwegians had the lowest WTP. The exception was that the Canadian WTP was highest for large increases in new jobs, followed by the Scots.

Table 3. Comparison of respondents' heterogeneous preferences for high-seas environment attributes[a].

Variable[b]	*Canada*		*Norway*		*Scotland*	
	Coefficient	*(SD)*	*coefficient*	*(SD)*	*coefficient*	*(SD)*
Health2	0.637***(0.098)	1.274***(0.115)	0.742***(0.120)	1.610***(0.142)	1.090***(0.135)	1.233***(0.148)
Health3	0.831***(0.111)	1.550***(0.110)	0.921***(0.122)	1.660***(0.133)	1.868***(0.167)	1.952***(0.166)
Litter2	0.641***(0.097)	0.985***(0.117)	0.797***(0.123)	1.503***(0.156)	1.800***(0.149)	1.401***(0.170)
Litter3	0.949***(0.112)	1.476***(0.112)	1.194***(0.142)	2.261***(0.161)	2.781***(0.205)	1.914***(0.186)
Area2	0.358***(0.099)	1.033***(0.133)	0.041(0.114)	0.604**(0.252)	0.502***(0.150)	1.840***(0.227)
Area3	0.336***(0.092)	0.852***(0.141)	0.241*(0.138)	1.372***(0.205)	0.613***(0.136)	1.623***(0.183)
Area4	0.413***(0.097)	0.712***(0.177)	0.557***(0.150)	2.315***(0.194)	1.039***(0.192)	2.735***(0.243)
Job2	0.328***(0.087)	0.697***(0.132)	0.398***(0.103)	1.049***(0.136)	0.964***(0.116)	0.870***(0.197)
Job3	0.506***(0.098)	1.049***(0.104)	0.286***(0.107)	1.117***(0.135)	0.560***(0.127)	1.028***(0.266)
ASC_SQ	−0.609***(0.131)		−0.168(0.124)		−0.273(0.180)	
Cost	−0.205***(0.016)		−0.307***(0.020)		−0.261***(0.026)	
Number of respondents	491		465		498	
Log L	−3 601		−3 660		−2 995	
AIC	7 242		3 760		6 031	
BIC	7 368		7 486		6 157	
McFadden R^2	0.182		0.172		0.323	

[a] *Significance: *** 1%; ** 5%; * 10%.*
[b] *Variables defined in Table 1. Other abbreviations: ASC_SQ, alternative-specific constant for status quo; log L, log-likelihood; AIC, Akaike information criterion; BIC, Bayesian information criterion.*

Table 4. Estimates of marginal willingness to pay for high-seas ecosystem conservation in a survey of the public in Canada, Norway, and Scotland (€/person/year)[a].

Variable[b]	*Canada*				*Norway*				*Scotland*			
	mean	*median*	*quantile*		*Mean*	*median*	*quantile*		*mean*	*median*	*quantile*	
			2.5%	*97.5%*			*2.5%*	*97.5%*			*2.5%*	*97.5%*
Health2	33.0	35.9	−98.0	150.4	25.7	28.2	−84.9	125.0	43.1	45.4	−56.6	132.7
Health3	42.9	46.4	−116.6	185.8	31.6	34.1	−75.8	143.0	73.7	77.3	−84.1	215.5
Litter2	32.7	34.9	−68.6	123.5	27.4	29.7	−114.2	120.0	70.5	73.1	−42.7	172.3
Litter3	48.5	51.8	−103.3	184.5	41.0	44.5	−39.6	180.5	108.7	112.2	−46.0	247.7
Area2	19.1	21.4	−87.2	114.2	1.9[d]	2.8	−85.1	39.2	21.3	24.7	−127.4	154.9
Area3	17.7	19.6	−69.9	96.2	9.1[c]	11.3	−81.2	93.8	25.3	28.3	−105.9	143.2
Area4	21.2	22.8	−52.1	86.8	20.3	24.0	−138.6	163.1	42.9	47.9	−178.2	241.6
Job2	17.1	18.6	−54.6	81.3	13.9	15.6	−58.1	78.7	37.9	39.5	−32.4	101.1
Job3	26.3	28.6	−81.6	122.9	10.4	12.1	−66.2	79.3	22.6	24.5	−60.4	97.3

