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A comparison of point-scoring procedures for species prioritization and allocation of seed collection resources in a mountain region

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Introduction

Setting priorities is an essential requirement for biodiversity conservation, with the ultimate goal of optimizing resources in space and time (Wilson et al. 2006). Prioritization systems may be focused on the selection of high biodiversity areas (Anderson 2002; Heath and Evans 2000; Shi et al. 2005) or the identification of target species to which allocate the scarce resources commonly available (Mace et al 2006). In most of cases, species prioritization is interpreted as a listing method created in response to specific conservation goals at national or sub-national level (Dunn et al. 1999; Coates and Atkins 2001; Atkins 2005; Harris et al. 2005), and three main types of species lists should be considered for conservation and management in a given territory (Grammont and Cuarón 2006). These are: (1) Threatened Species Lists (Red Lists); (2) Conservation Priority Lists; and (3) Legal Lists. Although Red Lists are often the unique sources available for conservation managers, their use is seriously limited for species prioritization (Possingham et al. 2002). Thus, decision makers should consider criteria other than endangerment in setting conservation priorities (Mace and Lande, 1991; Possingham et al. 2002). Since Legal Lists are dependent on policy decisions and subject to uncertainty of expert assessment (Lunney et al. 1996; Regan et al. 2004), they are spatially constrained and not applicable to the selection of species priorities under scientific-based procedures. In consequence, Conservation Priority Lists have been developed as a successful system for species prioritization (Mace et al. 2007), permitting to integrate different criteria at any scale. Nevertheless, when conservation centres are asked to provide a list of priority species, divergences among different prioritization systems commonly arise (Mehlman et al. 2004; Schmeller et al. 2008). Such divergences may be caused by conceptual reasons (e.g., the ultimate variables to be considered for species prioritization) or methodological reasons (e.g., the type of prioritization system performed). Despite that conceptual background of prioritization ultimately depends on the particular objectives of each conservation centre, different methods can be employed for the development of species priority lists (reviewed by Mace and Collar, 2002), but scarce attention is paid to the possible consequences of using different systems when such lists are finally used for decision making.

Priority setting tools may be classified into two main groups: categorical and cumulative systems. The categorical systems (including the rule-scored and qualitative methods reviewed in Regan et al. 2004) are based on the assignment of pre-established priority groups from quantitative, qualitative or other kind of rules, as for example the categorical system used by IUCN (2001). Such methods are methodologically explicit, and therefore they are not affected by different alternatives to be computed, excepting possible implications of data uncertainty (Akçakaya et al. 2000). In contrast, the cumulative systems are based on the quantitative assignment of priority scores and their summarization. In particular, point-scoring methods are widely recognized as quantitative, repeatable and objective methods based on easily measured variables (Todd and Burgman 1998; Cofré and Marquet 1999). Although some authors have proposed mixed systems by establishing categories derived from the co-occurrences of priority values, such the “conservation cube” (Avery et al. 1994; Keller and Bollmann 2004), the application of cross-categories may be too complex when more than two criteria are considered. Thus, cumulative systems seem to be a better choice for multi-criteria assessment, and point-scoring methods are broadly applied for different purposes and taxonomic groups (Cofré and Marquet, 1999; Mehlman et al. 2004; Regan et al. 2004; Rodriguez et al. 2004; Pärtel et al. 2005; Abellán et al. 2005). Nevertheless, serious drawbacks are usually attributed to these methods, such as the correlation between criteria and the lack of objectivity in their transformation to a numeric score (Mace and Collar, 2002). Furthermore, the summarization of the scored criteria into a unique Priority Index is subject to methodological uncertainties, because a high number of mathematical procedures are possible (Carter et al. 2000). Although it has been suggested to always compare different lists for the assessment of species' conservation status (Knapp et al 2003), in most cases priority lists are computed through a unique system, and the impact of using different methodologies is commonly unknown.

In this paper, we compare point-scoring systems based on different transformation and summarization procedures for the prioritization of vascular plants in a Spanish mountain region, with the general aim of delineate cost-effective efforts for ex situ conservation of wild species. Ex situ conservation is a crucial aspect of plant biodiversity management (CBD 2001), which is commonly limited by funding, and therefore subject to prioritization (Maxted and Guarino 2003; Fransworth et al. 2006). Because most of seed banks focus on urgent seed preservation of high-priority species, considerations about optimal resources allocation such as conservation costs and probability of success are not usually considered (Joseph et al. 2009). However, important efforts for ex situ conservation are being developed at large scales (see for example the European network ENSCONET at www.ensconet.eu), and therefore cost-effective strategies for seed conservation are required. Our study is focused on a mountain range where most of the existing lists (red lists, normative lists and other conservation lists) are devoted to administrative areas at different scales, and therefore a unique Conservation Priority List for targeting seed collections is required. To integrate existing lists into a unique ranked prioritization list, it is essential to combine different geographical levels (Hartley and Kunin 2003), and multi-scale systems permit to generalize concepts such as rarity or exclusivity (Master 1991; Stein 2002; Eaton et al. 2005). Thus, we adopted the responsibility concept (Dunn et al. 1999) in the sense of Keller and Bollmann (2004) as a mixed prioritization system including different characteristics of species, performing a cumulative and multiple scale point-scoring system. Our main goal is to investigate the implication of using different procedures for obtaining a Conservation Priority List to be applied in conservation strategies. We specifically asked two questions. First, how does transformation and summarization of conservation criteria affect the performance of point-scored priority lists? Second, what is the implication of using such priority lists for allocating conservation resources?

