The nature of threat category changes in three Mediterranean biodiversity hotspots

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Step changes in threat category can be quantified and analyzed in relation to reasons for the change or threat intensity in Red List classifications. First, we studied the reasons contributing to changes in the conservation status of more than 2800 threatened plants in California, Spain, and Western Australia over a 10 year period. Second, we investigated the reported threats to these species and their association with particular step changes in the Red List categories.

Results indicated that the reasons for step changes are varied and not necessarily linked to the types of threat processes affecting the species, nor actual conservation outcomes. In fact, increasing knowledge about a species from one listing date to the next is the most frequent cause of change in all studied territories, with all regions showing a general upgrading (more threatened) trend in threat category. Threats originating from human activities represent more than 80% of all threat types. The most frequently reported threats in California and Spain are related to population density, whereas in Western Australia threat types are modulated by human presence rather than human abundance. A strong relationship between increasing risk (upgrading in threat categories) and threats derived from human activities was found only for Spanish plants. Nevertheless, when conservation reasons are the cause for a category to change, they are associated with direct upgrading of species in Spain and Western Australia.

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1. Introduction

Red listing is a fundamental strategy for species conservation. Originally applied as a method to establish game control for hunting industries in Africa, it became a successful tool in threat analysis for vertebrates during the 1960s, and later was extended to plants (Walters, 1971; Scott et al., 1984). Red listing is now applicable to the whole compendium of biota on Earth and enables conservation practitioners to rank threatened species according to their threat status. Specifically for plants, a Red List is a floristic catalogue where plants are classified according to their level of threat. Usually these Red Lists are produced utilizing the expert opinion of the scientific community (academics, conservation managers, professionals and amateurs) and any quantitative data available for the species. They discuss and evaluate conservation problems and risks of those species considered to be threatened, and test known data against criteria thresholds, to arrive at a consensus on conservation status and the Red List category of threat for each plant species.

The most wide-spread classification system has been developed under the auspices of the International Union for the Conservation of Nature (IUCN) since the last century (Holdgate, 1999). Currently, the IUCN system classifies threatened species into threat categories (critically endangered, endangered, and vulnerable) following qualitative and quantitative criteria based on range and population size, condition and demographic trends (IUCN, 2010). A Red List summarizes the conservation knowledge of the species at a particular time, so it is important to produce Red List assessments on a regular basis to identify changes in the status of the biota and specific conservation trends.

Regular assessments are one of the few tools to show the changing nature of conservation status across time (Bailie et al., 2008; MEA, 2005; Nichols and Williams, 2006), with important advances being made in such assessments for some taxonomical groups (see for example: Butchart et al., 2004; Brooke et al., 2008). However, little is known about the mobility of plants across threat categories (Schatz, 2009); that is, how fast and how far do plants move along...
the conservation category continuum from one Red List to the next one to produced.

There are several factors contributing to changes in the conservation status of plants. Plants step down or up in a Red List for reasons related to conservation matters (worse or better scenarios) but not exclusively. For example, the work of taxonomists lumping or splitting taxa may produce down or upgrading respectively. In addition, improvement in knowledge of the taxon relating to its conservation status is also a factor affecting movement across categories. Finally, classification systems are not immutable; they evolve according to the improvement in knowledge in conservation biology, whether in new methods or in new concepts (Possingham et al., 2002; Rodrigues et al., 2006; Mace et al., 2008). Therefore changes in category definitions and limits as well as criteria used for the category assignment, have been and will be in constant change following progress in plant conservation science.

Those reasons shape the movement of plants across conservation categories. But, are particular reasons producing biases in conservation trends? In other words, if some reasons produce movement in IUCN categories in a particular direction, and those factors are predominant, we may expect under- or over-estimation of conservation trends.

To explore this idea we proposed our first null hypothesis as “changes in categories have no sensitivity to the reason or factor dominance”. If the null hypothesis is rejected we may find that some changes may be more affected for a particular factor than for others. For example, changes in taxonomy may produce a concentration of critically endangered species due to taxonomic splitting, or, changes in knowledge may produce a high amount of species moving to lower threat categories because more populations or individual are discovered.

