Using choice experiments to estimate the simulated exchange value of species preservation services for ecosystem accounting

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Abstract [use this style font, Calibri 13 point, for 1st level headings]

We present a choice experiment for the valuation of preservation services for threatened aquatic wild birds in the coast wetlands of the southwest of the Iberian Peninsula. We test the potential of stated preference methods to estimate non-market exchange values for ecosystem accounting. The experiment was administered to a sample of the adult population of Spain (n = 800) and Portugal (n = 179) in 2019. The program attributes were described as the variation in the number of aquatic wild bird species in each of the three threat categories of the red list of species plus a one-time increase in income taxes for the implementation of the program. The preferred model shows that passive consumers are willing to pay more to reduce a higher number of species in each category, but marginal willingness to pay (WTP) is substantially higher for "critically endangered" species. Based on this model, we estimate a marginal WTP-based simulated exchange value of €440 per person for a one-time payment (equivalent to €16.41 per year for 30 years), which would be paid by 34% of passive consumers. These estimates represent exchange values consistent with the valuation criteria of national accounts in contrast to the Hicksian surplus, which is 1.6 times higher in our application.

Keywords: biodiversity conservation, landscape management

Introduction, scope and main objectives

Biodiversity protection has become one of the most pressing matters in the environmental policy agenda (European Commission, 2020) and species and habitat loss is identified by citizens as an environmental concern (European Union, 2020). However, official statistics and national accounts keep considering the economic value of species preservation based only on its cost of provision. The monetary SEEA ecosystem accounting was adopted in March 2021 as internationally recognized principles and recommendations for the monetary valuation of ecosystem services and assets (United Nations, 2021), with the aim of explicitly accounting the economic contribution of nature to human consumption in a consistent way with transaction price valuation of national accounts. However, the economic valuation of non-market output, such as that from species preservation, is a pending challenge (Hein et al., 2020). United Nations (2019) encouraged the debate about the role of non-market valuation in ecosystem accounting and recommended undertaking pilot studies providing empirical scientific sound applications for its future standardization aligned with the SNA.

We present a proposal to estimate the part of the non-market final output of threatened species preservation services corresponding to the net operating margin (NOM) exchange value of the activity that can be integrated in an ecosystem accounting framework. We used a choice experiment to estimate the demand for these non-market services. This demand is then used to derive the NOM simulated exchange value embedded in the final product consumption. To this end, we find the single price that would maximize the earnings from a potential market of species preservation, beyond the taxes already paid for this activity, and the percentage of consumers that would pay it (Caparrós et al., 2017). Results are presented for the case of threatened aquatic wild bird species in the coast wetlands of the southwest of the Iberian Peninsula: provinces of Cádiz and Huelva, in Spain, and the regions of Algarve and Alentejo, in Portugal.

Methodology/approach

We used a choice experiment to obtain respondents' WTP, additional to the general taxes already paid, to "buy" the preservation of threatened species in the study area. To simulate this demand, we set the payment context by defining a baseline situation (status quo) where the current government expenditure on species preservation in the study area does not guarantee that the species maintain their current preservation status in a 30-year horizon. This assumption is based on the observed tendency of bird species loss world-wide.

We focused on the preservation of the singular genetic variety of threatened species (Pearce and Moran, 1994). We left out of the valuation exercise non-threatened (more abundant) species pertaining to other categories of values such as active recreational (e.g., ornithological) or scenic (e.g., iconic species) consumption. We further assume that the utility of a passive consumer for the preservation of threatened species increases with the number of species targeted and for species with a higher threat category. This hypothesis is based on: (i) a higher threat category implies a higher probability of extinction; and (ii) a higher threat category implies a higher relative scarcity (less individuals for the species). Based on this, we designed a choice experiment to estimate the probability of payment for a program that avoid an increase in, or reduces, the number of species in different threat categories in a 30-year horizon. For ecosystem accounting, which focuses on current consumption, this design needs to include among the attribute levels those that represent the current provision of threatened species preservation services; that is, keeping species in their current threat category.

We used a one-time tax increase for a program with effects on species preservation in 30 years. This payment intends to "buy" the preservation status (or to improve it) for the stock of threatened aquatic wild bird species in that period. Considering that this payment is already net of costs (the current costs devoted to this activity only covers the preservation of species as defined by the status quo alternative), the value obtained can be interpreted as the discounted value of future net operating margin (NOM), both manufactured and environmental. Using a capitalization formula, which would require assuming a social discount rate, we can derive the expected simulated annual value of the NOM for these services for every year in that 30-year period.