Methods

Case study

The study was focused on the prioritization necessities of vascular plants in the Cantabrian Range, a mountainous area extending to circa 15 000 km^2 in northern Spain. This area is part of the European Atlantic Biogeographical Region (Roekaerts 2002), and supports a number between 3 000 and 3 500 species of vascular plants, from which circa 2.5 % are local endemics (Jiménez-Alfaro 2009). The territory is divided into four administrative regions (Spanish Autonomous Communities) where different conservation lists of vascular plants exist (Figure 1). We performed an initial dataset of species of conservation concern to the study area, including: (1) all the vascular plants threatened at national level, categorized as CR (critically endangered), EN (endangered) or VU (vulnerable) in Spanish IUCN categories of Vascular Plants (Moreno, 2008) and (2) all the species included in the local normative lists affecting the study area, excluding those categories based exclusively on forestry or medicinal management. We also revised European and Spanish normative lists, although all the species considered had already been included .The dataset contains a total number of 127 vascular plants for which conservation efforts should be dedicated in the study area. Species were then assessed using four conservation criteria (Table 1) related to different geographical areas: (1) national threat (THR) according to the Spanish red list; (2) local protection (PRO) under regional laws of Spanish Autonomous Communities, (3) endemicity (END) in the context of the European Atlantic Biogeographical Region, and (4) local rarity (RAR) measured as the number of known localities (10x10 km grid) in the Cantabrian Range. Threat and Protection criteria are intended as a real biological conservation status of species at national and sub-national scale, whilst Endemicity and Rarity are interpreted as a surrogate of exclusivity and relative occupancy in the study area, respectively. All criteria were classified in four importance categories (Table 1), including a non-priority class with the lowest conservation concern. An initial correlation analysis (Kendall´Tau rank correlation coefficient) was calculated in order to check the relations between selected criteria. We finally used common point-scoring procedures (typically based on ordinal scoring and mean summarization) to develop a set of alternative priority lists to be compared, performing four alternative prioritization systems (Figure 2) as explained below.

Transformation

An ordinal point-scoring transformation was first computed using the most commonly used procedures (Millsap et al. 1990; Marsh et al. 2007) that is applying ordinal values (from 0 to 3) to the four pre-defined classes. Since that option can be subject to unpredictable weighting of criteria (Mace et al 2007), we computed an alternative transformation based on weighted scores. Because weighting of criteria can depend on specific conservation objectives or subjective decisions, many alternatives exist, and any weighted transformation would be valid. However, to avoid aprioristic decisions, and for comparison purposes, we performed an automatically weighting system based on a meaningful quantile transformation of the original rank scale (or ordinal classes) into a numeric scale. The quantile transformation proposed here is based on the premise that the conservation efforts allocated to each species depend on the proportional number of species included in each category. To do this, the non-priority class was considered as the 'null class' and the species therein were not considered to compute the relative frequencies. The rest of the classes are associated with its corresponding quantile. Thus, the numeric scale ranges always from 0 (minimum priority) to 1 (maximum priority). For example, if the frequencies of the different classes for a given criterion (from non-priority to maximum-priority) are 20, 10, 20 and 50, then the null class has 20 species and the priority classes have 80 species. The quantiles are 10/80, 30/80, and 80/80 respectively. Thus, the numeric transformation assumes the values 0, 0.125, 0.375 and 1 for the species in each respective class. In this case, the large difference between the value of the species in the last class and the rest implies that a greater relative effort is needed for the conservation of such species. On the contrary, if the frequencies of the classes ordered according to the priority are 20, 40, 50 and 10 respectively, the transformation would lead to a numeric variable, assuming the values 0, 0.4, 0.9 and 1 for the species in each respective class. Then, the smaller difference between the third class and the fourth class implies a greater relative effort for the species in the third class in comparison with the previous example (although, of course, the greatest effort should always devote to the fourth class).

Summarization

In order to integrate the information provided by each one of the transformed criteria into a synthetic Conservation Priority Index (CPI), a way of combining them was needed, but several possibilities have been suggested in the literature (see Rizzi 2007 for a discussion). Here we applied two different summarization systems to both ordinal and quantile point-scored criteria (Figure 2). The first indices were obtained following a common procedure (Mean) performed in most of point-scoring systems, using the normalized sum of the ranks (*M*), that is:

$$M = (THR + PRO + END + RAR)/12$$

In the second case, we based on possible alternatives for the summarization of interrelated criteria. For this, it has been suggested to employ a multiplicative scoring (Burgman et al. 2001) as the geometric mean of the rates, by assuming the lack of priority as the referential situation. As an alternative to mean-based approaches, multivariate techniques can be applied to combine different scores or even results of scoring methods (Knapp, et al 2003). Here, and to get a linear combination of the different criteria explaining a greater amount of variability, we used a factorial technique where the normalized first factor is retained. Thus, we calculated a second, factorial index:

$$F = aT_{THR} + bT_{PRO} + cT_{END} + dT_{RAR}$$

where $a, b, c, d \in [0,1]$ are the weights corresponding to the first factor of a factorial analysis applied to the 4 criteria normalized to add up 1 (given a rank criterion C, we denote by T_C the corresponding transformation). Since the resulting indices have values on a numeric scale, the partial contribution of each criterion to the priority indices was quantified by means of the Pearson correlation coefficient.