Reporting threats in plants is closely associated with Red listing and conservation status assessments (Wilcove et al., 1998; Coates and Atkins, 2001; Burgman et al., 2007). For that, it is necessary to know which are the most important threats for a particular biota; how these threats are affecting the threatened taxa across their area range; and what emerging patterns may arise. One may expect that causes or origin of threats are highly idiosyncratic depending on location. They also may depend on the quality of information which in turn depends on intensity of field surveys and the level of taxonomic knowledge, among other things (Possingham et al., 2002).

In spite of these issues it is possible that some types of threats may be associated with particular step changes in categories. For example, threats associated with land use changes are more prone to produce real conservation upgrading of threatened taxa than other types of threats that are more difficult to quantify, such as those related to stochastic environmental changes or intrinsically biological problems such as lack of pollinators or natural competition. This is especially the case when monitoring spans relatively short time frames compared to the generation time of the taxon. Thus, our second null hypothesis is: “threat type is independent of step changes in threat category”.

To test these two hypotheses, we used data from three Mediterranean-type ecosystems (MTEs): California, Spain and Western Australia. MTEs share particular distinct evolutionary conditions (considering plants see for example Cowling et al., 1996), and are one of the most densely human populated and diverse biomes in the world (Underwood et al., 2009). MTEs tend to have well established threat processes such as land clearing, grazing or fire disruption which interact with novel risks (introduced species, urban development, natural areas fragmentation, etc.). There are also a profusion and diversity of conservation resources (in comparison with other areas of the Globe) able to be directed at managing threats and threatened species. The diversity of both conservation problems and resources available to combat them in MTE may enable us to draw some general conclusions to better manage biodiversity losses in other parts of the World. One tool available to assess the net effect of these factors is plant Red Lists, which have been systematically produced since the 1980s in some of these Mediterranean regions. Such plant Red Lists have been produced by scientific communities in California, Spain and Western Australia.

2. Methods

2.1. The lists

For the Spanish threatened flora we used two currently published lists, one produced in 2000 (AV, 2000) and one published in 2008 (Moreno Sáiz, 2008). Although 8 years apart, the rationale and the methodology used to produce both lists are similar. In summary, regional, local and monographic experts were contacted across the country; they propose the plants and categories from within their area of expertise, and in a final workshop develop an overall threatened species Red List.

For Western Australia (WA), the process of Red listing differs because the taxonomic and conservation knowledge of a much richer flora remains relatively incomplete. Two main approaches have been taken for listing plants in WA:

1. Only species that have had sufficient surveys to provide field information on the status of the species were candidates to be listed (other potentially rare or threatened species are assigned to the poorly known or data deficient category).
2. Species considered to be threatened and requiring conservation actions are assessed against IUCN criteria and listed. Due to the large number of potential species to be considered, those that could meet IUCN criteria but are not considered to be threatened were not a priority for listing. This mainly applied to those which met IUCN category VU D2.

Data for the WA Red Lists as produced in 2000 and 2008 was obtained from the State government conservation agency (Department of Environment and Conservation), which manages the lists and the listing process. For the threat analysis, only the top four threats as determined by local flora experts were identified for each species (see online Supplementary material for details).

Finally, the California Native Plant Society (CNPS) maintains lists of plants that qualify for various degrees of protection in their online Inventory of Rare and Endangered Plants (www.rare-plants.cnps.org). This organization has been active in threatened plant cataloging since the production of its first list in 1974 (AV, 1974). We compared changes in the California Native Plant Society’s system using data from the 2001 Inventory (CNPS, 2001) and present information from the online Inventory (as retrieved in March 2010). It is noted, however, that the online Inventory represents a progressive re-assessment of the conservation status of Californian species since its 2001 publication, and not a systematic re-assessment as has occurred in the Spanish and Western Australian floras.

In order to compare trends in the three selected territories, we only considered those plants that were ranked as threatened under IUCN categories. Usually conservation listings produce two main groups of floras: those with clear threats and included in formal Red Lists, and those considered rare or subject to conservation concern but without enough qualification (normally because they are not considered to be threatened or because they are data deficient). This study focuses on the former listing approach.

For Spanish and Western Australian plants, we compared all species listed as threatened on the Red Lists in 2000 (i.e. with a risk
category of VU, Vulnerable, or greater) with those similarly listed in 2008. Thus, species not in the 2000 list, or with a lower than VU category in the 2000 list, are only included in the comparison if they appear in the 2008 list in any of the threat categories (VU or above). In addition, we ruled out species changes due to mistakes or those species where a reason for a change cannot be identified. The total flora included in the analysis for Spain was 1040 plant taxa, and 432 for the WA flora.