[a] *Variables are described in Table 1. Exchange rates to euros on 12 November 2019: CAD 1.457, NOK 10.076, and GBP 0.859. Significant at 1% unless otherwise noted. There are no significant willingness-to-pay differences between the weighted mixed logit models relative to unweighted.*
[b] *Variables defined in Table 1.*
[c] *Significant at 10%.*
[d] *Not significant.*

WTP determinants

The individual WTP was elicited from the MXL model with the pooled data set (Table 5). The amount of variation explained by the determinants of the WTP ranged from 4% to 17%. Though small, this is a common occurrence in such models and does not rule out the validity of the model because our interest was to determine the relationship between explanatory and dependent variables rather than make predictions. Nevertheless, some of the individual variables showed significant effects. This suggests that the explanatory variables provided valuable information about the response variable. In the RE model, named multi-attribute model (last column, Table 5), the attribute-level variables were dummy coded. Job was the reference variable and the others included as indicator variables. The remaining variables were the same as for the OLS model. These indicators were positive and highly significant, implying that improvements in litter, health, and area attributes attracted higher WTP values than improvement in job attribute in absolute terms. Litter was the highest ranked attribute, followed by health, area, and finally job, ceteris paribus.

Men had a higher WTP for the health attribute (€8.1), being a member of environmental organizations attracted higher value to multi-attribute (€8.2), and those

Table 5. Ordinary-least-squares (OLS) and random-effect (RE) regression model of determinants of public willingness to pay for high-seas ecosystem conservation[a].

Variable[b]	*OLS models*								*RE model*	
	health		*litter*		*Area*		*job*		*multi-attribute*	
	coefficient	*SE*	*coefficient*	*SE*	*coefficient*	*SE*	*coefficient*	*SE*	*coefficient*	*SE*
Indicator for attribute level										
health									28.0***	4.4
litter									41.4***	7.7
area									7.0**	3.3
constant	30.6**	3.3	29.3*	7.4	15.0	5.8	18.2*	2.8	4.2	8.4
Covariate										
male	8.1**	1.1	3.9	4.2	1.1	3.0	0.9	0.9	3.5*	1.9
age 18–35	−5.0	1.8	5.4	7.2	−1.3	4.0	5.4*	1.6	1.1	1.8
age 36–65	−1.3	0.7	−0.6	4.3	−6.2	4.8	1.8	2.1	−1.6	2.3
Nongovernmental organization	12.0*	2.9	13.3	7.1	5.3	4.0	2.1	1.6	8.2**	3.3
tertiary degree	4.0	2.8	5.5**	1.0	2.5	1.2	−0.9	2.6	2.8**	1.3
awareness	−3.0	2.4	−5.7	5.9	−4.1	3.1	3.8	1.8	−2.2	2.0
condition2	−5.4	2.8	−4.4	10.4	−7.9	7.0	0.5	2.1	−4.3	3.8
condition3	1.7	1.4	−0.4	2.5	−3.6	3.3	−1.5	1.5	−0.9*	0.5
condition4	−1.6	4.1	−2.7	2.5	−5.6	2.6	−3.2	1.6	−3.3**	1.4
condition5	−2.6	3.0	0.2	2.5	−1.4	3.0	−3.6	2.7	−1.8	2.4
condition6	−5.7	2.2	−3.4	7.5	−12.9	6.1	2.2	4.0	−5.0***	1.3
effect2	−3.7	6.2	−8.2	6.0	−5.6	3.1	−0.4	0.6	−4.4	3.4
effect3	9.5**	1.4	9.6*	2.3	8.0*	2.4	2.4**	0.2	7.4***	0.8
effect4	12.7**	2.4	15.8	7.6	14.0***	0.9	3.9	2.7	11.6***	1.9
management2	−1.0	1.0	0.6	2.3	3.1	2.9	−1.1	0.9	0.4	0.8
management3	4.2	3.7	1.4	6.1	0.9	6.1	3.1	1.6	2.4	3.9
management4	−7.2**	1.6	−5.6	6.3	2.1	5.4	0.7	1.0	−2.5	3.0
confidence2	6.1	3.5	17.0**	2.1	12.1*	3.9	2.0	1.4	9.3***	2.0
confidence3	6.8*	2.1	17.1	6.0	10.9	6.0	3.1	2.6	9.4***	3.2
confidence4	13.9***	1.3	21.4*	5.6	5.8**	0.7	−2.4	2.5	9.7***	1.6
confidence5	−5.6	10.9	−6.6	8.2	−9.2**	61.0	−7.4	4.0	−7.2	5.4
Spatial covariate										
Norway	−6.2***	0.4	−1.4***	0.0	0.3	1.1	−8.3***	0.3	−3.9***	0.2
Scotland	10.3***	0.6	22.6***	1.2	7.8***	0.7	−2.9**	0.4	9.4***	0.7
Model statistics										
R^2	0.08		0.09		0.04		0.06		0.17	
Observation	1454		1454		1454		1454		5816	
σ_ν									1.83	
σ_ϵ									4.15	