Comparison of Priority lists

To evaluate possible divergences among the different methods employed here, we realized pair-wise comparisons between the four CPI obtained through the combination of ordinal/quantile and mean/factorial procedures (see Figure 2). A pair-wise correlation test was used to analyze the degree of agreement of the Priority Indices, performing a regression line to visually identify possible differences among them (each index was treat as both dependent and independent variable). Since values are not independent, we used a randomization test for calculating *p* values. We also tested the implication of subsequent ranked lists for allocating resources for ex situ conservation in the study area. For this, we established a hypothetical cost of 1 000 € for collecting and processing seeds from one wild population. Using a minimal distance of 1 km to differentiate populations, we calculated the total number of collection sites by each species as the number of 1x1 km^2 grid units where each species occurs. Thus, we estimated a total amount of 600 000 € to covering the ex situ conservation of a total number of 627 populations/sites for the 127 species. Because the number of sites was expected to be higher in the species with less priority, additional systems for targeting populations within species could be conducted (Farnsworth et al 2006; Bacchetta et al 2009). In this case, and for comparison purposes, we reduced the data set to the most priority species, assuming that all of their populations should be sampled for seed collection. For this, we established three realistic scenarios of available funds (50 000, 100 000 and 20 0000 €) and through a contingency table we detected possible discrepancies in the species composition when different CPI are used. We calculated the concordance in the number of selected species for each scenario and CPI, using the Cohen´ Kappa coefficient (*k*) as a measure of agreement. In order to permit an equal comparison of the four lists, species with tied ranks (when existing) were selected according to their alphabetical order.

Results

Scoring criteria

The pairwise Kendall's correlations showed significant ($p < 0.05$) relationships between the criteria *THRxPRO* ($\tau = 0.334$), *THRxEND* ($\tau = 0.412$), *THRxRAR* ($\tau = 0.263$) and *PROxEND* ($\tau = 0.235$), but *PROxRAR* and *ENDxRAR* correlations were non significant ($p > 0.05$). The 127 species of conservation concern were scored according to the ordinal (*Or*) and quantile (*Q*) transformations. Whereas ordinal transformation scored always equally (0,1, 2 and 3), different values from 0 to 1 were obtained from quantile transformation, according to the relative frequency obtained for each criteria (Table 2). The wider range of score weighting between classes 1 and 2 was assigned to Endemicity, because of the high relative frequency of species included in END1, and the lower number of species included in END2 and END3. In contrast, a higher frequency of species in class 2 and class 3 provided narrow differences in Threat classes THR1 and THR2, and especially in Protection classes PRO1 and PRO2. On the other hand, frequencies on the number of species were relatively homogeneous in Rarity, and the final scores taken by the classes of this criterion were more equally weighted.

Conservation Priority Indices (CPI)

The summarization of criteria into the four CPI provided remarkable differences in the range of the scores finally obtained (Table 3). The scale of the *OrM* Index (resulted from ordinal transformation and mean summarization) was discrete (12 absolute values; mean = 0.32 ± 0.19) showing a higher frequency of tied values. In contrast, a wider range of values was obtained for the factorial summarization *OrF* (45 absolute values; mean = 0.45 ± 0.20) and the quantile indices *QM* (51 absolute values; mean = 0.29 ± 0.20) and *QF* (51 absolute values; mean = 0.36 ± 0.35). In consequence, the scale adopted by *OrF*, *QM* and *QF* can be attributed to a continuous distribution, although they showed an increasing number of tied-ranked species in the second part of the lists.

As expected, most of the criteria had a significant correlation with the four CPI, but a remarkable difference affected the contribution of each criteria when computed by ordinal (*Or*) or quantile (*Q*) transformations (table 4). Although Protection (PRO) was the criterion with the greatest correlation for the two CPI derived from ordinal transformation, it was also the criterion with the lowest contribution for the two quantile-transformed indices, with a non-significant relationship with *QF*. On the other hand, the contribution of the other three criteria was always significant, with an inverse effect on their correlation with quantile- or ordinal-transformed indices.

Concordance between CPI

Pair-wise comparisons between the four indices showed a significant linear correlation ($p < 0.001$) (Figure 3), but some differences were detected. In general terms, the lowest concordance was related to the most different indices *OrM* and *QF* ($R^2 = 0.907$) and the higher agreement ($R^2 = 0.977$) was related to mean-summarized indices. Nevertheless, different types of fit with the linear correlation were detected between indices. While *OrM* x *QF* and *QM* x *QF* pairs agree better for low values, they were more different for higher values. Conversely, both *OrM* x *QM* and *OrF* x *QF* pairs better agree for high values, the latter showing a much closed correlation. On the other hand, *OrF* x *OrM* and *OrF* x *QM* pairs did not agree in absolute values, but they showed an almost constant scale change over the entire interval.

The comparison of the selected species using the four CPI under different funding scenarios showed a clear pattern, in which the agreement of target species was higher when available funds were lower (table 5). The total agreement in species composition was generally high (> 95 %; Cohens´ Kappa $k > 0.8$), and a full concordance was found in the comparison between the two mean-summarized indices ($k = 1$) under the lowest funding scenario. However, when higher resources (200 000 €) are available (and more populations and species are selected) the total agreement was lower (from 88 to 93%), and a higher number of species are included or excluded depending of the CPI to be used. Moreover, a total rate between 9 and 22 species changed when higher funds for ex situ conservation are available, which means a rate between 14 and 32 % of the total species selected (Table 5). As previously indicated, the higher divergence was found in the comparison between the most different indices *OrM* and *QF*, for which an allocation of 200.000 € would imply a difference rate of 22 species within the total number of selected conservation targets.