The Californian data-set does not follow the IUCN system for threat category determination but uses a system developed by the CNPS. We produced a series of transformations to make both systems compatible (see online Supplementary material). In total, 1392 plants were selected as putative threatened flora under IUCN criteria from the CNPS lists.

Category movements in the CNPS and IUCN system are different. This is a drawback in our analysis because step length is not proportional, and one step move in the CNPS system does not necessarily correspond with one step move for the IUCN system. This potential bias may not be significant for the purpose of this analysis because both systems have the same step span, that is, five steps from the lowest (i.e. not being included in the lists) to the highest classifications (extinct for IUCN system and 1A for CNPS).

Finally, the three regions selected for this analysis have Mediterranean climates, although the Mediterranean climate zones do not extend over all of each region. In the case of California and Spain, the Mediterranean climate zones account for a large proportion of the administrative region, and the flora included in this study are primarily of Mediterranean plants. However, for the Spanish analysis, taxa occurring in the Canary Islands (non-Mediterranean) were excluded, because of its distinctive biogeography (patterns of species richness, endemism and endangerment are highly unique to this volcanic archipelago) (Caujapé-Castells et al., 2010). Western Australia has a different climatic zoning, with only the south west corner of this large state being within the Mediterranean climate zone (taken as the Southwest Floristic Province (Beard, 1990)). This southwest corner is a floristic hotspot (being a global biodiversity hotspot (Mittermeier et al., 2004), and includes the majority of the listed Western Australian threatened flora. Indeed, only eight species (5%) of the threatened flora that showed changes in their conservation status over the time of this study were from outside the Mediterranean climate zone.

Thus, while the analyses for these regions are not restricted to Mediterranean plants, they are primarily relating to this region, and are indicative of the threat processes impacting Mediterranean flora.

2.2. Reasons controlling changes

Five types of reasons for movement in threat categories were used in this analysis:

1. Criteria revision. This only applies to the IUCN system and is due to changes in thresholds of some particular criteria. The vulnerable category threshold for criterion A was set at 20% ongoing reduction of individuals in the 1994 classification (IUCN, 1994), and changed to 30% in the 2001 system (IUCN, 2001). Similarly, the criterion D2 threshold for vulnerable category changed from 100 km² to 20 km².

2. Improved knowledge. Threat categories can change due to increasing information about the real status of the plant, mainly through a better knowledge of its current distribution or population censuses. Some of these changes are related to minimization of the uncertainties of the endangerment processes or to a better understanding of the risk level of potential threats.

3. New findings. Findings of new populations of species known to occur elsewhere outside the studied territories (also known as novelties), and discoveries of new species, were considered to be an independent reason for change. Although strictly speaking, these movements in IUCN categories are also derived through improved knowledge of the flora.

4. Conservation. This measures a genuine, real change in the status of plants in the time between the two listing assessments. They are linked to direct improvement or weakening of conservation practices, or the effect of threat processes.

5. Taxonomy. Changes in the two assessment period Red Lists that are related to taxonomic studies that occurred during that period can result in increased or decreased threat status. As a result of taxonomic revision, some former taxa have been reduced to synonymy while others are now considered minor taxonomic entities (varieties or forms). Equally, taxonomic changes in categories are also produced due to splitting of species to sub-specific ranks.

Reasons for change assignments have been extracted for the three studied territories based on several sources of information related to ongoing plant databases and experts involved in plant classification in their respective zones (see online Supplementary material for more information). We developed a common classification system to enable a comparison of threats across the different data sets. Here we defined threat as any activity or process that is natural or artificial that ultimately produces a reduction in species abundance or capacity to sustain or grow in number. Artificial activities or processes are directly caused by human intervention. What are termed “natural threats” are derived from intrinsic factors, related to particular traits of rare species such as narrow habitat requirement, inbreeding depression, lack of dispersal, and low population numbers, that would be expected to contribute to the extinction of the plant population. Problems with this definition arise when the same intrinsic factors may come into effect after, and only after, a human-related intervention. For our classification purposes, these factors were not considered to be natural threats but rather consequences of a particular human-related threat. In other words, low plant population numbers, lack of dispersal or low genetic diversity, were only considered as threats provided their origin was natural. If low population numbers, low genetic diversity and others factor are only acting as a threat due to the effect of a prior human activity they were not considered intrinsic threats, but were treated as increased sensitivities to other threats.

