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1 **Untangling perceptions around indicators for biodiversity**

2 **conservation and ecosystem services**

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11
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13 **ABSTRACT**

14 Biodiversity indicators are commonly monitored to ensure the sustainable management of
15 ecosystems and the conservation of multiple ecosystem goods and services. Indicators are important
16 for tracking the ecological outcomes of conservation programmes, but they are also important in a
17 wider context such as monitoring progress towards broader sustainability goals and serving to
18 generate public support and funding for these programmes. Little attention is usually given to the
19 social and cultural dimensions of biodiversity indicators. In this paper, using a discrete choice
20 experiment, we compare the impact of within-species, between-species and within-ecosystem level
21 biodiversity indicators on public preferences for conservation programmes in Spanish pine forests.
22 Specifically we show that preferences towards conservation programmes are significantly affected
23 by the interaction between indicators and their perceived role in delivering ecosystem services.
24 Genetic variation, the number of invasive species and keystone elements were associated equally
25 frequently with provisioning, regulating and cultural ecosystem services, whereas population
26 structure, the number of native species and the area of land conserved were more variable in how
27 they were associated with different ecosystem services. Our results highlight the importance of
28 considering the perceived social relevance of indicators alongside their ecological suitability in the
29 design of conservation programmes and monitoring.
30

31 **HIGHLIGHTS:**

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

36 **KEYWORDS:** Ecosystem-based management; Forest conservation; Forest management; Choice experiment;
37 Biodiversity indicators; Public perception.
38

39 **1. Introduction**

40

41 Understanding public preferences concerning biodiversity, ecosystem goods and services is
42 important for managing ecosystems, since the implementation and effectiveness of management
43 interventions frequently depend on support from society (Hirsch et al., 2011; Mace, 2014; Martín-
44 López and Montes, 2015). Biodiversity indicators are used as a measure of success of specific
45 conservation programmes, and as part of monitoring progress towards the Sustainable Development
46 Goals (Chaudhary et al., 2018; Khoury et al., 2019; Reyers et al., 2017). More broadly, they provide
47 information on the sustainable use of ecosystems and the preservation of multiple goods and
48 services (Failing and Gregory, 2003), and can be used to infer the resilience of ecosystems and
49 human wellbeing in the face of global environmental changes (Butchart et al., 2010; Millar et al.,
50 2007). They can also be used to inform options for future benefits from ecosystems beyond those
51 currently experienced (Austin et al., 2016; Cardinale et al., 2012; Harrison et al., 2014; Mace et al.,
52 2012). However, determining the biodiversity indicators best-suited for these different roles is not
53 straightforward. Indicators need to be clearly linked in an objective manner to the ecological
54 phenomena they are intended to represent, but the increasingly socio-economic dimensions of their
55 applications also require that they align with the local values and preferences of stakeholders
56 and that their meaning to society is understood (Díaz et al., 2018; Heink and Kowarik, 2010; Mace
57 and Baillie, 2007). Analysis of how reliably a specific biodiversity indicator represents the potential
58 supply of ecosystem services therefore provides only partial information (Tallis et al., 2012). The
59 process of making conservation decisions also requires *a priori* information on how the indicator is
60 perceived as a social metric capturing the ‘use’ of these ecosystem services for well-being (Aslan et
61 al., 2018; Martínez-Harms et al., 2015, p.; Wolff et al., 2015), so that project outcomes can be
62 understood and shared, enhancing communication across stakeholders and building trust across
63 policy makers, researchers, practitioners and local communities (Goggin et al., 2019).

64

Julia María Touza Montero 4/2/19 11:43
Comment [1]: I have included the full reference
of this paper in a comment below.