Discussion

Prioritization systems are commonly used for target plants in conservation planning, being especially adapted for allocating conservation efforts (Pärtel et al. 2005; Marsh et al. 2007; Martin et al. 2010). Because one basic objective of ex situ prioritization is the long-time preservation of important genetic resources, and most of the species we considered have desiccation-tolerant seeds (or spores), we assume an equal probability of success for their conservation. However, other considerations for optimizing ex situ conservation could exist, such as the capability of the species to be storage or re-introduced in the wild (Fransworth et al. 2006), the probability of management success (Joseph et al. 2009) or the integration with in situ efforts (Volis and Blecher 2010). In this study, we investigate the effect of applying distinct procedures for combining conservation criteria through point-scoring methods, as a feasible approach for the allocation of seed collection resources. In similar cases, the main limitations commonly attributed to point-scoring regard the arbitrariness in variable selection and the lack of independence between criteria (Millsap et al. 1990; Mace and Collar 2002; Mehlman et al. 2004; Abellán et al. 2005). The four criteria we employed here are usually considered for prioritization of vascular plants (Coate and Atkins 2001; Kolberg 2003), and three of them represent existing lists for which, other than possible criticisms, local conservation centres are required to attend. Since the correlation of the criteria was relatively low (a maximum of 0.42; Kendall Tau), the statistical information provided by each criterion can be considered different. The explanation for such slight correlation (and the non-significance relationship detected for some pair-wise comparisons) can be attributed to the different scale of reference used for each criterion, supporting the statement that multi-scale methods improve the significance of conservation lists (Hartley and Kunin 2003). Nevertheless, a certain correlation should be expected when similar criteria are used, considering known relationships among rarity, endemicity and extinction risk (Rabinovitz 1981; Major 1988; Holsinguer and Gottlieb 1991; Dominguez Lozano et al. 2003), and the relevance of such correlation should be always carefully assessed. In our case study, correlation between criteria should minimize divergences between point-scoring methods, and therefore the discrepancies detected in the four indices compared here can be mainly interpreted on the basis of the different systems employed.

Effects of transformation and summarization

Besides the selection of criteria, a first decision for performing Conservation Priority Lists regards the way in which those criteria are computed. In according with their conceptual basis, the two transformations computed here provide a different biological interpretation of the resulting lists (Table 4). Differences between ordinal and quantile methods can be explained by the different ratio of species-by-class provided by each criterion. Whereas ordinal transformation retain an equally contribution of criteria (because its ordinal nature) quantile transformation provide an unbalanced weight in the resulting lists. These results suggest that the effect of transformation is crucial for assigning conservation importance to species, even when different summarization procedures are computed. Furthermore, the numerical characteristics of transformation had an additional effect on their summarization. Ordinal-transformed criteria provided a narrower range of values to the final CPI than quantile-transformed, because in the first case the number of possible values is limited by the number of combinations in classes/criteria. On the contrary, unequally transformation of criteria (such the quantile method employed here) provides a more quantitative scoring of criteria and a wider range of values, avoiding high frequencies of tailed ranks. The limitation of ordinal scoring for providing wide ranges was reduced using a factorial summarization, as indicated by the more quantitative CPI derived from *OrF*, similar to the two indices obtained through quantile transformation. However, the *OrM* index showed a high frequency in tailed values, as a consequence of using only four criteria with four possible values (resulting in only 16 possible scores), producing a certain limitation for selecting species priorities through the final list. Although restricted to our case study, this finding contrasts with the generalized use of point-scoring systems, in which species priorities are selected according to ranked lists obtained from ordinal transformation and mean summarization (Cofré and Marguet 1999; Abellán et al. 2005). Despite other procedures or criteria / classes could have been employed, our results indicate that under similar circumstances (i.e. using few conservation criteria), and when the aim of prioritization is to define groups of conservation importance, unequal weight transformation could better be used for establishing rank thresholds. We also highlight that both transformation and summarization can affect the assignment of conservation ranks for the performance of priority lists. In particular, transformation seems to be a more crucial procedure, because it may produce a perdurable effect in the final priority indices.

Implications for conservation

The fact that the four CPI compared here are correlated is in concordance with previous comparisons of prioritization systems using similar criteria (Knapp et al. 2003; Mehlman et al. 2004). Although such correlation should minimize possible divergences in the application of the CPI for conservation, our results indicate that, in some cases, slight differences between indices can affect the application of ranking lists for selecting conservation priorities. For example, a selection of the top-ten conservation priorities in the study area would include exactly the same species using any of the four CPI indices (Table 3) because of the similar characteristics of lists in their high ranks. However, slight differences would be expected when groups of the most priority 30 or 40 species are wanted, with a maximum of 8 species being selected/not selected (results not shown). A great agreement would be expected again if a high number of species (say, more than 70) want to be prioritized, because of the high number of tailed values offered by the second part of the lists, and the lack of possible combinations derived from using just four criteria. In consequence, the impact of using different CPI for species selection would be low in general terms, excepting (a) the limitations detected for the *OrM* index to establish rank thresholds, and (b) possible implications of CPI divergences when a low-medium number of species are selected. The latter was tested comparing the four CPI under a realistic, population-based resource allocation system for seed collection (Table 5), suggesting that the point-scoring procedures used here might have a high impact in the species to be finally selected. With low funds, few species can be selected as conservation targets, and the higher-priority species are very similar in all the cases. Nevertheless, with medium funds, scores of intermediate and especially low-priority species are more different, and then different species lists are selected. This effect is especially important in the comparison of the more different priority lists *QF* and *OrM*, even when a general agreement between both indices was detected. The explanation for such differences is attributed to the different amount of populations existing by each species, and it is in concordance with the agreement detected among indices over their first interval (Figure 3). Since available funds are difficulty obtained for more than 30 species in short-medium periods of time, the implications of using different CPI might be relevant for planning ex situ conservation efforts in the study area. If we should to select one of the CPI computed here for conservation planning (and it is the case), the *QM* is the index that better reflect our conservation expectations, because (i) it retains a high range of values for species selection (Table 3) and (ii) all criteria have a significant contribution to the ranked list (Table 4), which is explainable according to the weighted scores (Table 2).

