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Martínez-Jauregui, Maria, White, Piran Crawfurd Limond orcid.org/0000-0002-7496-5775, Touza-Montero, Julia Maria orcid.org/0000-0001-8170-1789 et al. (1 more author) (2019)
Untangling perceptions around indicators for biodiversity conservation and ecosystem services. Ecosystem Services. 100952. ISSN 2212-0416

Untangling perceptions around indicators for biodiversity conservation and ecosystem services

María Martínez-Jauregui[12*]; Piran C. L. White[3]; Julia Touza[3]; Mario Soliño[124]

[1] National Institute for Agriculture and Food Research and Technology (INIA), Forest Research Centre (CIFOR). Ctra. de La Coruña km. 7.5, 28040 Madrid, Spain
[2] Sustainable Forest Management Research Institute, University of Valladolid & INIA, Avda. de Madrid 57, 34004 Palencia, Spain.
[3] Department of Environment and Geography, University of York, Wentworth Way, York; YO10 5NG, United Kingdom
[4] Complutense Institute for International Studies (ICEI), Complutense University of Madrid, Finca Mas Ferré, Edif. A. Campus de Somosaguas, 28223 Pozuelo de Alarcón, Spain.

*Correspondence to: martinezmari@gmail.com (M. Martínez-Jauregui)

ABSTRACT

Biodiversity indicators are commonly monitored to ensure the sustainable management of ecosystems and the conservation of multiple ecosystem goods and services. Indicators are important for tracking the ecological outcomes of conservation programmes, but they are also important in a wider context such as monitoring progress towards broader sustainability goals and serving to generate public support and funding for these programmes. Little attention is usually given to the social and cultural dimensions of biodiversity indicators. In this paper, using a discrete choice experiment, we compare the impact of within-species, between-species and within-ecosystem level biodiversity indicators on public preferences for conservation programmes in Spanish pine forests. Specifically we show that preferences towards conservation programmes are significantly affected by the interaction between indicators and their perceived role in delivering ecosystem services. Genetic variation, the number of invasive species and keystone elements were associated equally frequently with provisioning, regulating and cultural ecosystem services, whereas population structure, the number of native species and the area of land conserved were more variable in how they were associated with different ecosystem services. Our results highlight the importance of considering the perceived social relevance of indicators alongside their ecological suitability in the design of conservation programmes and monitoring.

HIGHLIGHTS:

- People's preferences for conservation are affected by how they view the functional role of biodiversity.
- Regulation is the ecosystem service most frequently associated with biodiversity, followed by cultural services.
- Provisioning services are least frequently associated with biodiversity.
- The choice of indicators for conservation programmes should take account of social and cultural considerations.

KEYWORDS: Ecosystem-based management; Forest conservation; Forest management; Choice experiment; Biodiversity indicators; Public perception.

1. Introduction

Understanding public preferences concerning biodiversity, ecosystem goods and services is important for managing ecosystems, since the implementation and effectiveness of management interventions frequently depend on support from society (Hirsch et al., 2011; Mace, 2014; Martín-López and Montes, 2015). Biodiversity indicators are used as a measure of success of specific conservation programmes, and as part of monitoring progress towards the Sustainable Development Goals (Chaudhary et al., 2018; Khoury et al., 2019; Reyers et al., 2017). More broadly, they provide information on the sustainable use of ecosystems and the preservation of multiple goods and services (Failing and Gregory, 2003), and can be used to infer the resilience of ecosystems and human wellbeing in the face of global environmental changes (Butchart et al., 2010; Millar et al., 2007). They can also be used to inform options for future benefits from ecosystems beyond those currently experienced (Austin et al., 2016; Cardinale et al., 2012; Harrison et al., 2014; Mace et al., 2012). However, determining the biodiversity indicators best-suited for these different roles is not straightforward. Indicators need to be clearly linked in an objective manner to the ecological phenomena they are intended to represent, but the increasingly socio-economic dimensions of their applications also require that they are align with the local values and preferences of stakeholders and that their meaning to society is understood (Díaz et al., 2018; Heink and Kowarik, 2010; Mace and Baillie, 2007). Analysis of how reliably a specific biodiversity indicator represents the potential supply of ecosystem services therefore provides only partial information (Tallis et al., 2012). The process of making conservation decisions also requires *a priori* information on how the indicator is perceived as a social metric capturing the ‘use’ of these ecosystem services for well-being (Aslan et al., 2018; Martinez-Harms et al., 2015, p.; Wolff et al., 2015), so that project outcomes can be understood and shared, enhancing communication across stakeholders and building trust across policy makers, researchers, practitioners and local communities (Goggin et al., 2019).

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Here, we analyse perceived interrelationships between biodiversity, ecosystem services and biodiversity indicators to provide new insights into the links between ecosystems and human well-being, specifically in terms of how preferences for conservation are influenced by the components of biodiversity being used as indicators and the ecosystem services with which they are perceived to be associated.

