

## Role of scavengers in providing non-material contributions to people

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### ABSTRACT

In today's societies, scavengers play an important role as providers of nature's contribution to people (NCP), such as disease control and carcass removal. Yet very little is known about the non-material NCP (i.e. nature's effects on subjective and psychological aspects of people's well-being) that scavengers provide societies with. The first aim of this study is to determine which species of obligate and facultative scavengers provide different non-material NCP in Spain, including recreational and aesthetic experiences, learning and inspiration, and supporting identities. The second aim is to identify which ecological variables determine their capacity to provide the aforementioned non-material NCP. To assess non-material NCP nationwide, data were collected from different sources, including the Internet (websites of nature photography and wildlife watching tours, Global Biodiversity Information Facility, and Google Trends), outreach magazines and scientific articles. A top predator, *Canis lupus*, followed by an obligate scavenger, *Gyps fulvus*, were among the most prominent species to provide multiple non-material NCP. Aesthetic experiences were provided mainly by common species, such as *Genetta genetta*, *Milvus migrans* and corvids. The NCP of recreation and learning by civil society were provided by threatened and charismatic species, such as *C. lupus*, *Ursus arctos* and *Aquila adalberti*. Knowledge acquired by scientists was provided mainly by meso-carnivores. Finally, the NCP of supporting identities was related with species capable of providing beneficial and detrimental contributions, such as *C. lupus* and *Sus scrofa*. Integrating data mined from different sources has allowed it to reveal the interweaving among non-material categories. Recognising that all species of scavengers are essential for providing non-material NCP can raise society's awareness about their important cultural role and may, hence, contribute to their conservation.

### 1. Introduction

In the last 20 years, a new stream of studies has emerged to disentangle the link between nature and humans (Costanza et al., 2017) to highlight the dependence of human well-being on the maintenance of ecosystem functioning. This dependence on nature was first named "nature's services" by Westman (1977), but it was from Daily (1997) and Costanza et al. (1997)'s publications when this topic began to receive wider scientific attention. The term "ecosystem services" was formalised in the Millennium Ecosystem Assessment (MEA) (2005) to define the direct or indirect benefits that people obtain from ecosystem functioning. Recently, and drawing on the ecosystem service concept, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has coined the concept of "nature's contributions to people" (NCP), which comprises both positive and negative effects of living nature to people's quality of life (Díaz et al., 2018).

The generalising perspective of NCP, which seeks to compare multiple NCP, recognises three broad categories: regulating, material and non-material. Regulating NCP refers to the functional and structural aspects of ecosystems and biodiversity that contribute to societies' well-being by modifying environmental conditions and regulating the provision of material and non-material NCP. Material NCP are elements collected from ecosystems and biodiversity that directly contribute to people's physical existence through supplies; e.g. food, energy or raw materials. Non-material NCP are nature's effects on the subjective and psychological aspects of people's well-being, including recreational and aesthetic experiences, learning and inspiration, and supporting identities (which in this research refers to people's satisfaction derived from knowing that a particular species exists) (Díaz et al., 2018).

Most previous research into ecosystem services and NCP has focussed to date on material and regulating contributions (Luederitz et al., 2015; Fagerholm et al., 2016; Hevia et al., 2017) and has left non-

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material NCP underrepresented (Daniel et al., 2012; Milcu et al., 2013). Different reasons have been argued for this underrepresentation of non-material NCP, such as the epistemological challenge of engaging with multiple disciplinary and methodological perspectives (Milcu et al., 2013), and the challenge of unpacking the interlinkages between biodiversity and non-material NCP (UK NEA, 2011; Balvanera et al., 2016). In addition, little research has focused on understanding which functional traits of biodiversity are important for the provision of non-material NCP (Hevia et al., 2017), despite linking functional traits with non-material NCP provision can offer a way to understand people's appreciation of biodiversity (Echeverri et al., 2019).

Furthermore, some taxonomic groups and functional guilds in ecosystem services and NCP research have received little attention, such as vertebrates (Cardinale et al., 2012; Hevia et al., 2017) and the scavenger guild (Moleón et al., 2014; DeVault et al., 2016). However, scavengers (i.e. animals that rely totally -obligate scavengers- or partially -facultative scavengers- on carrion as a food resource) have always benefited humans by helping to find food, providing feathers and other animal tissues as ornamental resources (i.e. material NCP), controlling diseases and pests by eliminating carcasses, and recycling nutrients (i.e. regulating NCP; Moleón et al., 2014). Scavengers have contributed to the well-being of ancient societies by providing non-material NCP too. For example, vultures were involved in many sacred rituals and celebrations held by Egyptians and Native Americans (Gordillo, 2002; Morelli et al., 2015). In addition, human-scavenger relations also lead to conflicts because of the predatory behaviour of some species. For example, top predators in Europe and North America, such as the grey wolf (*Canis lupus*) and the brown bear (*Ursus arctos*), have been historically persecuted and hunted for years because their attacks to livestock and game species (Chapron et al., 2014). In Africa, hyaenas (*Crocuta crocuta*, *Hyaena* sp.), lions (*Panthera leo*) and leopards (*P. pardus*) have been killed in retaliation for livestock predation (e.g. Kissui, 2008; Yirga et al., 2014; Koziarski et al., 2016), and in Asia, tigers (*P. tigris*), snow leopards (*Uncia uncia*) and leopards may cause livestock losses (e.g. Sangay and Vernes, 2008; Bhattarai and Fischer, 2014; Carter et al., 2014; Johansson et al., 2015). Moreover, farmers may also perceive that vultures attack their livestock. For example, in South America, farmers associate the Andean condor (*Vultur gryphus*) with predation of sheep and cattle (Manzano-García et al., 2017; Restrepo-Cardona et al., 2019). Likewise, in Southern Europe farmers have complaint reports about griffon vultures (*Gyps fulvus*) attacking livestock (Margalida et al., 2011, 2014; Duriez et al., 2019).

In today's societies, scavengers also play a relevant role in providing NCP, particularly regulating. For instance, Old World vultures contribute widely to regulate zoonotic diseases (O'Bryan et al., 2018), to remove human corpses in the Zoroastrian culture (Markandya et al., 2008), to remove organic material (Grilli et al., 2019) and to remove waste in urban areas (Gangoso et al., 2013). Some scavenging mammals, such as spotted hyenas (*Crocuta crocuta*) and golden jackals (*Canis aureus*), contribute to the removal of livestock carcass and waste in rural environments (Yirga et al., 2015; Ćirović et al., 2016). In Spain, scavengers contribute to reduce greenhouse gas emissions through the natural elimination of livestock carcasses that should otherwise be transported in trucks to incineration and processing plants (Morales-Reyes et al., 2015). Although there is evidence for the importance of scavengers to provide regulating NCP, their role in the provision of non-material NCP remains understudied. Only a few studies have explored the role of particular scavengers on providing wildlife-based tourism and recreation in protected areas. For example, large carnivores have been identified in Africa as potential providers of non-material NCP, such as wildlife-based tourism and aesthetic experiences (Willemen et al., 2015; Ament et al., 2017). Moreover, it has been estimated that the economic annual value of viewing the Eurasian griffon vulture (*Gyps fulvus*) in Israel to be more than 1.1 million USD (Becker et al., 2005).