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

70

71 We examine public preferences regarding indicators and ecosystem services using economic
72 valuation, which is a common approach to valuing natural and common goods. There is a range of
73 frameworks and approaches (e.g. participatory, expert-based, or process-based approaches) that can
74 be used to understand people's support for conservation projects, and some of these integrate both
75 ecological and social values (e.g. Ban et al., 2013; Whitehead et al., 2014; Wolff et al., 2015).
76 However, economic valuation has some specific advantages because it links expressed preferences
77 to behaviour or experience towards goods and services, and consequently willingness to conserve,
78 which can be compared to the costs of project implementation and the opportunity costs of
79 conservation. Moreover it allows different contributing factors towards preferences to be compared
80 in a quantified manner. Consequently, economic valuation and in particular stated preference
81 methods (Bateman et al., 2002; Johnston et al., 2017) have been used frequently for quantifying
82 social preferences as a measure of support for environmental management programmes (Balmford
83 et al., 2011; De Groot et al., 2012; Giergiczny et al., 2015; Kenter et al., 2016; Masiero et al., 2018;
84 Rolfe et al., 2000; Tallis and Polasky, 2009; TEEB Foundations, 2010). Studies have shown that
85 society is commonly willing to pay to support biodiversity and conservation (Bartkowski et al.,
86 2015; Christie et al., 2006; Czajkowski et al., 2009; Nijkamp et al., 2008). Identifying the
87 determinants and motivations behind preferences for biodiversity conservation is important for
88 retaining and building public support for conservation. Evidence already exists showing that the
89 level of support varies according to individuals' demographic and socioeconomic characteristics
90 (such as gender, age, level of education and income), institutional determinants (e.g. law, cultural

91 traditions), home-site factors (location, neighbourhood, environmental conditions), or even personal
92 traits (Ceriaco, 2012; Martín-López et al., 2007; Ressurreição et al., 2012; Soliño and Farizo, 2014).
93 However, the interplay between preferences toward biodiversity conservation, the delivery of
94 different ecosystems goods and services, and how these are represented by different biodiversity
95 indicators is not well understood (Albert et al., 2016; Graves et al., 2017; Lindemann-Matthies et
96 al., 2010). Recent ecological research has highlighted the complex relationship between biodiversity
97 and ecosystem services (Balvanera et al., 2013; Birkhofer et al., 2018; Cardinale et al., 2012;
98 Gamfeldt et al., 2015; Lefcheck et al., 2015) but there has been little work on how indicators
99 relating to biodiversity and/or ecosystem services are perceived and understood. Untangling the
100 biodiversity-ecosystem service-indicator relationship is therefore important to advance our
101 understanding of societal preferences and support for biodiversity conservation.

102

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

117

118 In this paper, a discrete choice experiment is conducted to understand how preferences regarding
119 regulating, cultural and provisioning services in Spanish pine forests are associated with, and
120 captured by biodiversity indicators. Specifically, we seek to quantify how different perceptions of
121 ecosystem services – embedded in specific biodiversity attributes - influence societal support
122 towards biodiversity conservation. The use of a discrete choice experiment allows us to investigate
123 preferences across several biodiversity indicators, whilst obtaining a detailed understanding of the
124 relative importance of different attributes (Garnett et al., 2018; Hanley et al., 2001; Shoyama et al.,
125 2013). The results of the study contribute to our understanding of determinants of willingness to pay
126 for biodiversity conservation and the choice of indicators to maximize the possibilities of funding
127 for environmental management programmes, and have implications for the design of economic
128 valuation studies focusing on preferences for biodiversity and ecosystem services.