We examine public preferences regarding indicators and ecosystem services using economic valuation, which is a common approach to valuing natural and common goods. There is a range of frameworks and approaches (e.g. participatory, expert-based, or process-based approaches) that can be used to understand people's support for conservation projects, and some of these integrate both ecological and social values (e.g. Ban et al., 2013; Whitehead et al., 2014; Wolff et al., 2015). However, economic valuation has some specific advantages because it links expressed preferences to behaviour or experience towards goods and services, and consequently willingness to conserve, which can be compared to the costs of project implementation and the opportunity costs of conservation. Moreover it allows different contributing factors towards preferences to be compared in a quantified manner. Consequently, economic valuation and in particular stated preference methods (Bateman et al., 2002; Johnston et al., 2017) have been used frequently for quantifying social preferences as a measure of support for environmental management programmes (Balmford et al., 2011; De Groot et al., 2012; Giergiczny et al., 2015; Kenter et al., 2016; Masiero et al., 2018; Rolfe et al., 2000; Tallis and Polasky, 2009; TEEB Foundations, 2010). Studies have shown that society is commonly willing to pay to support biodiversity and conservation (Bartkowski et al., 2015; Christie et al., 2006; Czajkowski et al., 2009; Nijkamp et al., 2008). Identifying the determinants and motivations behind preferences for biodiversity conservation is important for retaining and building public support for conservation. Evidence already exists showing that the level of support varies according to individuals' demographic and socioeconomic characteristics (such as gender, age, level of education and income), institutional determinants (e.g. law, cultural traditions), home-site factors (location, neighbourhood, environmental conditions), or even personal traits (Ceríaco, 2012; Martín-López et al., 2007; Ressurreição et al., 2012; Soliño and Farizo, 2014). However, the interplay between preferences toward biodiversity conservation, the delivery of different ecosystems goods and services, and how these are represented by different biodiversity indicators is not well understood (Albert et al., 2016; Graves et al., 2017; Lindemann-Matthies et al., 2010). Recent ecological research has highlighted the complex relationship between biodiversity and ecosystem services (Balvanera et al., 2013; Birkhofer et al., 2018; Cardinale et al., 2012; Gamfeldt et al., 2015; Lefcheck et al., 2015) but there has been little work on how indicators relating to biodiversity and/or ecosystem services are perceived and understood. Untangling the biodiversity-ecosystem service-indicator relationship is therefore important to advance our understanding of societal preferences and support for biodiversity conservation.

The role of the biodiversity in delivering ecosystem goods and services is context-dependent (Duncan et al., 2015; Hein et al., 2006; Ricketts et al., 2016) and the relationship is influenced by a number of factors including the composition, structure and function of the ecosystem. As a consequence of this complexity, there is a general consensus that no single indicator catches all the dimensions of biodiversity (Bartkowski et al., 2015; Gao et al., 2015; Pereira et al., 2013). There are a long array of indicators available to measure biodiversity, and many different approaches to measure the relationships between biodiversity and ecosystem services. There is also a settle statement saying that biodiversity plays any different roles which make it difficult to assign into provisioning, regulating and cultural services (Mace et al., 2012; Millennium Ecosystem Assessment, 2005). In forest systems, for example, species richness is generally positively linked to timber production (provisioning services) and pollination (regulation services), whereas habitat area is more important in relation to water flow regulation and water purification (regulation services) (Harrison et al., 2014). What is more the relationships between biodiversity and ecosystem service delivery are varied and frequently non-linear (Cardinale et al., 2012, 2006).

In this paper, a discrete choice experiment is conducted to understand how preferences regarding regulating, cultural and provisioning services in Spanish pine forests are associated with, and captured by biodiversity indicators. Specifically, we seek to quantify how different perceptions of ecosystem services – embedded in specific biodiversity attributes - influence societal support towards biodiversity conservation. The use of a discrete choice experiment allows us to investigate preferences across several biodiversity indicators, whilst obtaining a detailed understanding of the relative importance of different attributes (Garnett et al., 2018; Hanley et al., 2001; Shoyama et al., 2013). The results of the study contribute to our understanding of determinants of willingness to pay for biodiversity conservation and the choice of indicators to maximize the possibilities of funding for environmental management programmes, and have implications for the design of economic valuation studies focusing on preferences for biodiversity and ecosystem services.

2. Material and methods

2.1 Case study system

Pine forests are widely distributed along all the Spanish Iberian Peninsula (Figure 1) and provide a good example of multifunctional Mediterranean forests. In this sense, wood (e.g. timber, firewood, and other wood-based products) and non-wood forest products (e.g. pine nuts, fruits, hiking, hunting, landscape and biodiversity) are economically relevant throughout the region (Campos et al., 2017; Caparrós et al., 2001; Quintas-Soriano et al., 2016). As well as being of value in itself, biodiversity plays an important role in the maintenance and delivery of these goods and services from the pine forests, and the conservation of biodiversity is therefore an essential part of any sustainable management programme for the forests.