Despite the importance of scavengers providing NCP, many are

globally endangered species, particularly vultures and large carnivores (Estes et al., 2011; Ogada et al., 2012; Ripple et al., 2014). On the one hand, 12 of the 23 vulture species are globally threatened (nine of them are Critically Endangered; IUCN, 2018). Poisoning, climate change, sanitary policies on leaving domestic carcasses in the field, and collision with wind turbines and power lines are some of the main causes that lead to declining vulture populations (DeVault et al., 2016). On the other hand, top-predators are globally threatened as a result of a wide array of human-related impacts (Estes et al., 2011). In addition to these pressures, the skewed viewpoints provided by magazines and media as to damage caused by scavengers, i.e. attacks on livestock by vultures (Margalida et al., 2011) or wolves (Dressel et al., 2015), foster negative social perceptions that challenge the conservation of scavengers (O'Bryan et al., 2018). However, social perceptions of scavengers vary according to the functional guild. For example, whereas obligate scavengers (i.e. vultures) are usually perceived positively by farmers as providers of NCP, some facultative scavengers are negatively perceived due to their role as predators (e.g. foxes, wolves and bears) (Morales-Reyes et al., 2018). Moreover, conflicts and detrimental NCP have been more widely studied in the scientific literature than the beneficial NCP provided by carnivores (Expósito-Granados et al., 2019; Lozano et al., 2019), which can also influence social perceptions of scavengers and social support for their conservation (Martín-López et al., 2009). Evidencing the beneficial NCP provided by scavengers may not only contribute to improve scientific knowledge but might also promote positive social perceptions and support conservation policies.

The main goal of this study is to assess the beneficial role played by vertebrate scavengers in people's well-being by uncovering the provision of non-material NCP. In particular, it firstly aims to determine which scavenger species are able to provide: (1) physical and psychological experiences related to recreational and aesthetic enjoyment; (2) learn and inspire in association with knowledge acquisition; (3) supporting identities (i.e. people's satisfaction derived from knowing that a particular scavenger exists). Secondly, it aims to identify which ecological variables (i.e. conservation status, taxonomy and functional traits) determine scavengers' capacity to provide non-material NCP. We considered both obligate (vultures) and facultative scavengers (other raptors, corvids and mammals). We conducted this study in Spain, which hosts more than 90% of European vultures (Margalida et al., 2010) and important populations of large facultative scavengers, such as the brown bear and the grey wolf (Chapron et al., 2014).

## 2. Methods

### 2.1. Data collection

To determine the role of scavengers as providers of non-material NCP, we collected 12 indicators of: *physical and psychological experiences*, particularly aesthetic enjoyment and recreation; *learning and inspiration*, derived from knowledge acquisition; *supporting identities*, based on people's satisfaction derived from knowing that a particular scavenger species exists (see Table 1). We considered 22 obligate and facultative scavenger species that inhabit in Spain (see the complete list in Table D.1 in Appendix D).

To assess the aesthetic enjoyment provided by scavengers, we used three different indicators to represent the aesthetic relevance of these species through photography. The photographs posted on social media platforms, such as Panoramio, Instagram and Flickr, have been used to evaluate people's aesthetic appreciation of species (Willemen et al., 2015; Martínez Pastur et al., 2016), with Spain being one of the countries with more users of social media in relation to Important Bird and Biodiversity Areas (Hausmann et al., 2019). In this research, we used the images posted on Fotonatura ([www.fotonatura.org](http://www.fotonatura.org)), which represents the Spanish-speaking nature photographers' community. The Fotonatura platform has already been used to assess cultural ecosystem services associated with trees in the Iberian Peninsula (Vaz et al., 2018).

**Table 1**

Indices and indicators used to assess non-material nature's contributions to people (NCP) provided by scavengers in Spain based on six sources of information: photography, wildlife-based tourism, outreach magazines, the Global Biodiversity Information Facility (GBIF), scientific articles and Google Trends. Associations between indices and non-material NCP were established based on the literature.

Index	Indicators	Non-material NCP	References
Photography	<ol style="list-style-type: none"> <li>1. Percentage of photos posted relative to the total number of scavenger's photos</li> <li>2. Average number of received views</li> <li>3. Average number of received votes</li> </ol>	<i>Physical and psychological experiences</i> , particularly aesthetic enjoyment. They can also represent recreational experiences, and <i>supporting identities</i> (people's satisfaction of knowing that a species exists).	Willemen et al., 2015; Martínez Pastur et al., 2016
Wildlife-based tourism	<ol style="list-style-type: none"> <li>1. Percentage of websites offering wildlife-based tours related to each species relative to the total of records</li> <li>2. Average number of times that each species name appears on the websites</li> </ol>	<i>Physical and psychological experiences</i> , particularly recreational experiences based on wildlife-based tourism. They can also represent aesthetic enjoyment, and <i>supporting identities</i> (people's satisfaction of knowing that a species exists).	Nahuelhual et al., 2013
Outreach magazines	<ol style="list-style-type: none"> <li>1. Percentage of covers in which each species appears relative to the total of issues</li> <li>2. Percentage of issues in which each species appears on their headlines relative to the total of issues</li> <li>3. Percentage of articles in which each species appears in the summary relative to the total of the summaries</li> </ol>	<i>Learning and inspiration</i> , particularly citizens acquiring knowledge. They can also represent <i>Physical and psychological experiences</i> , particularly recreational experiences, and <i>supporting identities</i> (people's satisfaction of knowing that a species exists).	Herrera, 1989; Sastre et al., 2004
The GBIF	<ol style="list-style-type: none"> <li>1. Percentage of recorded human observations relative to the total of records</li> <li>2. Percentage of recorded human observations relative to the total of records, excluded the records of the official census of the Spanish Ministry of the Environment</li> </ol>	<i>Learning and inspiration</i> , particularly scientists acquiring knowledge.	UN Environment World Conservation Monitoring Centre, 2017
Scientific articles	<ol style="list-style-type: none"> <li>1. Percentage of publications of each species in the biodiversity conservation literature relative to the total number of reviewed articles</li> </ol>	<i>Learning and inspiration</i> , particularly scientists acquiring knowledge.	Fazey et al., 2005; Velasco et al., 2015
Google Trends	<ol style="list-style-type: none"> <li>1. Average search score</li> </ol>	<i>Supporting identities</i> , based on human satisfaction of knowing that a particular scavenger exists.	Nghiem et al., 2016; Soriano-Redondo et al., 2017