129

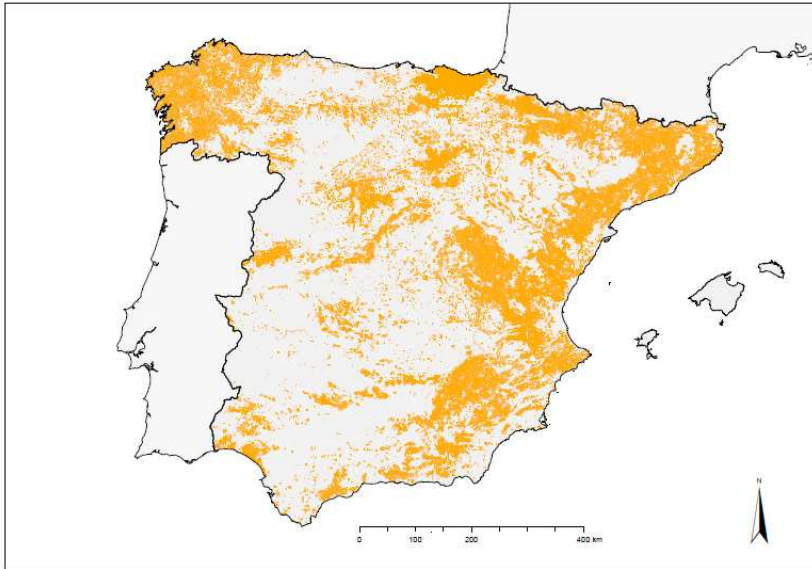
130 **2. Material and methods**

131

132 *2.1 Case study system*

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

141



142
 143 Figure 1. *Pinus* spp. distribution (in orange) in the Spanish Iberian Peninsula. Source: Spanish Forest Map
 144

145 2.2 Categorisation of ecosystem services

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

158

159 *2.3 Survey and choice experiment*

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

173

Level of biodiversity	Biodiversity indicators	Quantification
Within species	<i>Genetic variation (GEN)</i> : 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	<i>Population structure (POPSTR)</i> : 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	<i>Number of native species (NNS)</i> : Number of native birds in the pine forests, based on estimates from (Martinez-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	<i>Number of invasive alien species (NIAS)</i> : 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	<i>Keystone elements (KEY)</i> : 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	<i>Area involved in the programme (EXT)</i> : 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).

175 Table 1. Attributes and levels used to describe biodiversity

176

177

178

179 The questionnaire was tested in a pilot survey of 40 people chosen at random from an internet panel

180 of consumers considering the whole Spanish population in the Iberian Peninsula. This pilot was

181 used to obtain the priors for the experimental design. Moreover, we tested the number of choice

182 cards that an individual could complete without showing effects of fatigue. As a result of this, 12

183 choice cards were shown to each individual in the final version of the questionnaire. Choice cards
 184 comprised three alternative programmes and an opt-out option explaining the predicted
 185 consequences of the no-intervention alternative (with no additional costs for the individual). The
 186 most widely used criterion (i.e. D-Efficiency) to generate efficient designs in previous literature was
 187 considered in order to perform our experimental design (Olsen and Meyerhoff, 2016). The
 188 experimental design was performed using the Ngene® 1.1.2. software. The resulting D-error took a
 189 value of 0.0146.

190

191 We used a random parameters logit (RPL) model to analyze the discrete choice data. Other
 192 econometric approaches (e.g. latent class models, multilevel models, etc.) are available to analyze
 193 discrete choice data, but RPL is the most currently used (Train, 2009). The individual's i indirect
 194 utility function (V_i) can be represented as $V_{ij} = \alpha_j + S_{ij}\bar{\beta} + S_{ij}\theta_i + \varepsilon_{ij}$, where α_j is an alternative
 195 specific constant (ASC) reflecting the choice of the status quo, S_{ij} is the attributes vector (Table 1),
 196 $\bar{\beta}$ represents the population mean preference values, θ_i represents the deviations in means, and ε_{ij}
 197 is an *i.i.d.* type I extreme value random component of utility. Coefficients vary in the population
 198 with density $f(\beta|\Omega)$, with Ω denoting the parameters of density. In the analysis, a panel data
 199 structure is assumed, i.e. decision heuristics are common for the 12 choices of each individual.
 200 Thus, the probability of individual i 's choices $[y_1, y_2, \dots, y_T]$ is calculated by solving the integral:

201

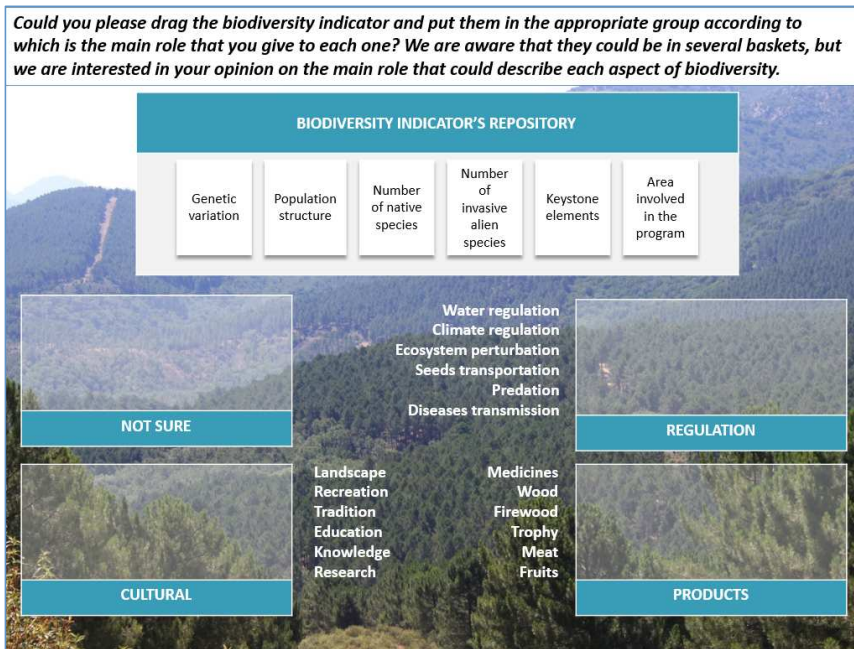
$$202 \quad P_i[y_1, y_2, \dots, y_T] = \int \dots \int \prod_{t=1}^T \left[\frac{e^{\mu(\alpha_j + S_{jt}\beta_t)}}{\sum_{k=1}^J e^{\mu(\alpha_k + S_{kt}\beta_t)}} \right] f(\beta | \Omega) d\beta$$

203

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

205

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



209
 210 Figure 2. Question that gathers the respondents' perceptions of the relationship between the biodiversity
 211 indicators and the ecosystem goods and services represented
 212

213 Two choice models with normally distributed random parameters were estimated using the Nlogit®
 214 6.0 software. The first model (Model 1 in Table 2) considered only the biodiversity indicators. The
 215 second model (Model 2 in Table 2) also included the associations identified by the respondents
 216 between the biodiversity indicators and ecosystem services.

217

218 **3. Results**

219

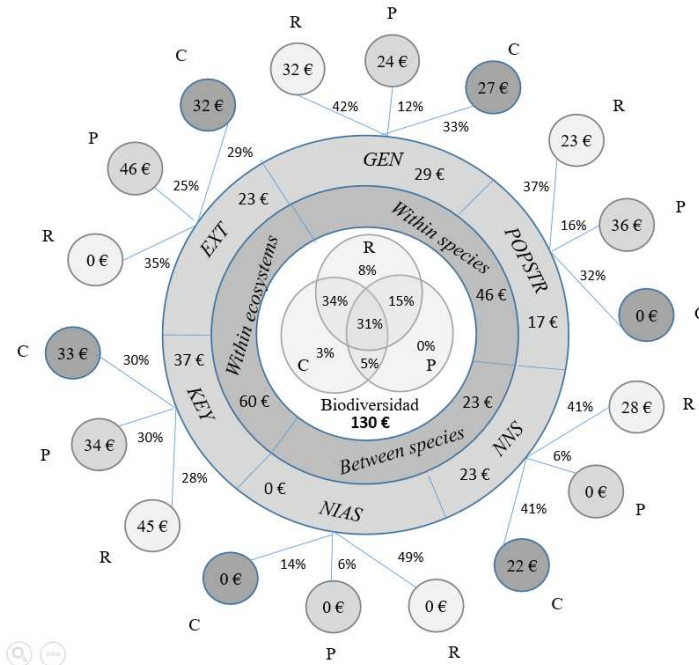
220 *3.1. Association between biodiversity attributes and ecosystem services*