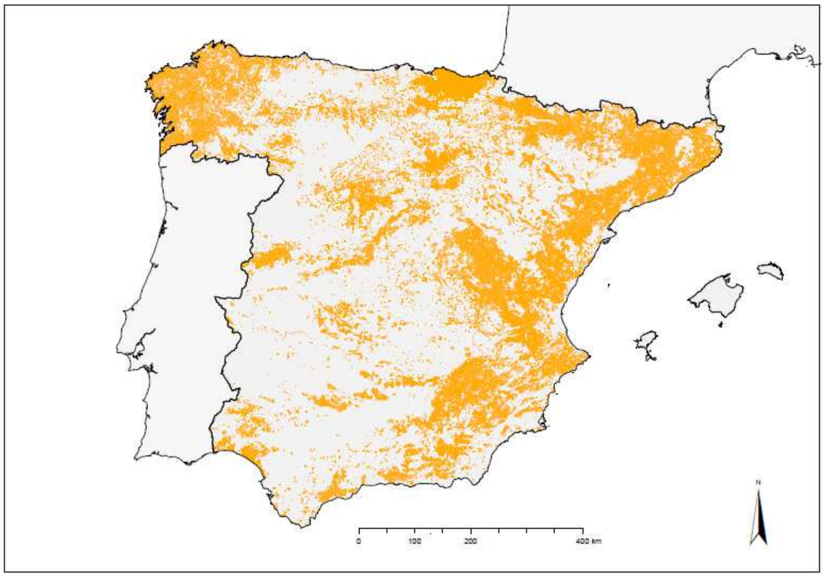

Figure 1. *Pinus* spp. distribution (in orange) in the Spanish Iberian Peninsula. Source: Spanish Forest Map

2.2 Categorisation of ecosystem services

The range of roles played by biodiversity in ecosystems makes it difficult to assign it to a specific ecosystem service category (Mace et al., 2012; Maes et al., 2016; Millennium Ecosystem Assessment, 2005). It contributes to provisioning services such as medicines, wood, firewood, trophy, meat and fruits, cultural services such as landscape, recreation, heritage, education, knowledge and research, and regulating services such as water regulation, climate regulation, seed transportation, pollination and pest regulation. Because of this underpinning role, some previous studies have considered biodiversity as a supporting ecosystem services, which are those services necessary for the generation of the other services. In this study, we do not distinguish supporting services as a separate category, since we consider, as other authors (e.g. Ojea et al., 2012; Costanza et al., 2017), that they are embedded in the other three ecosystem service categories (provisioning, regulating and cultural) and because differences between ecosystem functions and ecosystem services can be difficult to understand by citizens.

2.3 Survey and choice experiment

We conducted an on-line survey of 360 Spanish citizens older than 18 years from a stratified consumers' panel attending to rural-urban areas, age and gender. The questionnaire included a discrete choice experiment to elicit preferences among different biodiversity indicators frequently used in the literature (see Bartkowski et al., 2015; Czajkowski et al., 2009; Feld et al., 2009 for a review). Biodiversity indicators were defined at three levels of organization following the definition adopted by the Parties to the Convention on Biological Diversity (within species, between species, and within ecosystems), and we used two indicators for each level of organization. Table 1 explains these biodiversity indicators and how they were quantified. Effects coding (Bech and Gyrd□Hansen, 2005) was used for the qualitative variables relating to genetic variation (GEN), population structure (POPSTR) and keystone elements (KEY). Biodiversity indicators were presented to respondents using graphical aids, including images of mammals, birds, and plants to avoid taxon bias (Ressurreição et al., 2012). In order to avoid yea-saying bias (Blamey et al., 1999), flag and endangered species were not considered.

Level of biodiversity	Biodiversity indicators	Quantification
Within species	*Genetic variation (GEN):* Associated with adaptability of species to changes in the ecosystem.	Effect code: takes value of -1 or 1 Genetic diversity not controlled (GEN=-1). Control measures are established to maintain genetic diversity (GEN=1).
Within species	*Population structure (POPSTR):* Age and sex structure for each species.	Effect code: takes value of -1 or 1 Populations not balanced (POPSTR=-1); Measures in place to ensure that the populations are balanced (POPSTR=1).
Between species	*Number of native species (NNS):* Number of native birds in the pine forests, based on estimates from (Martínez-Jauregui et al., 2016).	Takes value of 24, 25 or 26: 24 native bird species (NNS=24). 25 native bird species (NNS=25). 26 native bird species (NNS=26).
Between species	*Number of invasive alien species (NIAS):* Negative biodiversity indicator because invasive alien species commonly have negative effects on native species. Numbers and impacts of control programmes based on Martínez-Jauregui et al. (2018) estimates.	Takes value of 2, 1 or 0: There is no programme in place for controlling invasive alien species. Two invasive alien species in the forest (NIAS=2). A programme is in place that controls some invasive alien species. One invasive alien species present (NIAS=1) A programme is in place that controls all the invasive alien species. No invasive alien species present (NIAS=0).
Within ecosystem	*Keystone elements (KEY):* Relates to the presence of ecosystem functions and habitat in a suitable condition to support many species in the pine forest.	Effect code: takes value of -1 or 1 There are no measures in place to preserve the keystone elements of the pine forest (KEY=-1). There are measures in place to preserve the keystone elements of the pine forest (KEY=1).
Within ecosystem	*Area involved in the programme (EXT):* Spatial extent enhances biodiversity in an area.	Three values based on the percentage of the territory to be preserved: 1% of the pine forests prioritized for biodiversity conservation, corresponding approximately to the area of National Parks in Spain (EXT=1). 21% of the pine forests prioritized for conservation, corresponding approximately to the Red Natura 2000 area (EXT=21). 100% of the pine forests prioritized for conservation (EXT=100).