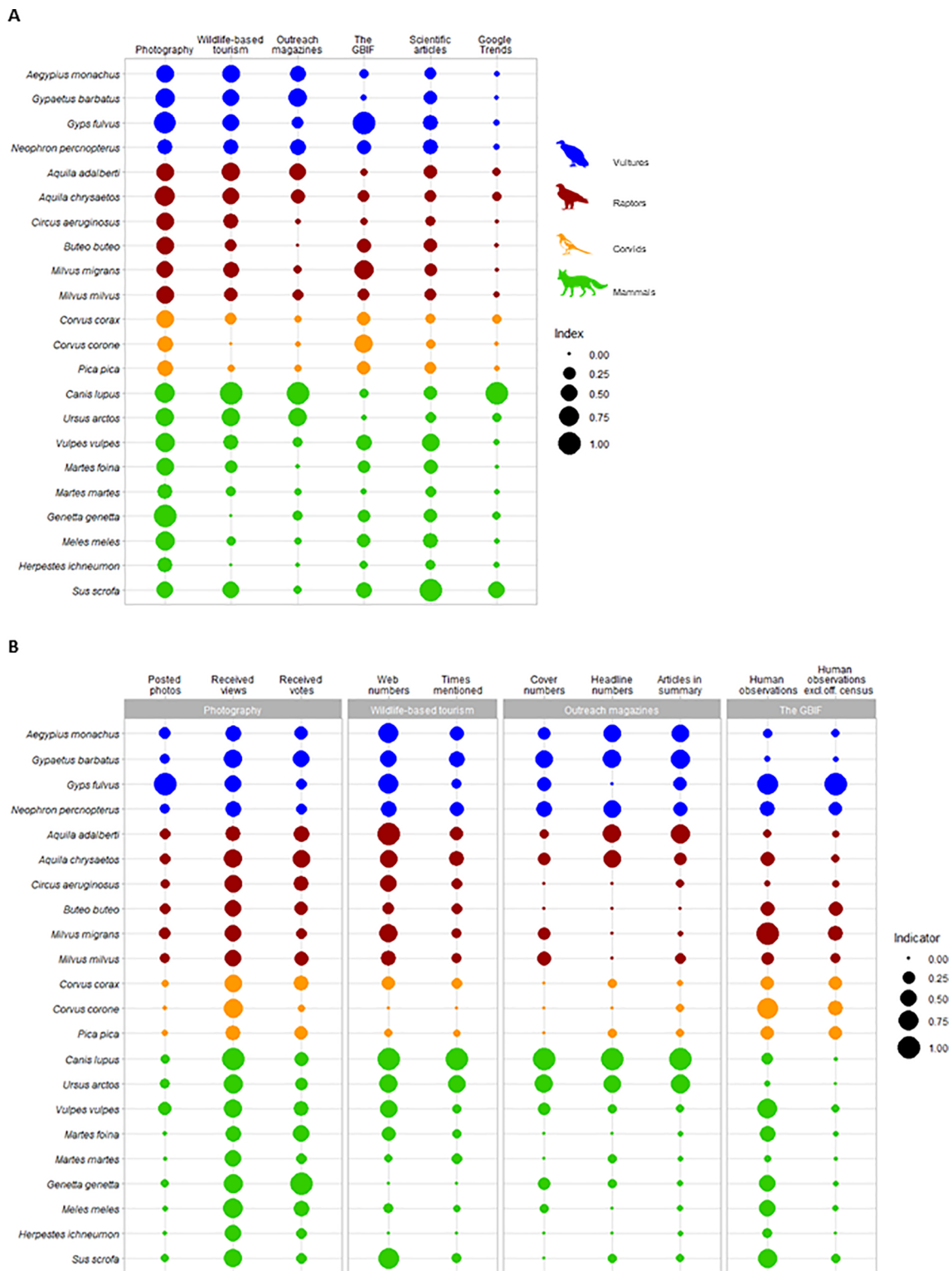
We derived three quantitative indicators to represent the aesthetic enjoyment of scavengers of each species: (1) the percentage of photos posted for each species relative to the total number of scavenger's photos; (2) the average number of received views in the photos by the Fotonatura audience; (3) the average number of obtained votes. Of the 38,454 photos posted between 2000 and 2016 on Fotonatura in Spain, we selected those that represented any of the 22 species considered herein; i.e. 1,174 images (3.05% of all the photos posted on Fotonatura). All the analysed images were stored in the Fotonatura gallery "geotagged" to check geographical locations, and were assigned to the dominant species on the photograph or whose species name appeared in its title. We considered images representing both wild and captive animals.

To assess the recreational experiences provided by scavengers, we collected information on wildlife-based tourism in Spain. We used two different indicators: (1) the percentage of websites that advertise wildlife watching tours and include any of the 22 species regards to the total web reviewed; (2) the average number of times that each species name appears on each website. To identify those websites offering nature-based tours related to the 22 scavenger species, in 2017 we searched on the World Wide Web using Google's Search Engine. We used a search string for each species, which included either its popular English name or scientific name, recreational activity, i.e. "wildlife watching", and location, i.e. "Spain" (see details in Appendix A). We analysed those websites provided by the first five Google search pages, by excluding personal comments and blogs, reports about wildlife-based tours and governmental information webs. We also excluded those websites that presented captive animals, such as zoos. We obtained 150 records on 40 different websites.

We evaluated *learning and inspiration* by considering the knowledge acquired by citizens and scientists. To assess the knowledge acquired by citizens, we examined the Spanish outreach magazine *Quercus*, which is the oldest and most prestigious publication related to the study, observation and defence of nature (Martínez-Abraín et al., 2013). Both authors and the readership include researchers from universities and other scientific institutions, environmental managers, NGOs' staff and other agents concerned with national and international wildlife.

*Quercus* sales 12 000 copies per month and has more than 40 000 followers in social networks (<https://revistaquercus.es/>). We used three indicators: (1) the percentage of covers in which each species appears, relative to the total issues; (2) the percentage of issues in which each species appears on their headlines, relative to the total issues; (3) the percentage of articles in which each species appears in the summary, relative to the total articles in the summaries. We explored all the 204 issues with a total number of 3254 articles in the summaries published from 2000 to 2016.