Conclusions

Although discrepancies among different prioritization systems have been highlighted before (Burgman et al. 1999; Knapp et al. 2003) our study specifically compares point-scoring methods for species prioritization and allocation of resources under a multi-criteria and multi-scale perspective. Many international or multi-regional initiatives are interested in target species for ex situ conservation in biogeographical areas at any scale (for example in bioclimatic regions or mountain ranges), but comprehensive approaches are nowadays barely represented, assuming that political/administrative boundaries are adequate for conservation management. Our study represents an example of using point-scoring for integrating existing lists under a biogeographical approach, in agreement with the general assumption that conservation prioritization must be adapted to regional scales (IUCN 2003). Studies dealing with large regions attempt to integrate existing lists made with different purposes, and Conservation Priority Lists seem to be especially adapted for integrating red lists and protection lists (or others) into a unique, multi-scale reference for conservation planning. In this study we demonstrated that, when point-scoring methods are used, both transformation and summarization procedures might provide divergences in the resulted ranked lists, which can be slight in general terms, but potentially strong for targeting priorities under certain conservation scenarios. Other than using accurate criteria to solve specific conservation goals of a given study area, we recommend to consider the adequacy of combining point-scoring procedures, and the capability of final ranks for targeting species. In particular, a serious limitation of ordinal-transformed and mean-summarized indices seem to exist, at least when few criteria are used, and alternative point-scoring procedures should be considered. The ordinal transformation commonly used is not necessary bad, and in many cases it might be applied to get an equal contribution to different conservation criteria. However, its summarization through arithmetic mean can provide high frequencies of tied values, and other methods such as factorial (computed here) or multivariate analysis are recommended. As a possible alternative, the quantile transformation proposed here allows assigning a meaningful value for weighting criteria using a non-subjective procedure, avoiding the arbitrary assignment of scores attributed to ordinal transformation (Mace et al 2007) and providing a feasible understanding of the final weights. This method is repeatable and easily applicable to any prioritization list, but it is not necessary better than other weighted procedures. Although in some cases conservation managers would want to give more importance to particular criteria, we believe that quantile transformation can be effectively used to automatically weighting criteria for conservation, when subjective scoring is not desirable.

Despite that assessing conservation priority is always subject to arbitrary decisions (Mace and Lande 1991; Burgman et al. 1999), we conclude that prioritization systems and especially point-scoring methods must be used having into account not only the adequacy of the criteria and the way in which they are combined, but also the way in which the list will be ultimately used. In any case, conceptual basis of point-scoring might be better understood using weighted and not arbitrary scores, as a better option for explaining the prioritization systems to conservation agencies. Furthermore, conservation managers should be always advised that applying alternative priority lists could have high impact for allocating conservation resources, when the lists are used on particular funding situations.

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Figure 1 Location of the Cantabrian Range (polygon) in Spain. Numbered areas reflect the administratively distinct regions (Spanish Autonomous Communities) for which different conservation and/or normative lists exist: Galicia (1), Asturias (2), Castilla y León (3), Cantabria (4) and the whole Spanish territory (5).

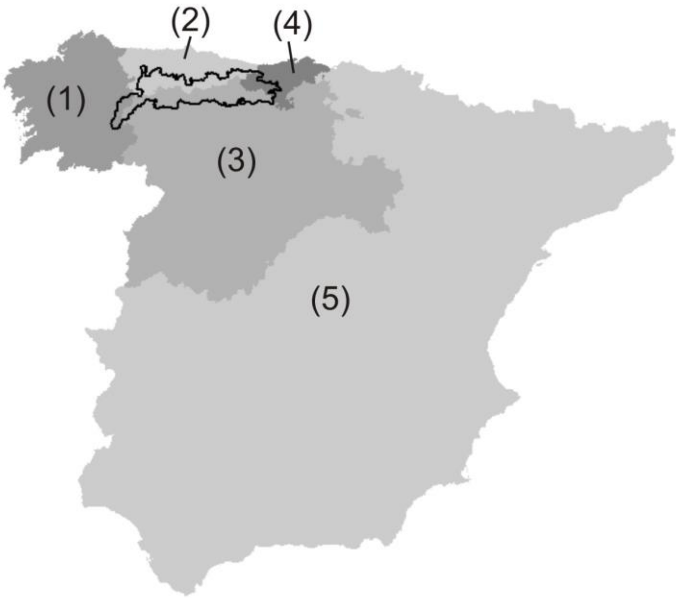

Figure 2 General scheme of the point-scoring methods compared in this study, using two different transformation and summarization procedures. A set of four Conservation Priority Indices (*OrM*, *OrF*, *QM* and *QF*) was finally obtained to perform priority lists for the study area.