Table 1. Attributes and levels used to describe biodiversity

The questionnaire was tested in a pilot survey of 40 people chosen at random from an internet panel of consumers considering the whole Spanish population in the Iberian Peninsula. This pilot was used to obtain the priors for the experimental design. Moreover, we tested the number of choice cards that an individual could complete without showing effects of fatigue. As a result of this, 12 choice cards were shown to each individual in the final version of the questionnaire. Choice cards comprised three alternative programmes and an opt-out option explaining the predicted consequences of the no-intervention alternative (with no additional costs for the individual). The most widely used criterion (i.e. D-Efficiency) to generate efficient designs in previous literature was considered in order to perform our experimental design (Olsen and Meyerhoff, 2016). The experimental design was performed using the Ngene® 1.1.2. software. The resulting D-error took a value of 0.0146.

We used a random parameters logit (RPL) model to analyze the discrete choice data. Other econometric approaches (e.g. latent class models, multilevel models, etc.) are available to analyze discrete choice data, but RPL is the most currently used (Train, 2009). The individual's *i* indirect utility function (V_i) can be represented as $V_{ij} = \alpha_j + S_{ij}\overline{\beta} + S_{ij}\theta_i + \varepsilon_{ij}$, where α_j is an alternative specific constant (ASC) reflecting the choice of the status quo , S_{ij} is the attributes vector (Table 1), $\overline{\beta}$ represents the population mean preference values, θ_i represents the deviations in means, and ε_{ij} is an *i.i.d.* type I extreme value random component of utility. Coefficients vary in the population with density $f(\beta|\Omega)$, with Ω denoting the parameters of density. In the analysis, a panel data structure is assumed, i.e. decision heuristics are common for the 12 choices of each individual. Thus, the probability of individual *i*'s choices [$y_1, y_2,...,y_T$] is calculated by solving the integral:

$$P_i[y_1, y_2, ..., y_T] = \int ... \int \prod_{t=1}^{T} \left[\frac{e^{\mu(\alpha_j + S_{ij}\beta_i)}}{\sum_{k=1}^{J} e^{\mu(\alpha_k + S_{ik}\beta_i)}} \right] f(\beta \mid \Omega) d\beta$$

where *j* is the alternative chosen in choice occasion *t* and μ is a scale parameter.

Following the discrete choice experiment, the questionnaire gathered each respondent's perceptions concerning the main ecosystem services provided by the six biodiversity indicators (question showed in Figure 2).

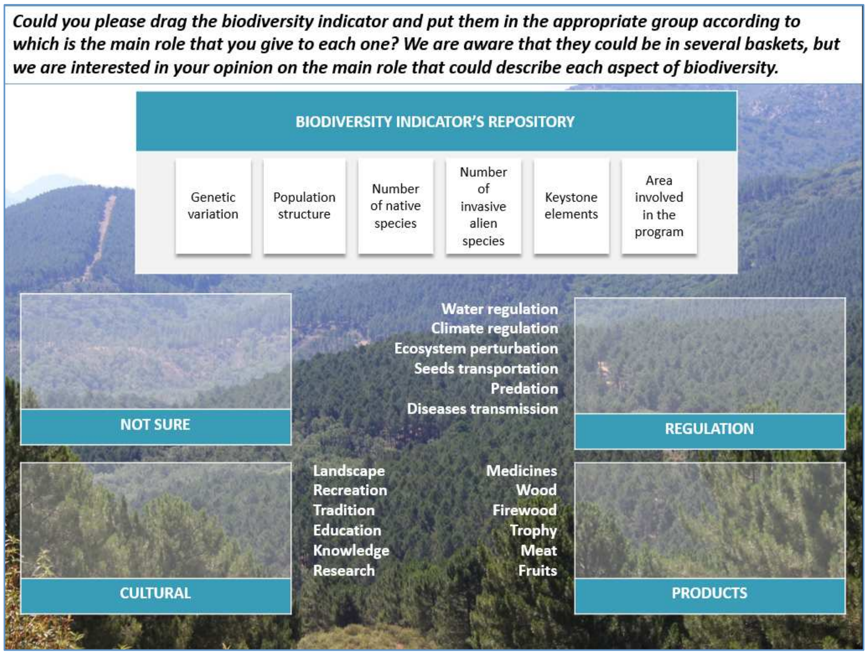

Figure 2. Question that gathers the respondents' perceptions of the relationship between the biodiversity indicators and the ecosystem goods and services represented