Threatened biodiversity indicator

To link respondent's marginal WTP (p: price) with an objective and quantifiable physical indicator (q: quantity) of the service being valued, we follow the proposal of Díaz et al. (2020) to identify the number of threatened aquatic wild bird species and their threat category in our study area. We start with the 98 species census by the public administration in 2015 in the study area (Consejería de Agricultura, Ganadería y Desarrollo Sostenible, 2020), and then focus on the 41 species included in Annex I of the Birds Directive (Official Journal of the European Union, 2010) because their populations are subject to an active management for which environmental public administrations incur a public cost and produce a non-market output of species preservation services. Then, we identified the threat category for each of these 41 species, by using the regional list of species of the IUCN Red Books of Birds for each country. This classification applies the criteria regionally for the classification of species according to the threat categories of the IUCN that assess the risk of extinction of wild species (IUCN, 2012). We only focus on those species classified as threatened, being 9 "vulnerable" (VU) species, 2 "endangered" (EN) species and 5 "critically endangered" (CR) species according to the Red Books of Spain, and 10 VU species, 6 EN species and 5 CR species according to the Red Book of Portugal. Since we need a single list of species for both countries, we assign to each species the observed threat category when they are similar in both lists and the highest threat category when they differ. This results in a list of 28 species (13 VU, 8 EN and 7 CR).

Experiment design

The participants in the choice experiment were presented with alternatives of programs described by the variation in the number of species of the study area in each of the three threat categories of the IUCN and by a one-time increase in the income tax. The alternatives are defined by the expected results of the program in 30 years. The attributes and their levels are presented in Table 1. The status quo alternative describes the expected results in 30 years if the same level of public budget is maintained for species preservation. This implies that no additional income tax would be paid in this alternative and that the number of species in each threat category would increase in that 30-year period: by three for VU species, by two for EN species and by one for CR species.

Table 1. Attributes and their levels in the choice experiment

Atributtes	Levels	Status quo level
Variation in the number of species in the category "vulnerable"	9 species LESS (from 13 to 4) 6 species LESS (from 13 to 7) 3 species LESS (from 13 to 10) No change (keep 13)	3 species MORE (from 13 to 16)
Variation in the number of species in the category "endangered"	6 species LESS (from 8 to 2) 4 species LESS (from 8 to 4) 2 species LESS (from 8 to 6) No change (keep 8)	2 species MORE (from 8 to 10)
Variation in the number of species in the category "critically endangered"	3 species LESS (from 7 to 4) 2 species LESS (from 7 to 5) 1 species LESS (from 7 to 6) No change (keep 7)	1 species MORE (from 7 to 8)
Increase in the Income Tax only this year	50 € 100 € 200 € 400 €	0 €

Each survey participant was presented with four choice cards containing three alternatives: two with levels of attributes varying from card to card according to an experimental design, and the status quo alternative with fixed attribute levels on all the cards. We used The NGENE software to generate a fractional factorial design. This design consisted of 16 choice sets divided into four blocks, which we used in four different questionnaire types each one with four different choice sets. This design gave a D-efficiency of 99.4%.

Econometric analysis

We assume that each individual *i* has a linear parameter utility function U_{ijt} for each alternative *j* (j = 1,…., *J*) in each choice situation *t* (t = 1,…., *T*) with a systematic component V_{ijt} and a random component ε_{ijt}:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} = \beta' X_{ijt} + \varepsilon_{ijt}, \qquad [1]$$

where β represents a vector of parameters, X_{ijt} is a vector of variable values observed for alternative *j*, the individual *i* and situation *t*; and ε_{ijt} are random errors.

We assume that the utility of individual *i* will depend on the number of preserved species (*n*) and on the threat category of the species (*t*) as well as on a payment associated each alternative. Thus, the values X_{ijt} are the levels of the attributes in Table 1 for each alternative *j* and situation *t* presented to each individual *i*: number of VU species, number of EN species, number of CR species and the one-time increase in tax payment (*TAX*). Thus, the utility function for the choice experiment analyzed takes the following form:

$$U_{ijt} = \beta_{VU} VU_{ijt} + \beta_{EN} EN_{ijt} + \beta_{CR} CR_{ijt} + \beta_{TAX} TAX_{ijt} + \varepsilon_{ijt}. \qquad [2]$$