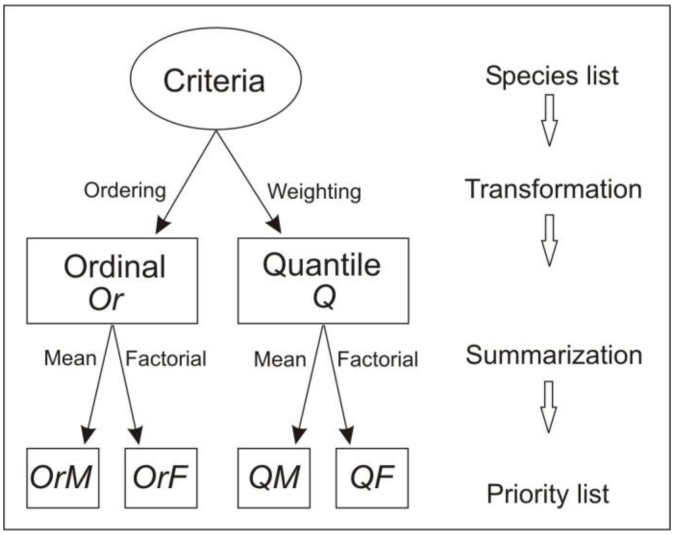

Figure 3 Relationships between the Conservation Priority Indices compared in this study, including determination coefficients (R^2) and the equation of linear regressions. Exact equality (single line) is compared with linear regression (dashed line) to better visualize the deviations.

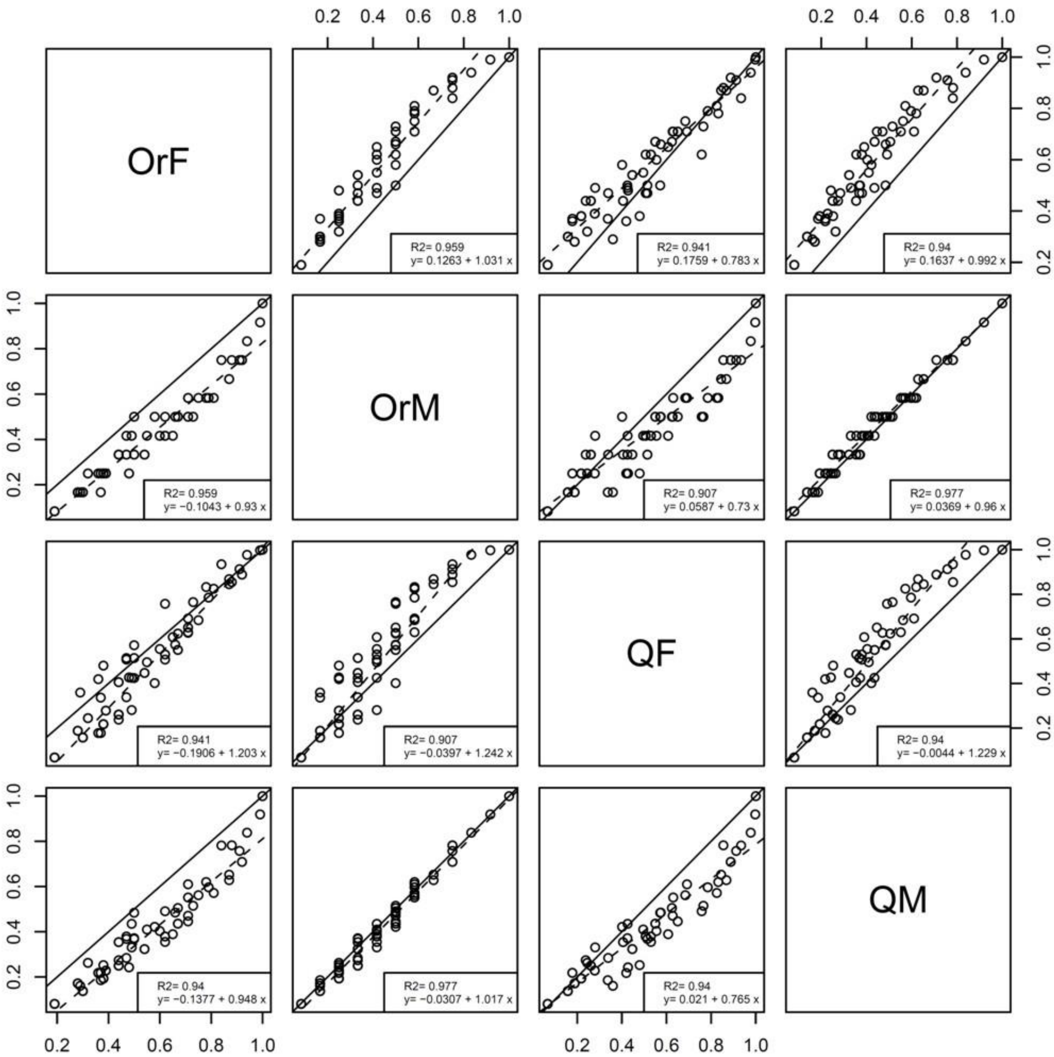

Table 1 Description of the criteria and classes used for assessing conservation priorities of vascular plants in the Cantabrian Range.