Two choice models with normally distributed random parameters were estimated using the Nlogit® 6.0 software. The first model (Model 1 in Table 2) considered only the biodiversity indicators. The second model (Model 2 in Table 2) also included the associations identified by the respondents between the biodiversity indicators and ecosystem services.

3. Results

3.1. Association between biodiversity attributes and ecosystem services

Regulation was the main ecosystem service associated with biodiversity by the respondents. The percentage of respondents that associated different indicators with regulating ecosystem services varied between 48.6% (for number of invasive alien species, *NIAS*) to 28.1% (keystone elements, *KEY*), with a mean value of 38.7% across the different indicators. Nearly one third of respondents linked cultural ecosystem services to the biodiversity indicators (29.9% average across all indicators), with the number of native species (*NNS*) being most frequently (41.4%) associated with cultural ecosystem services. Only 16.0% of respondents linked the indicators to provisioning ecosystem services, with keystone species (*KEY*) being the most frequently linked indicator to this ecosystem service (30.3%). Less than ten percent (7.8%) of respondents considered the main role of all six biodiversity indicators as regulating ecosystem services, 3.0% considered the main role of them all as cultural and 0.3% considered the main role of them all to be products (Figure 3). Around a third of participants classified the main role of biodiversity indicators as either regulation or culture (33.8%), and 31.1% divided the six biodiversity indicators across the three ecosystem service categories. Note that as an opt-out option ("Not sure") was always available to be chosen by the individuals (only three individuals chose always "Not sure"); therefore not all percentages add to 100%.

An analysis of biodiversity indicators by levels of organization (within species, between species and within ecosystem) was performed. At the within-ecosystem level, the associations of biodiversity indicators (*KEY* and the area involved in the programme, *EXT*) were evenly distributed among the three ecosystem service roles. The two biodiversity indicators at the between-species level (*NNS, NIAS*) showed the most uneven distribution of ecosystem service roles, although regulation was the most frequently associated role for both indicators. *NIAS* was the biodiversity indicator that resulted in the greatest uncertainty among participants (31.4% of the respondents were 'not sure' which group of ecosystem services it was most associated with). *NNS* was linked in a similar manner to both cultural and regulating ecosystem services (41.4% of respondents for both cases). Finally in the within species level, both indicators (genetic variation, *GEN,* and population structure, *POPSTR*) showed a similar pattern but with a more relatively even distribution among the three ecosystem service roles, but still having the lowest proportion of respondents associating them with provisioning ecosystem services than with the other ecosystem services.

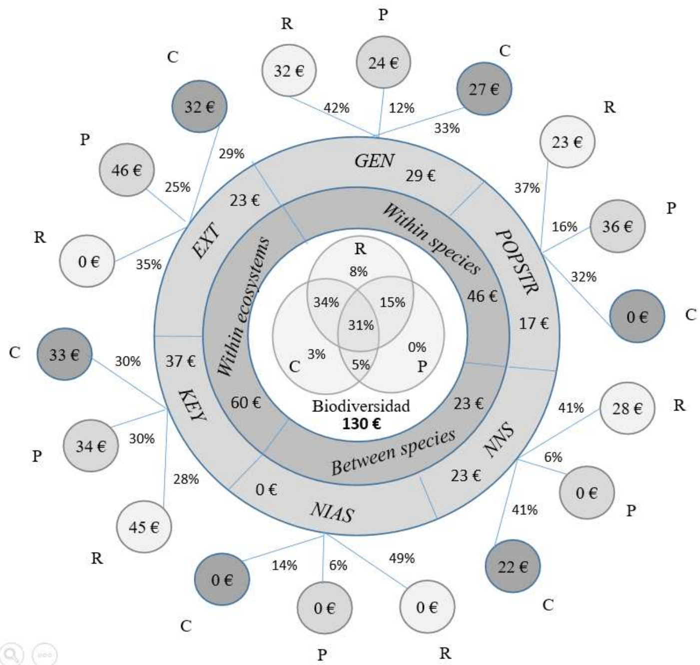

Figure 3 Main ecosystem services roles associated with each biodiversity indicator (percentage of respondents) and marginal willingness to pay of an intermedium change (GEN controlled, POPSTR balanced, NNS: 26 bird species; NIAS: 2 invasive alien species, KEY: keystone elements preserved, EXT: 21% of the pine forests) resulting from the model where the respondents' association between the biodiversity indicators and their main ecosystem services role are considered. Differences between percentages shown and 100% for each indicator correspond to the "Not sure" option. Abbreviations used: Genetic diversity: GEN, Population structure: POPSTR, Number of native species: NNS, Number of invasive alien species: NIAS, Keystone elements: KEY, Area involved in the programme: EXT; R: regulation ecosystem service; P: Provisioning ecosystem service; C: cultural ecosystem service).