Under this definition we produced a classification system based on three binary factors qualifying the threats: threat origin, time span, and spatial impact (space loss).

1. Origin: Human- or non-human-related. Threats were evaluated according to their link with major human activities impacting the species or their habitat, such as agricultural activities, livestock or housing development. The human link may not be operating at present, but may have in the past. Thus, some threats affecting population performance such as diseases or competition with non-native plants are not directly related to present-day human activity, but past human activity was the direct initial cause of the problem. Some threats have indirect relationships with human activities but they are treated as non-human related in our study. For example, natural grazing cannot be considered human related although we understand that due to present human caused habitat alteration, densities of natural plant predators may not be natural. In the same sense, hybridization is a natural threat but highly influenced by human activities where once geographically distinct populations are juxtaposed leading to hybridisation potential.

2. Time span: Stochastic or within the human timeframe. This factor considers time in the classification. When the time span for...
occurrences of a particular threat is outside an anthropogenic window (i.e. 100 years) or unpredictable, we classified them under stochastic. Therefore, a non-stochastic threat possesses a predictable, high frequency or permanent occurrence.

3. Spatially related: We took into account space loses in the proposed classification, i.e. land alteration or the loss of habitat. Thus, some threats are due to sudden consumption, alteration or loss of habitat directly linked to losses of individual plants or even populations, such as through urban sprawl, vegetation clearing for agriculture, forest plantations or expansion of transport infrastructure, and flooding. Other threats (grazing, natural competition, storms) although able to produce space alteration and individual losses at the time they occur, do not necessarily result in permanent or irremediable changes in space. This is a feature of the resilience of the system.

Eight threat classes were defined using the combinations of these three binomial factors (see Table 1).

To evaluate the reasons for change, we first tested the differences in category movement among the five reasons using a chi-square test. The null hypothesis (“changes in categories have no sensitivity to the reason or factor dominance”) assumed that the average step change in categories was independent of reason for that change. This analysis was able to identify reasons underpinning different trends in category changes. To identify which particular step changes were more important for each reason we used a Fisher’s exact test applying the algorithm independently to each explanatory variable (i.e. each reason). The null hypothesis was that the probabilities for each outcome or step change in IUCN categories are independent of the reason for such a change. We performed this analysis for those reasons where average step changes were not significant in the chi-square test. By performing these two analyses, we were able to first determine which reasons were inducing status change, and secondly if a particular level of change was more frequent for a particular reason than for others.

2.3. Threats analysis

We identified the reported threats to each taxon from available information to analyze the probable causes of change in threat categories using the classification system based on the three binary factors (threat origin, time span, and spatial impact (space loss)).

For each species in each territory the corresponding threat class was assigned to each threat, and a species-by-threat class score matrix produced. Sums over species for each threat class were calculated. Finally, we tested the hypothesis “threat type is independent of step changes in threat category” by determining if the score sum of each threat class was different for each group of plants defined according to reasons of change.

More specifically our null model consists of random draws of species from the total data set with sample size equal to those for each group of plants. We defined two plant groups: ‘conservation reason’ and ‘no change category’ group plants. One took into account those plants that experienced genuine changes in conservation status; category “conservation” in our previous analysis. The second group was established for those plants with no changes at all in the studied period, plants under “No change” category from our previous analysis. We produced 5000 Monte Carlo iterations and lower and upper confidence intervals of each sum were calculated for each plant group.

3. Results

3.1. Reasons for category changes differences

Fig. 1 shows that Spanish and WA threatened plants behave more similarly in overall patterns in the underlying cause of category movement, and California represents more of an outlier. This is especially obvious for the large proportion of plants that experienced ‘no change’ across the analysis years in California. This outcome may be attributable to the lack of a complete reassessment of all plants in the CNPS Inventory. Therefore, an unknown, but potentially large number of taxa that are included in the ‘no change’ category mirror a general knowledge deficit regarding their status. This is also supported by the small fraction of plants that have changed threat category in California due to increasing knowledge of their actual conservation status (both proportions produce statistically significant differences in respect to Spain and Western Australia, *χ² = 0.012, χ² = 0.449, p values <0.05 in both cases). The proportion of WA ‘no change’ species during this period represents up to 65% of the 432 total threatened species considered, whereas Spain, with more species under the IUCN system, has produced a slightly more dynamic assessment (43.4% taxa experienced no change from 1040 taxa).