To assess the knowledge acquired by scientists, we collected information from the Global Biodiversity Information Facility (GBIF, <http://www.gbif.org/>) and from English peer-reviewed scientific articles. The GBIF is the largest initiative worldwide to provide information about the occurrence of organisms over time and across space (Yesson et al., 2007; Otegui et al., 2013). In fact, the GBIF has been suggested as a useful tool to monitor the status and trends of biodiversity knowledge (Convention on Biological Diversity, 2016). In 2017 we searched the occurrence of the 22 scavenger species in the Spanish node of the GBIF (<http://datos.gbif.es>) between 2000 and 2016, which is considered the most representative sample of the biodiversity data available in the country (Otegui et al., 2013). Our search was conducted using the scientific name between quotation marks for each species, using two indicators: (1) the percentage of recorded human observations of each species, relative to the total of records for the 22 scavenger species; (2) the percentage of recorded human observations for each species, relative to the total of records for the 22 scavenger species, after excluding the official census records of the Spanish Ministry of the Environment in 2007 (MAPAMA, 2013). In addition, to assess the knowledge acquired by scientists, we also conducted a systematic review of scientific articles in English peer-reviewed scientific articles about the 22 scavenger species in Spain using the Web of Science engine. The search string comprised three main elements: (1) the functional group of scavengers (i.e. scavenger, scavenging and vulture); (2) species' scientific names; (3) their geographic location, i.e. 'Spain' (see Appendix A for the search string details). Searching was conducted in the research area of 'biodiversity conservation'. To avoid double counting in the review, we searched for



**Fig. 1.** Scavengers contribution index by species in Spain. A. Indices showing non-material nature’s contributions to people (NCP) provided by species. B. Indicators showing non-material NCP provided by species used to construct the indices that were comprised by more than one indicator (i.e. photography, wildlife-based tourism, outreach magazines and the GBIF). The different colours display the taxonomic groups -i.e., vultures (in blue), raptors (red), corvids (orange) and mammals (green)-. Calculation details of indices are in methods, Appendix C and Fig. C.1. The comparison among taxonomic groups is shown in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

original articles, but not reviews and conferences. The search was applied to the Abstract, Title and Keywords of articles published between 2000 and 2016. The search returned 460 articles and (see list of references in Appendix B). We calculated as indicator the percentage of

publications of each species relative to the total number of reviewed articles.

To evaluate *supporting identities*, we explored the search volume on the Internet of each species by using Google Trends Search Engine

(<https://trends.google.es/trends/>). Google Trends has been suggested to be one of the best proxies to assess public curiosity, attention and issue salience (Burivalova et al., 2018), also as indicator of the public interest in biodiversity and conservation topics (Ladle et al., 2016; Nghiem et al., 2016) and the public's perception of conservation (Soriano-Redondo et al., 2017). Therefore, we used Google Trends as a proxy for acquiring information that supports identity development. Despite using Google Trends to assess the NCP of supporting identities, we are aware that other sources of information, such as photography, wildlife-based tourism and outreach magazines, can also represent this NCP (Table 1). In this study, we extracted information from public searches made on the Internet by searching through each species' scientific name in quotations, filtered through the *bird* and *animal* categories and geographical locations in Spain. The use of scientific names and a category filter ensured that the data extracted from Google Trends were associated only with species to avoid any source of bias due to homonyms. For example, the term 'buitre' (i.e. vulture in Spanish) often refers to 'vulture funds', which actually presents information about political corruption. The search was done for the period between January 2004 (the beginning of the available data) and December 2016. In Google Trends, a search request can be conducted only to compare up to five species. The extracted data return a monthly score, which represents the frequency of any search query in Google between 0 and 100, with 100 being the peak of a relative search volume for each keyword of the search query during the requested period. To compare the search volume on the Internet of the 22 scavengers on the same scale, we first detected that the wolf was the species with the highest monthly scores before including it as reference in all the search queries of five species. Using the extracted data, we calculated the average score for each species.

To study the relationship between non-material NCP and species, we considered different functional traits of the species: body mass, foraging activity, home range, fecundity and diel activity. In addition, we included the conservation status (i.e. threatened or non-threatened species) and the taxonomic group (i.e. vultures, raptors -excluding vultures-, corvids and mammals) of scavenger species. We selected these functional traits because they are suitable to study the functional diversity of scavengers in Spain and they have been used to associate functional diversity with scavenging NCP (Morales-Reyes et al., 2018). Appendix D presents data details per species (Table D.1) and description of considered traits (Table D.2).

## 2.2. Data analyses

We created six indices of scavenger contribution to represent the non-material NCP according to the information sources (Table 1): photography, wildlife-based tourism, outreach magazines, the GBIF, scientific articles and Google Trends. Before creating the six indices and allowing their comparability, we scaled the values of the 12 indicators from 0 to 1 by considering the maximum value to be 1 and weighting the rest. To create the indices that were comprised by more than one indicator (i.e. photography, wildlife-based tourism, outreach magazines and the GBIF; Table 1), we summed up the scaled indicators and then we scaled the indices between 0 and 1 (see Appendix C and Fig. C.1 for calculation details of indices).

To explore whether the taxonomic group can determine scavengers' capacity to provide non-material NCP to society, we performed median and mean comparison tests (i.e. analysis of variance (ANOVA) for photography and wildlife-based tourism, and the Kruskal-Wallis test for outreach magazines, Google Trends, the GBIF and scientific articles;  $\alpha = 0.05$ ). Before the comparison analysis, we tested normality by the Shapiro-Wilk test ( $\alpha = 0.05$ ).

To determine which ecological variables underpinned scavengers' capacity to provide non-material NCP, we performed a canonical correspondence analysis (CCA). We used the six indices as the dependent variables in the CCA. We included conservation status, taxonomic