3.2. Relationships between ecosystem services and biodiversity indicators

Table 2 presents results of the random parameter logit models fitted to the data. In the models, the alternative specific constant (ASC) represents the status quo predisposition of people, i.e., the preferences for the no-intervention option (dummy variable where 1 denotes the choice of the status quo alternative). Its negative estimated coefficient shows that people are willing to pay (WTP) for the implementation of a conservation program in Spanish pine forest ecosystems. Without taking into account perceptions of the links between biodiversity indicators and ecosystem services (Model 1), keystone elements and population structure were the most valued biodiversity indicators, whereas the number of invasive species was not a significant determinant of WTP (Table 2). When perceived links with ecosystem services were taken into account in the model, single biodiversity indicators were no longer significant (Model 2 in Table 2). The only statistically significant determinants of WTP for biodiversity conservation in Model 2 were the interactions between biodiversity indicators and the main ecosystem service role perceived by individuals. Thus, preferences for the conservation programmes are strongly influenced by the interaction between biodiversity and its perceived main ecosystem service role. This means that the influence of biodiversity indicators on individuals' WTP is different depending on which ecosystem services are associated with those indicators.

Table 3 shows the individual marginal willingness to pay and Figure 3 shows a marginal WTP of an intermedium change resulting from the model where the respondents' associations between the biodiversity indicators and ecosystem services were considered (Model 2). Of the biodiversity indicators, we found that only genetic diversity (*GEN*) and keystone elements (*KEY*) were consistently significant positively determinants of WTP (alpha of significance = 0.05) regardless of the main ecosystem service they were associated with by respondents, although in both cases, marginal WTP were larger when regulation was the main perceived role of the indicator. The area involved in the programme (*EXT*) was a statistically significant determinant of WTP when provisioning was identified as the main associated ecosystem service. Population structure (*POPSTR*) was weakly significant (alpha = 0.01) when respondents assigned it a regulation or provisioning ecosystem service role, with stronger effects on WTP when provisioning was perceived as its main role. With regard to the between species indicators, *NIAS* was again not statistically significant (in this case for any of the ecosystem service categories). Number of native species (*NNS*) was a significant determinant of WTP when regulation or cultural were the main associated ecosystem services, with stronger evidence when regulation was the main role.

	Coefficient	Standard Error	t-ratio	*Std.Devs of normally distributed RPs.* Coefficient	Standard Error	t-ratio
MODEL1						
GEN	0.104***	0.025	4.15	0.241***	0.037	6.53
POPSTR	0.219***	0.035	6.24	0.436***	0.035	12.29
NNS	0.069**	0.0314	2.19	0.361***	0.040	9.01
NIAS	0.020	0.038	0.52	0.551***	0.041	13.49
KEY	0.258***	0.032	8.03	0.396***	0.035	11.21
EXT	0.038***	0.005	8.05	0.014***	0.001	10.63
EXT2	-0.290×10^{-3}***	0.435×10^{-4}	-6.60	0.475×10^{-4}*	0.251×10^{-4}	1.89
ASC	-0.160*	0.096	-1.66	Fixed		
TAX	-0.017***	0.001	-13.78	Fixed		
MODEL 2						
GEN	-0.104	0.065	-1.590	0.191***	0.041	4.670
POPSTR	0.063	0.090	0.700	0.430***	0.032	13.280
NNS	-0.103	0.092	-1.130	0.346***	0.037	9.350
NIAS	0.056	0.066	0.850	0.542***	0.041	13.150
KEY	-0.018	0.083	-0.220	0.328***	0.037	8.940
EXT	0.013	0.012	1.110	0.013***	0.002	5.220
EXT2	0.000	0.000	-1.550	0.595×10^{-4}*	0.340×10^{-4}	1.750
ASC	-0.165*	0.096	-1.720	Fixed		
TAX	-0.017***	0.001	-13.700	Fixed		
Interactions within Biodiversity indicators and classification of Ecosystem Services:						
GEN:RE	0.265***	0.072	3.670			
GEN:PR	0.202**	0.089	2.270			
GEN:CU	0.223***	0.074	3.010			
POPSTR:RE	0.192*	0.102	1.880			
POPSTR:PR	0.301**	0.119	2.530			
POPSTR:CU	0.171	0.104	1.640			
NNS:RE	0.232**	0.101	2.300			
NNS:PR	0.100	0.149	0.670			
NNS:CU	0.186*	0.101	1.850			
NIAS:RE	-0.082	0.082	-1.010			
NIAS:PR	0.100	0.158	0.630			
NIAS:CU	-0.012	0.116	-0.100			
KEY:RE	0.372***	0.096	3.890			
KEY:PR	0.281***	0.094	2.980			
KEY:CU	0.277***	0.094	2.950			
EXT:RE	0.019	0.013	1.450			
EXT:PR	0.041***	0.014	2.940			
EXT:CU	0.025*	0.013	1.880			
EXT2:RE	-0.495×10^{-4}	0.000	-0.400			
EXT2:PR	-0.0002*	0.000	-1.770			
EXT2:CU	-0.00013	0.000	-1.030			