Proportions of remaining reasons were fairly similar in the three areas. Most importantly, we found a low percentage of ‘conservation changes’ across sets of threatened plants during these years. Only 12 taxa out of 432 in WA (2.8%) and 89 out of 1040 Spanish endangered plants (8.5%) moved from one category of threat to another that reflect genuine changes in their conservation status. The most striking figure is for California where only three species (0.2%) experienced real conservation status movements.

Taxonomic reasons and new findings (related to new species descriptions) share similar values in the three territories. This comes as a surprise for California plants, because in spite of the issues relating to a lack of knowledge, this seems to have not affected the pace of new discoveries in this territory. Thus, Western Australia and especially Spain and California have similar rates of new species included in Red Lists.

3.2. Steps metrics

In relation to pace of movement in categories, the three regions show an upgrading trend, which means that on average more plants have been increasing their threat levels than plants that have declined in threat status. These results are independent of territory, but the largest movements are in Western Australia (average of 0.9 steps) and the lowest in California (0.25 steps) (Table 2). Table 2 also summarizes step changes by reason in each territory indicating that only new discoveries are significantly different from their respective overall means in all regions. In fact, these changes are the only significant movements for Western Australia plants (see online Supplementary material for further detailed results).

We considered the remaining reasons for changes in threat categories in the three areas: conservation, knowledge and taxonomy, in a further analysis, in order to identify which were the most

<table>
<thead>
<tr>
<th>Class</th>
<th>Definitions</th>
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<tbody>
<tr>
<td>HSS</td>
<td>Human, stochastic and space related</td>
</tr>
<tr>
<td>HSnS</td>
<td>Human, stochastic and non-space related</td>
</tr>
<tr>
<td>HnSS</td>
<td>Human, non-stochastic, and space related</td>
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<tr>
<td>HnSnS</td>
<td>Human, non-stochastic, and non-space related</td>
</tr>
<tr>
<td>nHSS</td>
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<td>nHSnS</td>
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<td>nHnSnS</td>
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important movement classes in categories for those reasons (Fig. 2). This was intended to provide a better understanding of the reasons driving changes across categories in these regions.

There is a consistent pattern in some areas related to the effect of conservation reasons in step category changes (Fig. 2, solid bars). Conservation reasons are mainly associated with direct upgrading of species both in Spain and in Western Australia. Consequently, there is significantly less downgrading than expected for conservation reasons in both territories, being particularly apparent for Spanish plants (just one plant has been downgraded during this period). The most substantial upgrading is related to one, or less than two, steps (mild upgrading) in both cases, which means conservation updates are the more likely cause for ranking plants less than two steps in both regions. Supporting these findings, it is also the fact that there is a significant difference for the WA flora in the case of highly substantial change (more than two steps). Thus, there are fewer plants upgrading two steps or more than expected for conservation reasons in this case, meaning that especially for WA plants conservation reasons mainly produce mild upgrading. Unfortunately, Californian data related to conservation reasons are so scarce (just three species have been reclassified) that little can be concluded.

With respect to underlying knowledge reasons, none of the category change steps in Spain depart from expectations (Fig. 2, dark gray). But for WA plants, there is a lower than expected number of plants increasing less than two steps in category ranking due to better knowledge of their populations. In other words, knowledge has produced less mild upgrading than expected in WA. This is the opposite reported for California, where there is a larger proportion than expected of plants being upgraded in less than two steps due to an improvement in their real status. Thus, improving the knowledge of the threatened flora has produced an even distribution of the magnitude of category changes in Spain, whereas in Western Australia more extreme upgrading was more frequent, and in California mild upgrading was the most frequent effect of increasing knowledge.

Taxonomic reworking produces an effect on ranking in Spain (Fig. 2, light gray). In particular, taxonomic reasons produce more downgrading and less than expected mild upgrading for the average reason (average step change of all reasons considered) in the Spanish flora. On the contrary, values of category changes in WA and Californian plants due to taxonomic reasons do not depart from those expected if taxonomy would have no effect on change steps distribution. Taxonomy is thus only a factor of unevenness in category movement in Spain.