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

237

238 An analysis of biodiversity indicators by levels of organization (within species, between species and
239 within ecosystem) was performed. At the within-ecosystem level, the associations of biodiversity
240 indicators (*KEY* and the area involved in the programme, *EXT*) were evenly distributed among the
241 three ecosystem service roles. The two biodiversity indicators at the between-species level (*NNS*,
242 *NIAS*) showed the most uneven distribution of ecosystem service roles, although regulation was the
243 most frequently associated role for both indicators. *NIAS* was the biodiversity indicator that resulted
244 in the greatest uncertainty among participants (31.4% of the respondents were ‘not sure’ which
245 group of ecosystem services it was most associated with). *NNS* was linked in a similar manner to
246 both cultural and regulating ecosystem services (41.4% of respondents for both cases). Finally in

247 the within species level, both indicators (genetic variation, *GEN*, and population structure,
 248 *POPSTR*) showed a similar pattern but with a more relatively even distribution among the three
 249 ecosystem service roles, but still having the lowest proportion of respondents associating them with
 250 provisioning ecosystem services than with the other ecosystem services.



251
 252 Figure 3 Main ecosystem services roles associated with each biodiversity indicator (percentage of
 253 respondents) and marginal willingness to pay of an intermedium change (GEN controlled, POPSTR balanced,
 254 NNS: 26 bird species; NIAS: 2 invasive alien species, KEY: keystone elements preserved, EXT: 21% of the
 255 pine forests) resulting from the model where the respondents' association between the biodiversity indicators
 256 and their main ecosystem services role are considered. Differences between percentages shown and 100% for
 257 each indicator correspond to the "Not sure" option. Abbreviations used: Genetic diversity: GEN, Population
 258 structure: POPSTR, Number of native species: NNS, Number of invasive alien species: NIAS, Keystone
 259 elements: KEY, Area involved in the programme: EXT; R: regulation ecosystem service; P: Provisioning
 260 ecosystem service; C: cultural ecosystem service).
 261

262 *3.2. Relationships between ecosystem services and biodiversity indicators*

263 Table 2 presents results of the random parameter logit models fitted to the data. In the models, the
 264 alternative specific constant (ASC) represents the status quo predisposition of people, i.e., the
 265 preferences for the no-intervention option (dummy variable where 1 denotes the choice of the status

266 quo alternative). Its negative estimated coefficient shows that people are willing to pay (WTP) for
267 the implementation of a conservation program in Spanish pine forest ecosystems. Without taking
268 into account perceptions of the links between biodiversity indicators and ecosystem services (Model
269 1), keystone elements and population structure were the most valued biodiversity indicators,
270 whereas the number of invasive species was not a significant determinant of WTP (Table 2). When
271 perceived links with ecosystem services were taken into account in the model, single biodiversity
272 indicators were no longer significant (Model 2 in Table 2). The only statistically significant
273 determinants of WTP for biodiversity conservation in Model 2 were the interactions between
274 biodiversity indicators and the main ecosystem service role perceived by individuals. Thus,
275 preferences for the conservation programmes are strongly influenced by the interaction between
276 biodiversity and its perceived main ecosystem service role. This means that the influence of
277 biodiversity indicators on individuals' WTP is different depending on which ecosystem services are
278 associated with those indicators.

279

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

292 statistically significant (in this case for any of the ecosystem service categories). Number of native
 293 species (*NNS*) was a significant determinant of WTP when regulation or cultural were the main
 294 associated ecosystem services, with stronger evidence when regulation was the main role.