Table 2 Results of the random parameter logit models (Panel data with 360 individuals and 12 choices per individual; Replications for simulated probabilities = 500; Halton sequences in simulations; significance at 1% level; ** significance at 5% level, ** significance at 10% level). Abbreviations used: Genetic diversity, GEN; Population structure, POPSTR; Number of native species, NNS; Number of invasive alien species, NIAS; Keystone elements, KEY; Area involved in the program, EXT, EXT2 (quadratic relationship); Alternative specific constant, ASC; Increment of taxes, TAX; Regulation, RE; Provisioning, PR; Cultural, CU).

		mWTP	**Standard Error**	**t-ratio**	**95% Confidence Interval**	
GEN						
	Regulation	31.831***	8.940	3.56	14.3092	49.3520
	Provisioning	24.251**	10.815	2.24	3.0534	45.4477
	Cultural	26.817***	9.102	2.95	8.9779	44.6554
POPSTR						
	Regulation	23.062*	12.381	1.86	-1.2050	47.3283
	Provisioning	36.127**	14.491	2.49	7.7257	64.5288
	Cultural	20.505	12.577	1.63	-4.1453	45.1559
NNS						
	Regulation	13.925**	6.126	2.27	1.9178	25.9322
	Provisioning	5.984	8.941	0.67	-11.54074	23.50833
	Cultural	11.185*	6.099	1.83	-0.7694	23.1390
NIAS						
	Regulation	-4.945	4.924	-1.00	-14.59731	4.70659
	Provisioning	5.982	9.481	0.63	-12.60072	24.56559
	Cultural	-0.709	6.977	-0.10	-14.38479	12.96653
KEY						
	Regulation	44.698***	11.882	3.76	21.4100	67.9854
	Provisioning	33.758***	11.558	2.92	11.1042	56.4128
	Cultural	33.247***	11.511	2.89	10.6853	55.8088
EXT						
	Regulation	1.151	0.797	1.44	-0.41158	2.71468
	Provisioning	2.470***	0.863	2.86	0.77879	4.16101
	Cultural	1.523*	0.818	1.86	-0.08075	3.12693
EXT2						
	Regulation	-0.003	0.007	0-.40	-0.01745	0.01151
	Provisioning	-0.014*	0.008	-1.75	-0.02925	0.00164
	Cultural	-0.008	0.008	-1.03	-0.02260	0.00705

Table 3 Marginal willingness to pay (mWTP) estimated from Model 2. Abbreviations used: Genetic diversity, GEN; Population structure, POPSTR; Number of native species, NNS; Number of invasive alien species, NIAS; Keystone elements, KEY; Area involved in the program, EXT, EXT2 (quadratic relationship).

4. Discussion

People usually show a positive willingness to pay for preserving biodiversity (see for example Bartkowski et al., 2015 for a review of valuation studies on biodiversity, or Varela et al., 2018 for an application). The novelty of this paper lies in showing how the perceived role of biodiversity in delivering ecosystem services is a key determinant of the respondents' support for conservation. This study was done in context of pine forest in Spain. In other habitats and other environmental and socio-economic contexts, patterns of preferences towards biodiversity indicators and their associations with ecosystem services may vary. When interpreting our results, some limitations should be borne in mind. For example, participants in online surveys usually have different characteristics from the average population, such as a higher level of education and under-representation of higher age groups, but it is not clear if these differences constitute a selection bias (Lindhjem and Navrud, 2011). Some other biases can arise when applying discrete choice experiments, such as cheap talk, hypothetical bias and non-attendance (Ladenburg and Olsen, 2014; Varela et al., 2014; Loomis, 2011; Hensher and Rose, 2009; Scarpa et al., 2009). Controlling for all of these biases is complex, and every application focuses on the more possible biases affecting their results. In this case study, we played special attention to the sample selection and used a stratified strategy in order to account for the disparities between rural and urban areas. Taking into account previous results from literature and consultations with experts, we also considered the yea-saying bias and avoided the use of flag and endangered species as visual references for the biodiversity indicators.