In summary, the most important trend relates to conservation reasons for category shifts, supporting consistent mild upgrading in both Spain and WA. In addition, increasing knowledge in WA produces more robust upgradings or downgradings than expected. The movement across the threat ranking due to the effect of increasing knowledge is highly idiosyncratic for each particular region. Finally, taxonomic reasons were identified as a factor in Spain that produces some bias in category movement, which is not the case for Western Australia and California.

### 3.3. Threat type distribution

Using a normalized classification of threat types allows a direct comparison of territories, avoiding biases inherent in each classification. The most significant result in relation to threat classification is that classes related to risks originating from human activities represent more than the 83% of all threat in all areas combined (see row \( \sum_{H} \) in Table 3).

The most common class combination is ‘human, non-stochastic events and lack of space’ (class HnSS in Table 1), being consistent among the three areas (representing an average value of 32.6%). The two other classes related to human risks (HSnS: human, stochastic and non-space related class; and HnSnS: human, non-stochastic, and non-space related) are also numerous but the WA data diverges from that for California and Spain (see Chi square probability values in Table 3). This, WA represents an opposite trend for these two classes. Among the non-human related classes, the most common is nHnSnS (non-human, non-stochastic, and non-space related) for Spain and California. ‘Non-human, stochas-

![Fig. 1. Threatened plants distribution according to reasons for change in threat categories since 2000.](https://example.com/fig1.png)
tic, and non-space related' class (nHSnS) is the most common class for WA, with the class differences being statistically significant (Table 3).

Finally, two out of eight possible combinations of threat classes do not produce any reported threat type: HSS and nHnSS.

3.4. Threat types and category movements

Are plants that experience no change in their conservation status across these years associated with some particular threat classes? Fig. 3 shows that this only holds true for Western Australia, and just for one particular class, HnSS, as the null model produced a lower interval larger that the real sum of scores for this threat class in this group of plants. Thus, on testing the hypothesis of threat type being different from the total pool of WA threatened plants, only this threat class for the no change group was statistically significant.

Spanish and Californian plants with no category movements do not depart from average threat class distribution, and no particular threats are related to these types of plants.

When considering plants that changed their conservation status specifically for genuine conservation reasons, only Spain provided a sample size large enough to be randomized with a null model (right bottom corner on Fig. 3). There are several threat classes that are expressed in this group of plants differently from the average pool. Most importantly, all human related classes, HSnS, HnSS and HnSnS, are positively linked to this type of category movement.

4. Discussion

4.1. The ‘knowledge factor’, steps metrics and monitoring programmes and indexes

This analysis shows that Red Plant Lists are dynamic, with plant threat classifications changing temporally. The reasons for these
changes are varied and not necessarily linked to the types of threat processes affecting the species. Most of the observed changes in threat category were determined by causes not directly related to natural conservation changes, with increasing knowledge about a species from one listing date to the next being the most frequent cause of change in all studied territories.

This ‘knowledge factor’ is explained by an uncoupling of actual changes in conservation status from the information needed for the less data-demanding criteria. Thus, the most frequent process sequence is to classify a plant based on already available data, which is often scarce, or based on rapid prospecting of easy to collect/readily accessible information. Then in later revisions, conservation classifications eventually use more accurate, data-rich assessments. For example, plants often are originally listed using criteria related to rough estimates of area of occupancy or number of populations, some of the first pieces of information readily available in rare plant surveying and monitoring. It is only later that a more precise classification will be performed, due to improved survey effort, more accurate measures of range size and populations, monitoring data of population trends, and improved data quality from specific conservation studies (for example those resulting from the implementation of Species Recovery Plans). These improved data are often obtained as a direct result of the species being listed and thus being identified as requiring conservation effort.

In relation to step metrics, even though the threat processes are diverse and regionally specific in some cases, all classification systems showed increasing endangerment for the Mediterranean floras during the study period, and all regions registered an average increase in threat status. There are clear cases both in Spain and Western Australia where threatened floras experience similar category shifts. Plants in these regions tend to undergo upgrading more frequently than downgrading. This indicates that overall, these geographically, phylogenetically and culturally different floras are facing increasing conservation risks. During the 10-year study period, the classification systems were able to show little positive impact of conservation practices, rather, there was an alarming increase in the taxa being upgraded in conservation status.