295

	Coefficient	Standard Error	t-ratio	<i>Std.Devs of normally distributed RPs.</i>		
				Coefficient	Standard Error	t-ratio
MODEL 1						
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	-0.290x10 ⁻³ ***	0.435x10 ⁻⁴	-6.60	0.475x10 ⁻¹ *	0.251x10 ⁻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	0.595x10 ⁻⁴ *	0.340x10 ⁻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	-0.495x10 ⁻⁴	0.000	-0.400			
EXT2:PR	-0.0002*	0.000	-1.770			
EXT2:CU	-0.00013	0.000	-1.030			

296 Table 2 Results of the random parameter logit models (Panel data with 360 individuals and 12 choices per
 297 individual; Replications for simulated probabilities = 500; Halton sequences in simulations; significance at
 298 1% level; ** significance at 5% level, * significance at 10% level). Abbreviations used: Genetic diversity,
 299 GEN; Population structure, POPSTR; Number of native species, NNS; Number of invasive alien species,
 300 NIAS; Keystone elements, KEY; Area involved in the program, EXT, EXT2 (quadratic relationship);
 301 Alternative specific constant, ASC; Increment of taxes, TAX; Regulation, RE; Provisioning, PR; Cultural, CU
 302).
 303
 304
 305

		mWTP	Standard Error	t-ratio	95% Confidence Interval	
GEN	<i>Regulation</i>	31.831***	8.940	3.56	14.3092	49.3520
	<i>Provisioning</i>	24.251**	10.815	2.24	3.0534	45.4477
	<i>Cultural</i>	26.817***	9.102	2.95	8.9779	44.6554
POPSTR	<i>Regulation</i>	23.062*	12.381	1.86	-1.2050	47.3283
	<i>Provisioning</i>	36.127**	14.491	2.49	7.7257	64.5288
	<i>Cultural</i>	20.505	12.577	1.63	-4.1453	45.1559
NNS	<i>Regulation</i>	13.925**	6.126	2.27	1.9178	25.9322
	<i>Provisioning</i>	5.984	8.941	0.67	-11.54074	23.50833
	<i>Cultural</i>	11.185*	6.099	1.83	-0.7694	23.1390
NIAS	<i>Regulation</i>	-4.945	4.924	-1.00	-14.59731	4.70659
	<i>Provisioning</i>	5.982	9.481	0.63	-12.60072	24.56559
	<i>Cultural</i>	-0.709	6.977	-0.10	-14.38479	12.96653
KEY	<i>Regulation</i>	44.698***	11.882	3.76	21.4100	67.9854
	<i>Provisioning</i>	33.758***	11.558	2.92	11.1042	56.4128
	<i>Cultural</i>	33.247***	11.511	2.89	10.6853	55.8088
EXT	<i>Regulation</i>	1.151	0.797	1.44	-0.41158	2.71468
	<i>Provisioning</i>	2.470***	0.863	2.86	0.77879	4.16101
	<i>Cultural</i>	1.523*	0.818	1.86	-0.08075	3.12693
EXT2	<i>Regulation</i>	-0.003	0.007	0.40	-0.01745	0.01151
	<i>Provisioning</i>	-0.014*	0.008	-1.75	-0.02925	0.00164
	<i>Cultural</i>	-0.008	0.008	-1.03	-0.02260	0.00705

306 Table 3 Marginal willingness to pay (mWTP) estimated from Model 2. Abbreviations used: Genetic diversity,
 307 GEN; Population structure, POPSTR; Number of native species, NNS; Number of invasive alien species,
 308 NIAS; Keystone elements, KEY; Area involved in the program, EXT, EXT2 (quadratic relationship).
 309

310

311 **4. Discussion**

312

313 People usually show a positive willingness to pay for preserving biodiversity (see for example
314 Bartkowski et al., 2015 for a review of valuation studies on biodiversity, or Varela et al.,
315 2018 for an application). The novelty of this paper lies in showing how the perceived role of
316 biodiversity in delivering ecosystem services is a key determinant of the respondents' support for
317 conservation. This study was done in context of pine forest in Spain. In other habitats and other
318 environmental and socio-economic contexts, patterns of preferences towards biodiversity indicators
319 and their associations with ecosystem services may vary. When interpreting our results, some
320 limitations should be borne in mind. For example, participants in online surveys usually have
321 different characteristics from the average population, such as a higher level of education and under-
322 representation of higher age groups, but it is not clear if these differences constitute a selection bias
323 (Lindhjem and Navrud, 2011). Some other biases can arise when applying discrete choice
324 experiments, such as cheap talk, hypothetical bias and non-attendance (Ladenburg and Olsen, 2014;
325 Varela et al., 2014; Loomis, 2011; Hensher and Rose, 2009; Scarpa et al., 2009). Controlling for all
326 of these biases is complex, and every application focuses on the more possible biases affecting their
327 results. In this case study, we played special attention to the sample selection and used a stratified
328 strategy in order to account for the disparities between rural and urban areas. Taking into account
329 previous results from literature and consultations with experts, we also considered the yea-saying
330 bias and avoided the use of flag and endangered species as visual references for the biodiversity
331 indicators.