However, the key finding of our work is likely to be generally applicable. We have shown that certain associations between biodiversity and ecosystem services (e.g. the association between the number of native bird species and provisioning ecosystem services, small game hunting meat for example) are not generally considered important. We also found that the number of alien invasive species was not a good determinant of WTP (i.e. it was never statistically significant), meaning that invasive species do not affect the preferences of the sampled population. But more research is necessary in this regard, since one would expect invasive species to have a negative effect on wellbeing. We asked respondents to make their choices within a context of six biodiversity attributes; context can alter the process by which choices are made and hence shift the choice outcomes (Thomadsen et al., 2018). In our case study, dealing with the complex concept of biodiversity, the configuration of the biodiversity indicators could be interpreted as the key elements of the choice context. Therefore, different strategies of experimental design and selection of attributes could potentially lead to different choice outcomes. In addition, the lack of significance among invasive species and any of the functional roles of biodiversity is perhaps indicative of a lack of knowledge of the real impacts of invasive species, which are severe, both locally and globally (García-Llorente et al., 2008; Pyšek et al., 2010). It would be expected that the number of invasive species would be a more important determinant of WTP in other parts of the world or ecosystems where the impact of invasive species is more generally recognized. In Spain, pine forests are frequently associated with managed landscapes and plantations rather than pristine landscapes, and this may have affected the relative importance of invasive species as well as the preferences for different types of ecosystem services. In line with previous experience in environmental accounting (Campos et al., 2019), biodiversity was mostly associated with regulating services, although the interpretation of this link is not straightforward since there are many different pine species and forests systems. For example, there are pine forests managed for the production of timber (provisioning services) and other pine forests that are managed with the main aim of restoration (to protect soil and water resources and the regulating services they provide, as well as biodiversity). The majority of the biodiversity indicators were statistically significant in their interaction with ecosystem services, but these relationships were strongest for regulating services. One possible explanation of this result is that regulating services could be linked to the future of biodiversity and sustainability, i.e. respondents may have been expressing their option and existence values. In our findings, cultural services was the second ecosystem service in order of relevance and provisioning services were associated least frequently with biodiversity indicators.

These results show clearly that the relationship between biodiversity indicators and ecosystem services should be considered when discussing biodiversity indicators to maximize the social support for management programmes. Previous literature already reflects that the selection of a single biodiversity indicator can be insufficient to capture all aspects of biodiversity or biodiversity conservation programmes (Bartkowski et al., 2015; Czajkowski et al., 2009; Gao et al., 2015). Our results show that the choice of indicators can be important socially and culturally, as well as ecologically, since the choice of indicator used can significantly influence people's preferences.

Biodiversity indicators are commonly monitored to ensure the sustainable management of the territory and the preservation of multiple goods and services. For example, for a programme focusing on biodiversity conservation across a large area of land, in order to maximize public support, it may be most appropriate to select an indicator which represents biodiversity in an holistic way, taking into account the composition, structure, and functionality of biodiversity. In the case of Spanish pine forests, the best biodiversity indicator in this regard would be keystone elements because it is associated in a diverse and balanced way with all the roles of ecosystem services (lowest deviation) and because it remains a statistically significant determinant of WTP in all of its roles.

Management programmes focusing on sustainable production, such as sustainable forestry, would be best served by biodiversity indicators relating to extent of habitat, population structure, genetic diversity, and keystone elements, rather than the numbers of native or non-native invasive species, since the former indicators all showed a significant association with provisioning ecosystem services. On the other hand, if the aim of a conservation programme is more related to cultural and regulating services (such as National Parks) then our results suggest that the number of native species would be the best single indicator. The number of native species is widely used as a biodiversity indicator (Bartkowski et al., 2015; Feld et al., 2009; Gao et al., 2015), and is perhaps one of the most readily understood measures. However, the fact that our results showed no significant effect of the association between the number of native species and provisioning ecosystem services suggests that the role of biodiversity in supporting production through pollination and other services such as soil quality regulation and water availability is not widely known and valued.

5. Conclusions

Our work has demonstrated that the choice of biodiversity indicators for management programmes needs to be considered carefully according to their objectives. Previous literature has shown that certain indicators are more meaningful in an ecological sense. Our results have shown that, in order to maximize public support for conservation management, the choice of indicators should also take into account social considerations, specifically an understanding of how the public perceives associations between biodiversity and ecosystem services. As well as being important for management programmes in practice, our results also have implications for environmental valuation studies of biodiversity, since they demonstrate that failure to incorporate an understanding of public associations of biodiversity may lead to erroneous results. Programmes seeking to maximize the funding towards nature conservation and incentivize donations must therefore be based on a more rigorous understanding of the preferences towards biodiversity and ecosystem services.

Acknowledgments

This study is framed within the project INIA ref. RTA2013-00048-C03-01 funded by the Spanish Ministry of Economy and Competitiveness. We thank Jesús de Miguel for his inputs on the graphical design of the choice experiment. We also thank two anonymous reviewers for their helpful comments and suggestions.

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