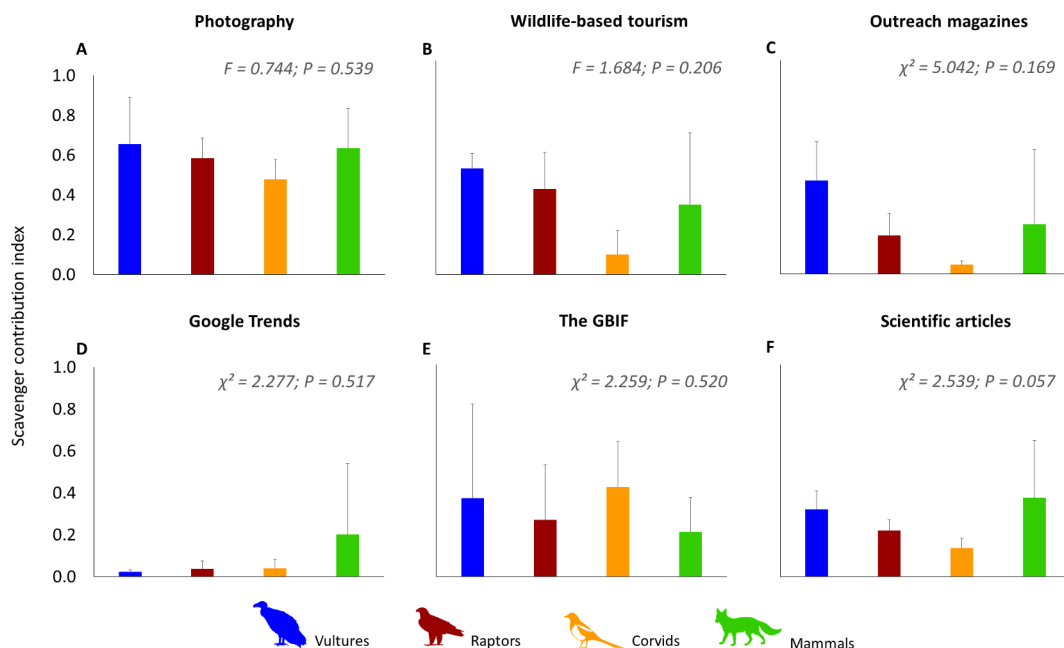
group and functional traits (body mass, foraging activity, home range, fecundity and diel activity) as explanatory variables (see Table D.1 in Appendix D for details). To avoid heteroscedasticity, we log-transformed the continuous variables; i.e. body mass and fecundity. We employed the Monte Carlo permutation test (500 iterations) to test the significance of the CCA.

We used the XLSTAT software (version 2016.04, Addinsoft) to conduct all the statistical analyses.

## 3. Results

The species that contributed to provide non-material NCP varied across the six indices (Fig. 1A), although the grey wolf emerged among the three most relevant species in four indices: photography, wildlife-based tourism, outreach magazines and Google Trends. Besides the wolf, the most relevant species in the index associated with photography were the common genet (*Genetta genetta*) and the griffon vulture. However, the saliency of these species varied according to the particular indicator used. Whereas griffon vultures were the most photographed, wolves obtained the most received views and common genets received the most votes (Fig. 1B). Regarding wildlife-based tourism, the wolf had the highest score, followed by the Spanish imperial eagle (*Aquila adalberti*) and the brown bear (Fig. 1A). In this case, the wolf was the most prominent species in the two indicators used: the number of websites advertising wildlife-based tourism (together with the Spanish imperial eagle) and the number of times each species was named in each website (Fig. 1B). In the index of outreach magazines, apart from bearded vultures (*Gypaetus barbatus*), two facultative scavengers, wolves and bears, were the most prominent species (Fig. 1A). Wolf was the most important species in the three indicators used to assess the knowledge acquired by citizens: number of covers, number of issues with headlines, number of articles (Fig. 1B). Regarding the knowledge acquired by researchers, we found differences for most of the relevant species between both indices (i.e. the GBIF and scientific articles). Whereas griffon vultures, black kites (*Milvus migrans*) and carrion crows (*Corvus corone*) obtained the most observations in the GBIF, two mammalian scavengers, the wild boar (*Sus scrofa*) and the red fox (*Vulpes vulpes*), were found in more scientific articles (Fig. 1A). Differences were also found in the source of the GBIF observations: whereas the black kite was the most observed when official censuses were considered, the griffon vulture had the highest record when official censuses were excluded (Fig. 1B). Finally, Google Trends revealed that mammals were the focus of web search interest, especially the wolf and the wild boar (Fig. 1A). Although different species of vultures, raptors, corvids and mammals were the most relevant in the different indices used to assess non-material NCP (Fig. 1A), we did not find any significant differences among taxonomic groups for each index (Fig. 2).

The CCA showed statistically significant associations between the ecological variables and indices representing non-material NCP. Three axes explained 93.74% of total variance (Table 2). The first axis (56.17% of variance) revealed a gradient between the information sources of photography and the GBIF (in positive scores) and outreach magazines and wildlife tourism (in negative scores). Whereas photography and the GBIF of scavengers were associated with the taxonomic group of corvids and with non-threatened species with small body mass and small home range, the indices of outreach magazines and wildlife-based tourism were associated with threatened species, with large body mass and large home range (Table 2). Griffon vultures, carrion crows, magpies (*Pica pica*), ravens (*Corvus corax*), black kites, common buzzards (*Buteo buteo*), western marsh harriers (*Circus aeruginosus*), common genets and red foxes were the species associated with the positive scores of the first axis, i.e. photography and the GBIF. In contrast, the Spanish imperial eagle, the wolf and the brown bear appeared in the negative scores, i.e. wildlife-based tourism and outreach magazines (Fig. 3A; Table D.3 in Appendix D). The second axis (25.62%) represented Google Trends in its positive scores in relation to non-



**Fig. 2.** Scavenger contribution index by taxonomic groups in Spain. Bars and whiskers indicate the mean value of indices showing non-material nature’s contributions to people (NCP) provided by taxonomic groups ± SD. Differences among taxonomic groups in photography and wildlife-based tourism were estimated by an ANOVA test ( $\alpha = 0.05$ ) and in outreach magazines, Google Trends, the GBIF and scientific articles by a Kruskal–Wallis test ( $\alpha = 0.05$ ). Calculation details of indices are in methods, Appendix C and Fig. C.1. Results per species are shown in Fig. 1.

**Table 2**

Summary statistics and results of the CCA showing the associations between the indices representing non-material nature’s contributions to people (NCP) provided by scavengers and the ecological variables (i.e. conservation status, taxonomic group and functional traits).