Criteria		***Classes***	***Description***
Threat (THR)	National status in Spanish Red List of vascular plants, according with IUCN 2001 criteria (Moreno 2008)	END1	Critically Endangered (CR)
		END2	Endangered (EN)
		END3	Vulnerable (VU)
		END4	LC, NT, other
Protection (PRO)	Legal conservation status following regional normative lists affecting the Cantabrian Range	PRO1	High extinction risk
		PRO2	Medium extinction risk
		PRO3	Low extinction risk
		PRO4	Not protected
Endemicity (END)	Endemiciy in relation to the Atlantic Biogeographical Region in Spain	END1	Microendemic (1 locality)
		END2	Endemic to the study area
		END3	Subendemic to nearest areas
		END4	Other
Rarity (RAR)	Area of occupancy (AOO), measured as a porcentual of UTM grid cells (10x10 km) occupied in the study area	RAR1	AOO = 1 % of study area
		RAR2	AOO = 2 % of study area
		RAR3	AOO = 3-5 % of study area
		RAR4	AOO > 5 % of study area

Table 2 Final scores assigned to the four criteria used in this study, according to Quantile (*Q*) and Ordinal (*Or*) transformations. Quantile transformations are based on the cumulative relative frequency of species (Rel. Freq.) according to the total number of species (*N*) included in the three most importance classes (see text for explanation).

CRITERIA	***CLASSES***			
Threat	*THR1*	*THR2*	*THR3*	*THR4*
Frequency	5	8	32	82
Rel. Freq. (*N* = 45)	11.1%	17.8%	71.1%	-
Q_{THR}	1	0.889	0.711	0
Or_{THR}	3	2	1	0
Protection	*PRO1*	*PRO2*	*PRO3*	*PRO4*
Frequency	3	27	91	6
Rel. Freq. (*N* = 121)	2.5%	22.3%	75.2%	-
Q_{PRO}	1	0.975	0.752	0
Or_{PRO}	3	2	1	0
Endemicity	*END1*	*END2*	*END3*	*END4*
Frequency	20	7	15	85
Rel. Freq. (*N* = 42)	47.6%	16.7%	35.7%	-
Q_{END}	1	0.524	0.357	0
Or_{END}	3	2	1	0
Rarity	*RAR1*	*RAR2*	*RAR3*	*RAR4*
Frequency	23	32	48	24
Rel. Freq. (*N* = 103)	22.3%	31.1%	46.6%	-
Q_{RAR}	1	0.777	0.466	0
Or_{RAR}	3	2	1	0

Table 3 Ranks for the 127 species of conservation concern assessed in the Cantabrian Range, according to the four CPI computed in this study (*OrM*, *OrF*, *QM and QF*, see Figure 2 for explanation). Species are ordered according to OrM and then OrF.

Species *	***OrM***	***OrF***	***QM***	***QF***
Tragopogon pseudocastellanus	1	1	1	1
Primula pedemontana	2	2	2	2
Ranunculus montserratii	3	3	3	3
Echium italicum subsp. *cantabricum*	4	4	7	6
Salix hastata subsp. *picoeuropeana*	4	4	7	6
Draba hispanica subsp. *lebrunii*	4	5	6	5
Androsace cantabrica	4	6	5	4
Quercus pauciradiata	4	8	4	8
Ranunculus parnassifolius subsp. *muniellensis*	5	7	8	9
Soldanella alpina subsp. *cantabrica*	5	7	9	7
Salix breviserrata subsp. *fontqueri*	6	9	13	11
Centaurium somedanum	6	10	12	12
Saxifraga aretioides subsp. *felineri*	6	10	12	12
Odontites asturicus	6	11	10	10
Ranunculus seguieri subsp. *cantabricus*	6	12	14	16
Juncus balticus subsp. *cantabricus*	6	14	11	15
Aster pyrenaeus	6	15	15	18
Fritillaria legionensis	7	13	16	13
Androsace halleri	7	16	21	19
Leontodon farinosus	7	16	22	17
Artemisia cantabrica	7	17	23	25
Drosera longifolia	7	17	23	25
Nuphar luteum subsp. *pumilum*	7	17	23	25
Utricularia minor	7	18	17	20
Cochlearia pyrenaica	7	19	19	22
Nepeta cantabrica	7	21	18	14
Saponaria caespitosa	7	24	25	38
Eleocharis mamillata subsp. *austriaca*	7	27	20	23
Cardamine raphanifolia subsp. *gallaecica*	8	20	28	21
Isoetes velatum subsp. *asturicense*	8	22	29	29
Orobanche lycoctoni	8	22	29	29
Paeonia mascula	8	22	33	26
Carex diandra	8	23	27	24
Centaurea janeri subsp. *babiana*	8	25	26	30
Juncus filiformis	8	29	24	34
Saxifraga babiana	8	29	35	42
Empetrum nigrum subsp. *nigrum*	8	31	30	27
Callianthemum coriandrifolium	9	26	36	32
Equisetum sylvaticum	9	26	36	32
Potentilla fruticosa	9	26	36	32
Callitriche palustris	9	28	32	28
Spergula viscosa subsp. *pourreti*	9	28	32	28
Spergula viscosa subsp. *viscosa*	9	32	37	40
Oreochloa blanka	9	33	31	35
Aquilegia pyrenaica subsp. *discolor*	9	34	34	37
Arabis serpillifolia subsp. *serpillifolia*	9	34	38	46