[a] *Significance: *** 1%; ** 5%; * 10%.*
[b] *Variables defined in Table 1; Because some respondents did not report their income (11.4%, 20.5%, and 17.5% of samples from Canada, Norway and Scotland, respectively) and all dummy purchasing-power-parity-adjusted income parameters in both OLS and RE models were insignificant, they were excluded from the estimations to keep all observations and improve model fit.*

with higher education also had a higher WTP for the litter attribute (€5.5) and multi-attribute (€2.8). The coefficients of condition4 and condition6, and management4 were negative and significant for multi-attribute and health models, respectively, showing that respondents who thought that the Flemish Cap ecosystems were in good condition and well-managed had lower WTP compared with those who had indefinite statements. The coefficients of effect3 and effect4 were positive and significant in almost all models, implying that respondents who thought that changes to Flemish Cap ecosystems would affect them personally had higher WTP than those with indefinite attitudinal statements. The coefficients of confidence2, confidence3, and confidence4 were positive and significant, suggesting that respondents who were confident regarding their choices had a higher WTP for protecting the Flemish Cap ecosystems, though these confidence levels were not significant for the job model. The confidence5 coefficient had a significant negative sign, indicating that when respondents felt very confident regarding their choices, they seemed to attribute less value to area. The youngest group (18–35 years) showed higher WTP for the job attribute but did not differ significantly from the oldest group (age 65+) for the remaining attributes (finding significant only at the 10% level).

The Scotland coefficient was positive and significant in all models, except for job, for which the coefficient was negative. This suggests that the Scots had higher WTP for health (€10.3), litter (€22.6), area (€7.8), and multi-attribute (€9.4), but lower WTP for job attribute (€2.9) relative to Canadians. Respondents living in Norway, to the contrary, had lower WTP for health (€6.2), litter (€1.4), job (€8.3), and multi-attribute (€3.9), but did not differ significantly from the Canadians regarding WTP for area attribute. There was no statistically significant difference in WTP for high-seas ES attributes between respondents who answered don't know or don't care and those who were in the definite negative category associated with the attitudinal variables (Table 5).

DISCUSSION

Overall, results from our DCE survey showed that the general public across diverse countries had preferences for ESs provided by the high seas and were willing to pay for ecosystems conservation via an increased income tax despite their unfamiliarity with and distance to these environments. This is an overall strong result in relation to arguments for high-seas conservation and provides input into the debate related to whether marine resources in BBNJ are the common heritage of humans or whether high-seas freedom provisions apply (Leary, 2019).

Canadians, Scots, and Norwegians seemed to have similar perceptions in relation to the relative importance of marine attributes, though WTP values that they had for the attributes were not all homogeneous. Respondents assigned the highest absolute value to marine litter control, followed by fish stocks health, MPA size, and new jobs. The overall strong preferences held by respondents concerning deep-seas litter reduction point to greater attention being given to this issue internationally (i.e., supporting efforts to include marine litter in the ongoing BBNJ negotiations) (Tiller & Nyman, 2018). Very few researchers have used stated-preference methods to investigate the link between nonuse values and policy support for marine habitat conservation in terms of MPAs (e.g., Aanesen et al., 2015; Armstrong et al., 2019b; Börger et al., 2014), and none of the earlier studies relate to high-seas closures. We identified public preferences not only for existence values of deep-seas species but also for marine conservation measures (i.e., MPAs), the latter of which is often viewed as important for protecting marine biodiversity. However, arguments remain related to whether most MPAs are an effective conservation measure or just networks of "paper parks" (Smith & Jabour, 2018).