Given this utility function, the probability of individual *i* choosing alternative *j* over any other alternative *h* ($\forall h \in J$) in situation *t* (Pr_{ijt}) is:

$$Pr_{ijt} = Pr\left[V_{ijt} + \varepsilon_{ijt} > V_{iht} + \varepsilon_{iht}\right] = Pr\left[V_{ijt} - V_{iht} > \varepsilon_{iht} - \varepsilon_{ijt}\right] \forall j, h \in J \qquad [3]$$

Different assumptions on the density function of the random errors $f(\varepsilon_{ijt})$ give different probability models. We use the conditional logit model, which assumes that the errors are distributed independently and identically with an extreme value distribution for the h alternatives ($\forall\ h \in J$), individuals i and situations t, and the mixed logit model, which assumes that the coefficients of the variables (attributes) have a component which is common to all the individuals and a component specific to each individual (Train, 2009). In the latter case, the utility function now adopts the following form:

$$U_{ijt} = \beta_i' X_{ijt} + \varepsilon_{ijt}, \quad [4]$$

where β_i is a vector of parameters specific to the individual i (the individual-specific component), X_{ijt} is the vector of the variables observed for alternative j, individual i and situation t; and ε_{ijt} are random errors (the error component common to all the individuals). The individual-specific component follows a distribution with density $f(\beta)$ which is a function of the parameters ϑ (for example, the mean and covariance of β in the population). This distribution is specified *a priori*. In our choice experiment, we assume a normal distribution for the parameters of the variables *VU*, *EN* and *CR*, and that the *TAX* variable has a fixed parameter.

All the attributes have been codified as continuous variables, normalizing the *status quo* values to zero and defining the attribute values as the difference between the *status quo* value and the level of the attribute in each case. We employed the NLOGIT software version 4.0 to estimate the parameters using the maximum likelihood method for the conditional logit and simulated maximum likelihood for the mixed logit.

Aggregation

The Hicksian surplus provides the value for the area below the Hicksian demand curve for the service valued and can be used in cost-benefit or welfare-based analysis. Our analysis focuses on the aggregate value for a combination of values of the attributes which make up a specific alternative. The change in the Hicksian surplus (HS) associated with the demand for the provision of a specific alternative for an individual i is calculated as (Train, 2009):

$$HS_i = \frac{1}{\beta_{TAX}}\left[ln\left(\sum_{j=1}^{J^1} e^{V_{ij}^1}\right) - ln\left(\sum_{j=1}^{J^0} e^{V_{ij}^0}\right)\right], \quad [5]$$

where the superscripts 0 and 1 represent the alternatives for which we evaluate the change in the Hicksian surplus. In the application dealt with in this study, the main interest is in the variation between the alternative defined as the *status quo* and the alternative by which the current number of species in each threat category is maintained. When using the mixed logit model, the above equation is calculated by taking the expected value € with respect to the random parameters and then calculating the mean Hicksian surplus.

The simulated exchange value (SEV) is the part of the Hicksian surplus area that could be potentially internalized in a market (the area under the price and to the left of the corresponding quantity). The SEV assumes that in a potential market only a single price could be paid. To determine that price, we need to assume a specific market structure along with the form of the supply function (cost of provision). We opted for the monopolistic competition and we assumed that all costs are fixed and therefore the price that maximizes the benefits equals the price that maximizes the earnings (Caparrós et al., 2017; Oviedo et al., 2016).

The aggregate earnings for an alternative j (EA_j) in the hypothetical market is calculated as the price paid for alternative j for provision of the service (p_j) multiplied by the quantity of consumers in the market that would pay it (q_j): $EA_j = pj\ qj(pj)$. According to this equation, qj is determined by pj. If we assume that all the potential consumers in the market would pay a $p_j = 0$ (i.e., $q_j(0) = Q_j$), then q_j can be expressed as the probability of paying p_j for the provision of alternative j ($\Pr_j$) multiplied by the potential number of consumers in the market (Q_j): $q_j(p_j) = \Pr_j(p_j)\cdot Q_j$. Thus, the earning function would be expressed as: $EA_j = p_j \Pr_j(p_j)\ Q_j$, and the price ($p_j^*$) which would maximize the income can be calculated; that for which the condition is met of first order of the derivative EA_j with respect to p_j ($EA_j' = 0$). Once p_j^* has been estimated, its corresponding qj^* is calculated by substituting p_j^* in $q_j(p_j) = \Pr_j(p_j)\cdot Q_j$ using the probability function of the estimated model. Thus, p_j^* is found when, based on the condition of first order for the derivative of EA_j with respect to p_j, the following condition is met:

$$exp(\beta' x_j) + 1 + \beta_{TAX} p_j = 0 \quad [6]$$

This is the most simplified form that can be arrived at for the first order condition and thus p_j^* must be estimated through iteration from the conditional logit model probability function. When using the mixed logit model, this condition is solved by taking the expected value (E) with respect to the random parameters and then calculating the mean p_j^* to estimate qj^* and I_j. In our experiment, the alternative *j* for which the SEV, p_j^* and qj^* are estimated is the alternative for which the current number of species in each threat category is maintained over the next 30 years (VU=3, EN=2 y CR=1).

Survey logistics

We used the online platform Tickstat (www.tickstat.com) to design the valuation survey. This platform allows questionnaires to be designed in digital format, with a specific module for choice experiments. We performed two validation phases. Firstly, we carried out various focus groups (15 individual ones and two groups of five and three participants, respectively). Then, we carried out a pre-test survey. The pre-test results confirmed that tax payment values used (Table 1) were appropriate according to the proposal by Alberini (1995) that uses the four quintiles of the estimated WTP distribution estimated with the pre-test data.

We defined (*ad hoc*) the target population of our experiment by the population of adults of the countries in which the study area is located, Spain and Portugal. The sample was obtained from a representative panel supplied by a professional company and was distributed proportionally to the adult population of Spain and Portugal in 2018 (an 82-18% distribution). The final valid sample for the choice experiment was *n* = 800 in Spain and *n* = 179 in Portugal, with a previous pretest of *n* = 78 and *n* = 17, respectively.

Results

We have tested several models using different specifications of the utility function, depending on the inclusion (or not) of a constant specific to the alternatives (ASC) implying a payment, and on the use of lineal or quadratic forms for the attributes of variation in the number of species in each threat category. For choosing the preferred models, we have taken into account the following indicators of model performance: (i) the margin of error in the WTP estimations; (ii) the individual significance of model coefficients; (iii) the consistency of coefficient signs; (iv) the convergence of WTP results among models; and (v) the AKAIKE information criterion. From our analysis, we concluded that we preferred a model without the ASC, and a linear over a quadratic model. This hold for both the conditional and the mixed logit models (see the preferred models in Table 2).

Table 2. Conditional and mixed logit models from the choice experiment for the valuation of wild aquatic bird threatened species preservation

Atributtes	Conditional logit	Mixed logit	
	Coefficients	Coefficients (mean)	Coefficients (st. dev.)
Variation in "vulnerable" species (VU)	0.0632***	0.0968***	
	(0.0050)	(0.0140)	
Variation in "endangered" species (EN)	0.0528***	0.1129***	0.3256***
	(0.0075)	(0.0133)	(0.0192)
Variation in "critically endangered" species (CR)	0.2157***	0.4017***	0.1803***
	(0.0155)	(0.0357)	(0.0251)
Increase in the Income Tax only this year	-0.0031***	-0.0037***	0.6075***
	(0.0002)	(0.0003)	(0.0495)
N	3,916	3,916	
Log-likelihood	-3.711	-3.135	
AIC	7.430	6.286	

Note: Standard errors are shown in parenthesis. N: number of observations; asterisks (e.g.,***,**,*) indicate significance level at 1%, 5% and 10%, respectively.

The preferred models (Table 2) show that all parameters are positive and statistically significant at 1% level. This indicates that individuals are increasing their utility through programs that decrease the number of species in each threat category, this utility being substantially higher for "critically endangered" species. The parameter associated with the payment attribute is also significant at 1% level and with a negative sign.

Using the mixed logit model, Table 3 shows the different metrics of economic value of the preservation services for the current number of threatened species in the study area. We show the value derived directly from the choice experiment (one-time payment) as well as its annualized equivalent obtained using a 1% real discount rate. In individual terms, the average consumer obtains a Hicksian surplus of 248.12 euros for a one-time payment. Aggregately, this value multiplied by the total population of consumers gives 11,622 million euros. The annualized equivalent Hicksian surplus for 30 years is 9.26 euros per year for the average consumer and 433 million euros per year for the aggregated population of consumers. In a real market, this value would be equivalent (in the case of the functional form of the utility function with which we are working) to assuming that each of the potential consumers of these services would pay their maximum WTP.

Table 3. Hicksian surplus and simulated exchange value of wild aquatic bird threatened species preservation services. Mixed logit estimations.