Artemisia umbelliformis	9	34	34	37
Nothobartsia alpina	9	34	41	44
Ephedra nebrodensis	9	34	41	44
Epipactis microphylla	9	34	41	44
Eriophorum vaginatum	9	34	41	44
Potentilla nivalis subsp. *asturica*	9	34	41	44
Saxifraga longifolia	9	34	41	44
Sibbaldia procumbens	9	34	41	44
Thalictrum alpinum	9	34	41	44
Callitriche platycarpa	10	30	42	33
Campanula latifolia	10	30	42	33
Adonis pyrenaica	10	35	43	43
Oxytropis foucaudii	10	35	43	43
Sideritis lurida	10	35	43	43
Bartsia spicata	10	36	40	31
Aethionema thomasianum	10	37	46	47
Allium moly	10	37	46	47
Anemone ranunculoides	10	37	46	47
Arenaria obtusiflora subsp. *ciliaris*	10	37	46	47
Astragalus turolensis	10	37	46	47
Cardamine pratensis subsp. *nuriae*	10	37	46	47
Carex atrata subsp. *atrata*	10	37	46	47
Carex rupestris	10	37	46	47
Myriophyllum alterniflorum	10	37	46	47
Platanthera chlorantha	10	37	46	47
Poa laxa	10	37	46	47
Primula integrifolia	10	37	46	47
Sedum alpestre	10	37	46	47
Sedum nevadense	10	37	46	47
Senecio boissieri	10	37	46	47
Utricularia australis	10	37	46	47
Apium repens	10	38	45	36
Carex muricata subsp. *muricata*	10	40	44	49
Diphasiastrum alpinum	10	40	44	49
Homogyne alpina subsp. *cantabrica*	10	41	39	45
Veronica mampodrensis	10	41	39	45
Sorbus hybrida	11	39	47	41
Androsace lactea	11	42	50	50
Atropa bella-donna	11	42	50	50
Baldellia alpestris	11	42	50	50
Barlia robertiana	11	42	50	50
Cardamine resedifolia	11	42	50	50
Carex capillaris	11	42	50	50
Carex frigida	11	42	50	50
Carex pyrenaica	11	42	50	50
Cerastium cerastioides	11	42	50	50
Dactylorhiza markusii	11	42	50	50
Epipactis palustris	11	42	50	50
Equisetum hyemale	11	42	50	50
Geranium pratense	11	42	50	50
Gymnadenia odoratissima	11	42	50	50
Lathyrus bauhinii	11	42	50	50
Lilium pyrenaicum	11	42	50	50
Lycopodium clavatum	11	42	50	50
Narcissus pallidiflorus	11	42	50	50
Orchis palustris	11	42	50	50
Orobanche teucrii	11	42	50	50

Primula farinosa	11	42	50	50
Pseudorchis albida	11	42	50	50
Pulsatilla rubra subsp. *hispanica*	11	42	50	50
Pulsatilla vernalis	11	42	50	50
Salix aurita	11	42	50	50
Salix repens	11	42	50	50
Sorbus torminalis	11	42	50	50
Tozzia alpina subsp. *alpina*	11	42	50	50
Ranunculus serpens subsp. *serpens*	11	43	49	39
Carex caudata	11	44	48	48
Eryngium duriaei	11	44	48	48
Hugueninia tanacetifolia subsp. *suffruticosa*	11	44	48	48
Nigritella gabasiana	11	44	48	48
Senecio legionensis	11	44	48	48
Equisetum variegatum	12	45	51	51
Gentiana ciliata	12	45	51	51
Horminum pyrenaicum	12	45	51	51
Huperzia selago	12	45	51	51
Menyanthes trifoliata	12	45	51	51
Ophrys insectifera	12	45	51	51
Orchis pallens	12	45	51	51
Swertia perennis	12	45	51	51
Taxus baccata	12	45	51	51
Triglochin palustre	12	45	51	51

* For detailed information about nomenclature and Spanish distribution range of any species, see the Spanish Plant Information System ANTHOS (www.anthos.es).

Table 4 Contribution of ordinal (*Or*) and Quantile (*Q*) transformed criteria THR (Threat), PRO (Protection), END (Endemicity) and RAR (Rarity) to the resulting Conservation Priority Indices (*OrF*, *OrM*, *QF* and *QM*), as detected by Pearson correlations (all indices were significant at $\alpha = 0.01$ excepting ^{ns}).

		Conservation Priority Index (CPI)				
		OrF	*OrM*		*QF*	*QM*
THR	(Or_{THR})	0.547	0.552	(Q_{THR})	0.877	0.759
PRO	(Or_{PRO})	0.770	0.783	(Q_{PRO})	0.146^{ns}	0.272
END	(Or_{END})	0.553	0.549	(Q_{END})	0.776	0.728
RAR	(Or_{RAR})	0.709	0.725	(Q_{RAR})	0.420	0.552

Table 5 Agreement between the four CPI (*QM*, *QF*, *OrM* and *OrF*) when different funds (counted in €) are available for allocating resources. N_1 indicates the total number of species equally classified in the contingency tables, and N_0 those included in one List but excluded in the other, or vice versa; *k* indicates the Cohen´s Kappa value of concordance assigned by each contingency table.

		OrM			***OrF***			***QM***		
		N_1	N_0	*k*	N_1	N_0	*k*	N_1	N_0	*N*
QF	*50.000 €*	15	4	0.864	15	5	0.834	15	4	0.864
	100.000 €	33	6	0.884	31	8	0.842	32	6	0.882
	200.000 €	47	22	0.652	49	15	0.761	47	15	0.759
QM	*50.000 €*	17	0	1	16	3	0.901	-	-	-
	100.000 €	35	2	0.961	32	6	0.882	-	-	-
	200.000 €	52	13	0.795	52	10	0.841	-	-	-
OrF	*50.000 €*	16	3	0.094	-	-	-	-	-	-
	100.000 €	33	6	0.884	-	-	-	-	-	-
	200.000 €	56	9	0.858	-	-	-	-	-	-