The WTP for the attribute-level improvements were highest for those residing in Scotland, followed by Canadians and then Norwegians, with the only exception being WTP for a large increase in new jobs, for which Canadian WTP was higher than for Scots. We expected Canadians to have a higher WTP for high-seas ecosystems conservation compared with those living in Norway and Scotland due to distance-decay effects. Distance decay implies that demand for a good declines with increased distance due to reasons, such as travel and time opportunity costs, the availability of substitutes, the increased search and information costs, and the feeling of moral obligation and responsibility declining with distance (De Valck & Rolfe, 2018). However, distance-decay effects vary depending on the type of value considered. They are more prevalent for use values (e.g., recreation), whereas they are less clear for indirect use and nonuse values, particularly existence values (De Valck & Rolfe, 2018). We did not find a clear distance-decay effect because the Scottish respondents had the highest WTP and the Norwegians the lowest WTP for almost all attribute levels. However, regarding the job attribute, Canadians not only had higher WTP compared with the Norwegians and Scots, but also had an increasing WTP trend for more jobs, whereas Norwegians and the Scots exhibited a declining trend. As the closest country, it might be the case that Canadians recognized they might benefit more in terms of job opportunities and in supporting economic activities taking place in the Flemish Cap.

The higher WTP for Scots compared with that of the Norwegians and Canadians may be due to the significantly higher education level in the Scottish sample. Moreover, respondents who were members of environmental organizations and indicated their concerns on the status of the high-seas environment had higher WTP for protecting high-seas ESs. This points to the need of both formal and informal education to improve public knowledge of the deep seas and its interactions with humans, thereby increasing their support for high-seas ecosystems conservation. The Norwegian and Scottish public generally have low perceived knowledge about the deep-sea and wildlife environment (Ankamah-Yeboah et al., 2020), making such education essential to high-seas ecosystem protection.

Our findings are timely in providing scientific evidence that reduces the knowledge gaps related to the impacts of high-seas governance actions on human welfare. People have preferences for high-seas ecosystem conservation, and our results provide support for international efforts in relation to governance and management of activities on the high seas. Including public conservation preferences in management could improve the resilience of high-seas ecosystems; increase the overall value of these ecosystems and the services they produce; and inform cost–benefit analyses in relation to increased management efforts. Moreover, the simultaneous public preferences for protective measures motivated by nonuse values and the development of commercial activities related to exploration and exploitation of high-seas resources show stakeholders' support for the so-called good environments status (GES) (EU, 2008) and blue growth strategies for the deep seas in the North Atlantic Ocean, insofar as these underlie our selected attributes. So far, socioeconomic criteria have not been discussed in detail in relation to GES aims, but rather as a separate issue (Bertram & Rehdanz, 2013), raising the question of the need for social science input into what could equivalently be described as good economic and social status. Although some contend stated-preference valuation overestimates WTP, in our study, it was the relative prioritization of environmental issues versus blue growth that was of central interest. However, we focused solely on public preferences for high-seas ecosystems conservation in wealthy countries, rather than underdeveloped and developing countries, which account for a large proportion of the world but are underrepresented and have less of a voice in, for instance, the BBNJ negotiations (Blasiak et al., 2016).

ACKNOWLEDGMENTS

This work received funding from the European Union's Horizon 2020 research and innovation program under grant agreement 678760 (ATLAS). This output reflects only the authors' views, and the European Union cannot be held responsible for any use that may be made of the information contained therein. We thank M. Gianni, K. P. Paudel, P. Durán Muñoz, A. García-Alegre Garralda, E. Kenchington, the ATLAS project, 2 anonymous reviewers, and editors for their insightful comments and input.

Supporting Information

Additional information is available online in the Supporting Information section at the end of the online article. 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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