332

333 However, the key finding of our work is likely to be generally applicable. We have shown that
334 certain associations between biodiversity and ecosystem services (e.g. the association between the
335 number of native bird species and provisioning ecosystem services, small game hunting meat for

336 example) are not generally considered important. We also found that the number of alien invasive
337 species was not a good determinant of WTP (i.e. it was never statistically significant), meaning that
338 invasive species do not affect the preferences of the sampled population. But more research is
339 necessary in this regard, since one would expect invasive species to have a negative effect on
340 wellbeing. We asked respondents to make their choices within a context of six biodiversity
341 attributes; context can alter the process by which choices are made and hence shift the choice
342 outcomes (Thomadsen et al., 2018). In our case study, dealing with the complex concept of
343 biodiversity, the configuration of the biodiversity indicators could be interpreted as the key
344 elements of the choice context. Therefore, different strategies of experimental design and selection
345 of attributes could potentially lead to different choice outcomes. In addition, the lack of significance
346 among invasive species and any of the functional roles of biodiversity is perhaps indicative of a lack
347 of knowledge of the real impacts of invasive species, which are severe, both locally and globally
348 (García-Llorente et al., 2008; Pyšek et al., 2010). It would be expected that the number of invasive
349 species would be a more important determinant of WTP in other parts of the world or ecosystems
350 where the impact of invasive species is more generally recognized. In Spain, pine forests are
351 frequently associated with managed landscapes and plantations rather than pristine landscapes, and
352 this may have affected the relative importance of invasive species as well as the preferences for
353 different types of ecosystem services. In line with previous experience in environmental accounting
354 (Campos et al., 2019), biodiversity was mostly associated with regulating services, although the
355 interpretation of this link is not straightforward since there are many different pine species and
356 forests systems. For example, there are pine forests managed for the production of timber
357 (provisioning services) and other pine forests that are managed with the main aim of restoration (to
358 protect soil and water resources and the regulating services they provide, as well as biodiversity).
359 The majority of the biodiversity indicators were statistically significant in their interaction with
360 ecosystem services, but these relationships were strongest for regulating services. One possible
361 explanation of this result is that regulating services could be linked to the future of biodiversity and

362 sustainability, i.e. respondents may have been expressing their option and existence values. In our
363 findings, cultural services was the second ecosystem service in order of relevance and provisioning
364 services were associated least frequently with biodiversity indicators.

365

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

373

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

383

384 Management programmes focusing on sustainable production, such as sustainable forestry, would
385 be best served by biodiversity indicators relating to extent of habitat, population structure, genetic
386 diversity, and keystone elements, rather than the numbers of native or non-native invasive species,
387 since the former indicators all showed a significant association with provisioning ecosystem

388 services. On the other hand, if the aim of a conservation programme is more related to cultural and
389 regulating services (such as National Parks) then our results suggest that the number of native
390 species would be the best single indicator. The number of native species is widely used as a
391 biodiversity indicator (Bartkowski et al., 2015; Feld et al., 2009; Gao et al., 2015), and is perhaps
392 one of the most readily understood measures. However, the fact that our results showed no
393 significant effect of the association between the number of native species and provisioning
394 ecosystem services suggests that the role of biodiversity in supporting production through
395 pollination and other services such as soil quality regulation and water availability is not widely
396 known and valued.

397

398

399 **5. Conclusions**

400

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

412

413

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415

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420

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