	Axis 1	Axis 2	Axis 3
<b>Indices of non-material NCP</b>			
Outreach magazines	-0.635	-0.383	0.067
Photography	<b>0.230</b>	-0.052	-0.150
Wildlife-based tourism	-0.320	-0.150	0.111
Google Trends	-0.817	<b>0.998</b>	0.125
The GBIF	<b>0.617</b>	0.072	0.341
Scientific articles	0.090	0.173	-0.254
<b>Conservation status</b>			
Threatened	-0.205	-0.214	-0.019
<b>Taxonomic group</b>			
Vultures	-0.027	-0.140	0.041
Raptors	0.037	-0.079	0.017
Corvids	<b>0.177</b>	0.034	0.074
Mammals	-0.111	<b>0.167</b>	-0.092
<b>Functional traits</b>			
Body mass	-0.299	0.085	0.000
Foraging act-social	-0.007	<b>0.144</b>	<b>0.144</b>
Home range	-0.230	-0.092	0.039
Fecundity	0.011	<b>0.212</b>	-0.027
Diel act-both	-0.048	-0.060	-0.019
Diel act-diurnal	0.125	-0.161	0.076
Diel act-nocturnal	-0.101	<b>0.212</b>	-0.069
<b>CCA statistics</b>			
Explained variation (%)	56.167	25.624	11.952
Cumulative explained variation (%)	56.167	81.791	93.743

Factor score of response (i.e. indices of non-material NCP), explanatory variables (i.e. conservation status, taxonomic group and functional traits) are shown in the first three axes. Bold font indicates the highest squared cosines (> 0.4) for the response variables and the significant regression coefficients for the explanatory variables. The eigenvalues for the first three CCA axes were significant (Monte Carlo permutation test with 500 iterations;  $P < 0.0001$ ). Additional information of response and explanatory variables are shown in Table 1 and Table D.1 in Appendix D. See Fig. 3 and Table D.3 in Appendix D for species details).

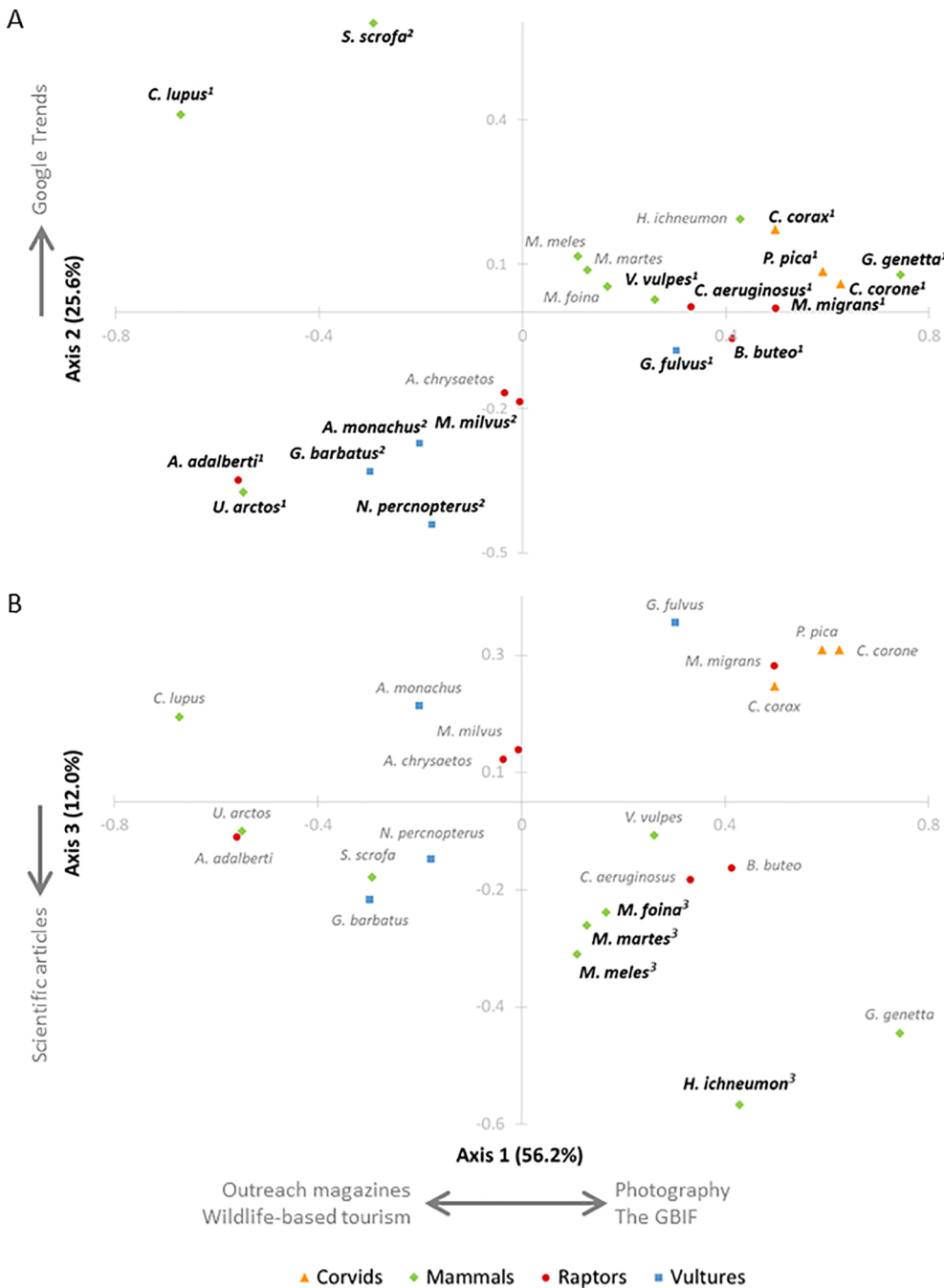
threatened species belonging to social mammals with high fecundity and nocturnal diel activity, i.e. wild boars (Table 2, Fig. 3A; Table D.3). The third axis (11.95%) represented the index of scientific articles in its negative scores. This index was related with non-social mammals (Table 2), particularly with the Egyptian mongoose (*Herpestes ichneumon*), the Eurasian badger (*Meles meles*), the pine marten (*Martes martes*) and the stone marten (*M. foina*) (Fig. 3B; Table D.3).

## 4. Discussion

### 4.1. Scavengers as providers of non-material NCP

Our findings show, for the first time, that different species in the scavenger guild are key for providing a large set of non-material NCP in Spain. The wolf, a top predator and facultative scavenger, reached the highest values in three of the six evaluated non-material indices, followed by the griffon vulture, an obligate scavenger that stood out with high values for two indices (Fig. 1). Previous studies have found that other NCP, such as the regulation of ecological processes by means of carcass consumption, were provided by both rare and common species, particularly vultures and top predators (Mateo-Tomás et al., 2017). Thus, top predators and vultures can be considered both ecological and cultural keystone species (Paine, 1969; Garibaldi and Turner, 2004), as they might play a major role in the functioning of social-ecological systems (Naidoo et al., 2011). Besides, both are functional groups in the scavenger guild that deserve particular attention because their populations are globally declining (Estes et al., 2011; Ogada et al., 2012; Ripple et al., 2014).