Metric	One-time payment			
	Individual (€ per person)	Total consumers paying (%)	Aggregated	
			Total (000's €)	Per hectare (€/ha)
Hicksian surplus	248.12 €	46,842,096 (100%)	11,622,460 €	108,859 €
Simulated exchange value	440.00 €	15,926,312 (34%)	7,007,577 €	65,635 €
	Annualized equivalent (30 years and 1% real discount rate)			
	Individual (€ per person)	Total consumers paying (%)	Aggregated	
			Total (000's €)	Per hectare (€/ha)
Hicksian surplus	9.26 €	46,842,096 (100%)	433,757 €	4,063 €
Simulated exchange value	16.41 €	15,926,312 (34%)	261,350 €	2,448 €

In the case of the simulated exchange value, the individual price that would maximize the earnings (net operating margin in our valuation context) in a potential market is 440 euros for a one-time payment, and this price would be paid by 34% of potential consumers of preservation services. In aggregate terms, this would mean 7,007 million euros. In the case of the annual payment over 30 years, these values would be equivalent to 16.41 euros per consumer and 261 million euros for the total population of consumers, respectively. These aggregate values represent the maximum earning that could be obtained in a potential market given the estimated demand function and assuming that only a single price would be established in the market.

Discussion

Our valuation proposal implies a first step for the integration of the part of the non-market output of an ecosystem service that is not included in its cost of provision and therefore represents the NOM of the activity. Against the alternative of valuing the output only by the costs of the provision, as proposed by the SNA, which implies a NOM of the activity equal to zero and thus a resource rent equal to zero (the resource rent is the environmental component of the NOM) (Campos et al., 2019), our proposal reveals the economic value of the part of the non-market output that is found above the cost function of the service and that is attributed by society to the provision of services for the preservation of threatened species. While the former criterion (output = cost) is arbitrarily decided a priori, the latter relies on the preference by the general population that, aggregately, provides and objective valuation of society for the preservation of species beyond the costs already incurred in this activity. The key question here is whether this part of the demand function above the cost function, and its corresponding exchange value, can be properly estimated with a choice experiment (a type of stated preference method). Our results indicate that these services are more valued for those species that are closer to the extinction threshold, which seems consistent with what would be expected from a normal demand function (higher WTP for a scarcer good). This may be an indication that our valuation proposal is adequate for valuing the existence value of species and this valuation is made independently of social preferences for iconic or recreational species that do not pertain to the category of the existence value.

Our proposal has the aim to obtain an economic value of the NOM for the activity of preservation of threatened species in similar conditions and valuation criteria than that of marketed goods and services that are registered as such in national accounts. This is a first step for bringing together market and non-market goods consistently in the same accounting framework. However, the estimated values reflect the consumption (present and future) of these services by society and this, by itself, does not provide sufficient information to guarantee the preservation of species. For this, information from biological sciences on the physical quantities and thresholds below which the species are more likely to disappear is a necessary condition. The economic science is able to contribute to the visibility to the economic values of the consumption associated to non-market services in similar conditions than those from marketed goods. However, a reduction in this consumption does not necessarily implies that the status preservation of species gets worse. Similarly, an increase in this consumption does not necessarily avoid the extinction of a species. In fact, this may be correlated to a reduction in a species population (higher threat category) and also implies higher costs of management, being the net result in terms of total social income unknown without the implementation of a complete system of ecosystem accounts (Campos et al., 2019).

Conclusions/ wider implications of findings

The results of this application show that we can obtain consistent and complete (marketed and non-marketed) demand values from a relatively simple design, which also uses international standards criteria, for threatened species preservation services. The estimated demand can be used to derive (under certain assumptions) a simulated exchange value for these preservation services. The logic of this simulation is similar to that adopted in the estimation of production and/or capital exchange values for a commercial good traded in a real market; that is, we obtain a single price that would be paid by a part of the population of potential consumers. This estimate enables the simulated exchange value to be integrated into ecosystem accounts in the case of non-commercial services, such as the preservation of threatened species. Likewise, the derivation of this value from a demand curve based on consumer preferences reinforces the consistency of the estimated values for their integration into national accounting-based systems.

Acknowledgements

This research has received the financial support of the project AQUA&AMBI (0240_AQUA_AMBI_6_P) and is a contribution to the projects TRENGOOD (ECO2017-84461-R) of the National R&D Plan of the Spanish Government and MECAPI (202010E141) of CSIC. The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO.

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