Our results showed that the indicator used to represent people’s supporting identities (i.e. Google Trends) might actually represent other aspects of human-scavenger relations. The grey wolf and the wild boar were the species most searched for by people in Google (Fig. 1). This can be explained by the fact that people may search information on these particular species not only because they show a positive interest in them, but also because people are interested in knowing about the damage that these species can cause. We also identified that the wolf is the most relevant scavenger for providing multiple non-material NCP,



**Fig. 3.** Results of the CCA showing the associations between the indices representing non-material nature's contributions to people (NCP) and the scavenger species. A. The axis 1 (i.e., photography and the GBIF in positive scores and outreach magazines and wildlife-based tourism in negative scores) and the axis 2 (Google Trends in positive scores). B. The axis 1 and the axis 3 (scientific articles in negative scores). Superscript numbers indicate the correspondent axis. Bold font indicates the highest squared cosines (> 0.4) for the response variables and the significant regression coefficients for the explanatory variables. Eigenvalues for the first three CCA axes were significant (Monte Carlo permutation test with 500 iterations;  $P < 0.0001$ ). Additional information of indices is shown in Table 1. See Table D.3 in Appendix D for factor score details.

including photography, wildlife-based tourism and outreach magazines. However, for rural people, livestock breeders and shepherds in Spain, the wolf is considered a dangerous predator that can cause livestock losses (Dressel et al., 2015; Morales-Reyes et al., 2018) and the wild boar is associated with damage to crops, animals and vegetation (Pascual-Rico et al., 2020). All over the world, farmers and shepherds developed negative perceptions towards wolves and wild boars because of the damages caused to livestock and crops, respectively (e.g. Linkie et al., 2007; Ogra, 2008; Suryawanshi et al., 2013; Li et al., 2015). The dual role of wolves and wild boars as providers of beneficial and detrimental contributions to people's well-being supports the use of the paradigm of "nature's contributions to people" (NCP) since this concept is defined as "all the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life" (Díaz et al., 2018).

#### 4.2. Traits and NCP in the scavenger guild

Biological and functional traits have been previously used for ecosystem service assessments (Díaz et al., 2007; Luck et al., 2009), but very little research has been conducted to date as to how to evaluate relations between traits and NCP, particularly for those interlinkages between non-material NCP and vertebrates (Hevia et al., 2017; Echeverri et al., 2019). Our results revealed that there are some interlinkages between non-material NCP and the selected functional traits, and that these interlinkages are mediated by the taxonomic groups of scavengers (Table 2). For example, higher body mass and larger home range together with the endangered status of species were associated with the indices of wildlife-based tourism and outreach magazines, which represent the NCP of physical and psychological experiences and learning and inspiration, respectively (Table 2). This might be interpreted because those threatened species with large body sizes tend to

have large home range (Tucker et al., 2014) and they are often charismatic species (e.g. the wolf, the Spanish imperial eagle, the brown bear and the bearded vulture) that attract the attention of customers. In fact, Clucas et al. (2008) revealed that the covers of US magazines focused on large charismatic species to attract new subscribers and to maintain membership. However, we also found that some species with high body mass, such as the wild boar, were not associated with the above-mentioned indices, but with Google Trends (Fig. 3; Table D.3).

In addition, we found that although photography has been considered a representative indicator of aesthetic enjoyment provided by wildlife (e.g. Martínez Pastur et al., 2016), our results demonstrated that the index created with the three photography indicators is closely related to the GBIF index (Table 2). This result means that those species able to be photographed are also those able to be observed and recorded in the GBIF. Indeed, this association can be explained by the probability of people sighting scavengers, which is higher for the common species widely distributed in Spain (e.g. griffon vultures, ravens and red foxes) than for other scavengers.

Finally, we found that the learning and inspiration acquired through scientific articles focused mainly on mesocarnivores, such as Egyptian mongooses, Eurasian badgers, pine martens and stone martens (Fig. 3; Table D.3). By contrast, a recent global review indicated that mesocarnivores received less scientific attention than large carnivores in human-carnivore relations research (Lozano et al., 2019). This could be explained because mesocarnivores in Spain are much more widely distributed and abundant than large mammalian scavengers, and thus can be investigated by comparatively more research groups. In addition, our results contrast with former research in Spain that has shown how the information provided by outreach magazines on different animal taxa goes hand in hand with scientific publications (Martín-López et al., 2009). However, when focussing on scavengers, we found that whereas the non-material NCP of the learning acquired through the outreach magazine *Quercus* relies mainly on charismatic and threatened species, the learning associated with scientific journals relies mostly on mesocarnivores.

The necessity to identify the traits of organism that intervene in the provision of NCP has been identified as an important knowledge gap in ecosystem service research (Luck et al., 2009; Bennett et al., 2015). This knowledge gap is particularly remarkable in the case of non-material NCP and vertebrates (Hevia et al., 2017). To our best knowledge, Echeverri et al. (2019) was the only study connecting functional traits with the provision of non-material NCP by birds. Similar to our findings, Echeverri et al. (2019) found that several functional traits, including plumage pattern, diet and having a crest, can contribute to explain the variation on non-material NCP provided by different bird species in Costa Rica. However, findings by Echeverri et al. (2019) also contradict our results since they found that scavengers are less likely to provide non-material NCP than other bird species because they are considered ugly and stinky. Future research is therefore needed to explore the connections between functional traits and detrimental NCP provided by scavengers.

#### 4.3. Methodological considerations: Insights for future research

This study follows recent calls to advance conservation science by considering the data mined from social media platforms and the Internet. The so-called digital conservation is emerging as an innovative field in biological conservation to monitor biodiversity (Van der Wal and Arts, 2015; Ladle et al., 2016) and to explore patterns of wildlife-based tourism (Willemen et al., 2015; Hausmann et al., 2017; Di Minin et al., 2018). In addition, the use of social media data has been recently highlighted in ecosystem service research to assess cultural ecosystem services (Guerrero et al., 2016; Oteros-Rozas et al., 2018; Vaz et al., 2018, 2019). Although very few studies on NCP and ecosystem services have considered diverse sources of information to date (e.g. Vaz et al., 2018), to the best of our knowledge, this study is the first to

comprehensively assess different non-material NCP by integrating multiple indicators derived from social media platforms and the Internet. Nevertheless, the use of data mined from social media platforms and the Internet requires some reflection as to their limitations.

Firstly, the data mined from these sources could represent only a particular sector of society. The Internet user profile seems closer to urban than to rural people (Oteros-Rozas et al., 2018) and, therefore, the results of this study may not represent the social actors who directly relate with scavengers, such as traditional livestock farmers and shepherds which perceive scavengers as beneficial and detrimental at the same time (Manzano-García et al., 2017; Morales-Reyes et al., 2018). However, in relation to livestock attacks by large carnivores, the media can widely echo the farmer perceptions, influencing the general public perception and management decisions (Fernández-Gil et al., 2016). Thus, the opinion of farmers and shepherds could partially be reflected in online resources, though probably biased towards conflicts (Fernández-Gil et al., 2016). The non-material NCP associated with farmers and shepherds deserve further scientific attention, which should be extended to hunters also.

The outreach magazine we selected to represent the NCP of inspiration and learning has a wide potential audience, including researchers, managers and the general public interested in nature. In Spain, 47.6% of people declare to be interested in ecology and the environment (CIS, Centro de Investigaciones Sociológicas, 2016). However, the magazine's monthly circulation only reaches the sector of society that is *a priori* most interested in environmental issues. Thus, *Quercus* does not capture the general motivation of the Spanish society. Interestingly, however, this magazine is very much used by environmental managers in Spain as the primary source of information on wildlife monitoring and conservation strategies, as well as to be informed on environmental offences. This indicates that this magazine may have important practical implications that may pervade other society sectors.

Secondly, regarding the NCP of supporting identities, we selected a proxy (i.e. Google Trends) that can represent people interest, in our case for scavengers. However, this indicator cannot represent the other dimensions embedded in this NCP, such as sense of place and belonging, connectedness with nature and the employment of nature for narratives, rituals and celebrations (Díaz et al., 2018). To reveal the contributions of scavengers to these other dimensions, further interdisciplinary research is needed that includes additional proxies, such as local species names, place names, stories, ceremonies and folklore (see e.g. Stara et al., 2016).

Thirdly, information sources, such as photographs uploaded in social media and the GBIF observations, can only represent those species that are not elusive, nocturnal and geographically limited or with small population sizes. For example, the fact that nocturnal mammals were less represented in the posted photographs and the GBIF observations than diurnal scavengers (Fig. 1A) does not necessarily mean that the former are not relevant for providing non-material NCP. This is the case of the common genet, which is very elusive and difficult to sight and photograph, but once it is portrayed, social media users experience aesthetic enjoyment as it obtains the most votes per photograph (Fig. 1B). These are not necessarily methodological pitfalls, but should be taken into account when interpreting the results of such studies.

Finally, this study demonstrates the importance of scavengers for providing non-material NCP, but was unable to determine to what extent this guild is more relevant than other guilds. Scavengers occupied 22% of magazine covers in *Quercus* and appeared in 3% of the photographs posted on Fotonatura. Nonetheless, these data do not provide information about the importance of this guild for providing non-material NCP relative to others. Future research could determine to what extent non-material NCP are provided by different ecological guilds and which functional traits can lead to higher levels of their provision. For example, Willemen et al. (2015) found that in African protected areas, the African elephant (*Loxodonta africana*) and large predators, such as

lions and leopards, were essential for providing wildlife-based tourism. Davies et al. (2018) also found that popular interest, measured by web searching, was greater in globally threatened mammals and birds than in those not threatened. Future research that applies data mining to social media platforms and the Internet should offer a high potential to unveil which species and which functional guilds and traits are essential for providing non-material NCP. In addition, the reason for people's attraction to some of scavengers remain unexplored. Although previous research has revealed that scavenger species can be dually perceived as beneficial or harmful depending on their consideration as primarily scavengers or predators (Manzano-García et al., 2017; Morales-Reyes et al., 2018), further research is needed.

#### 4.4. Conclusions

This study contributes to advance knowledge of NCP by assessing the role of scavengers in providing non-material contributions for two main reasons. First, it sheds light on the dual role of NCP as we found that the same species (e.g. the wolf and the wild boar) can positively and negatively contribute to people's well-being. Second, we found that non-material NCP are interweaved and, therefore, the way people benefit from scavengers in non-material terms does not squarely fit only one category. These two findings fall in line with the arguments of Díaz et al. (2018), who claimed a more inclusive and flexible system than ecosystem services to assess the diverse ways by which people relate with nature. This enables the recognition that different social sectors, such as here evaluated (i.e. photographers, tourists, magazine readers, scientists, and civil society) and maybe others (e.g. farmers, shepherds, hunters), may consider scavengers as providers of both beneficial and detrimental NCP and different NCP according to their relationship with wildlife.

The knowledge of non-material NCP provided by threatened species, such as brown bear and bearded vulture in Spain, could be underestimated if the assessment relies only on one source of information. For example, both species have few photographs posted on internet and few human observations in the GBIF because of their low population size and restricted distribution. However, their photographs have high scores of views, an important demand in wildlife-based tourism, and considerable occurrence in outreach magazines (Fig. 1). This shows the need of multiple indicators to comprehensible assess the capacity of threatened species to provide NCP. We hypothesize that the extinction of these threatened populations and species would drive the vanishing of the NCP they provide.

The present study also contributes to recent calls to better integrate scavenger conservation in the IPBES (Mateo-Tomás and Olea, 2018) by unravelling the non-material NCP provided by this guild. By assessing the non-material NCP provided by scavengers, our study supports current claims for conserving vultures and top predators because their current declining populations compromise not only the regulating NCP of scavenging, as demonstrated by the IPBES Regional Assessment of Europe and Central Asia (Martín-López et al., 2018), but also them providing multiple non-material NCP. Scavengers provide multiple beneficial non-material NCP by enhancing human-wildlife connections through recreation activities in nature, aesthetic enjoyment and learning. Identifying the ecological variables and functional traits that underpin each NCP might help to predict which NCP can be potentially provided by different species in a guild. For example, our result showed that widely distributed species (e.g. corvids and griffon vultures) acted as providers of aesthetic enjoyment, whereas scarce scavengers and species with higher body mass (e.g. bearded vultures and wolves) were associated with recreational experiences.

Detailed assessment of human-wildlife relations should be emphasized in conservation policies. Informing on both the species and the human actors involved in detriments and benefits provided by focal species groups to people may help to prioritize wildlife management strategies. Overall, this study, in combination with previous research

showing the role of scavengers for regulating NCP (e.g. Morales-Reyes et al., 2015; Ćirović et al., 2016), provides with powerful arguments to raise awareness about the importance of these species for our societies.

#### Credit authorship contribution statement

**Natividad Aguilera-Alcalá:** Methodology, Formal analysis, Investigation, Data curation, Visualization. **Zebensui Morales-Reyes:** Investigation, Data curation, Writing - review & editing, Visualization. **Berta Martín-López:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Marcos Moleón:** Writing - review & editing, Visualization, Supervision. **José Antonio Sánchez-Zapata:** Conceptualization, Writing - review & editing, Supervision, Project administration, Funding acquisition.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecolind.2020.106643>.

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