The analysis of the threatened flora of these territories has shown that increased knowledge is the leading cause of category shifting in all territories. But, particular step changes are highly idiosyncratic and regionally specific. For example, the fairly wide use of IUCN Vulnerable D2 sub-criteria in Spanish threatened plants in the 2000 list, resulted in a high proportion of plant status downgrading when the threshold for this criterion changed for the 2008 list assessment. For Western Australian plants, results indicate that new discoveries is the only reason producing statistical differences in category movements in this flora (see Table 2).

Taxonomic realignment is also a factor of variability in conservation assessment (Isaac et al., 2004; Agapow and Sluys, 2005), but taxonomy per se is not generally regarded as a significant factor in category distribution, at least in Iberian rare plants (Domínguez Lozano et al., 2007). However, this study reveals that taxonomy has a downgrading effect in some of the studied areas (i.e. Spanish flora).

These results have profound consequences for biodiversity assessments and monitoring. First, there will be a lag time for the Red listing process to be reflective of accurate, real conservation trends for plants. As most of the shifts in classification status depend on the knowledge and data available at that time, it is important, rather than to deal with uncertainty (Akcakaya et al., 2000), to reduce it in a consistent, systematic way. The level of information requirements at the time of assessing the conservation status of a species thus needs to be well defined in terms of the survey extent or monitoring data available, depending on the criterion being used (e.g. for IUCN: the size, area, extent and/or condition of the population or habitat of the species, or monitored change in
these attributes). Species that do not meet these standards should be assigned to the ‘data deficient’ category until such data is made available to enable a transparent and reliable conservation status assessment to be undertaken – but this may not always be practical where a flora is generally poorly known and conservation priorities need to be established.

Threat classification systems for biodiversity monitoring (Lughadha et al., 2005; Schatz, 2009) and in particular for Red Indexing (sensu Butchart et al., 2005), require some level of baseline data to mark the starting point of future trends or to calculate sound indexes. However, the paucity of conservation knowledge for an important portion of species usually means a delay in setting the baseline until the “knowledge factor” is adequately addressed. Equally, there will be limited capacity to audit the effectiveness of conservation measures using information provided by the lists until there is an adequate and similar amount of information available for all species. Nevertheless, category movements in threat classification systems do contribute to our understanding of conservation issues including taxonomic activity, survey effectiveness, and level of conservation awareness and activity.

An intriguing aspect of our analyses is how these three Mediterranean areas, truly hotspots in the global conservation arena (Cowling et al., 1996; Médail and Quézel, 1999; Mittermeier et al., 2004) and with a long tradition and resources devoted to plant conservation, produce so few plants with genuine conservation changes across the Red Lists over the 10 years of our analyses. On the basis of our results there are several potential causes. The Californian case has an apparently clear cause – not all plants have been fully reviewed from one list to the other, as a result the “no change” group of plants is clearly overestimated, with the remainder being consequently underestimated. At the moment, prioritization occurs on the basis that only plants that occur in development projects and have immediate associated threats are reviewed urgently. It is thus evident from this study that resources should be directed to regular reviews of the status of threatened plants in California to identify trends that may be occurring in this flora. Recent initiatives have been launched to reverse this trend (see for example treasure plant hunt CNPS initiative).

Increasing threat assessments, although being a key factor, however, do not assure conservation movements. Western Australian and Spanish species have been fully reviewed from one listing to the next and they experience a similar low proportion of plant shifts for conservation reasons. The lag time between some classification criteria thresholds and response time for some variables to be expressed in plants may explain these results.

Plants have some biological properties that may buffer the negative impact of some threat processes. Seed and seedlings banks, clonal growth, and asynchrony in plant productivity or mass seedling, all act to buffer demographic traits (Schemske et al., 1994). Complex and diverse breeding systems (Charlesworth and Charlesworth, 1995), polyploidy (Ramsey and Schemske, 2002), and the ability to cope with low genetic diversity (Ellstrand and Elam, 1993; Rieseberg, 2001) are also factors contributing to species resilience to threat processes.

It is also important to note the effect of rarity in Red listing. Many threatened plants in our study lists are the consequence of natural ‘intrinsic’ rarity (Fiedler, 1995; Domínguez Lozano et al., 2003). Therefore, it is understandable that these species will experience little or no improvement in their conservation movement due to their naturally restricted range distributions, whereas a deterioration of their status may occur if a threat process is causing further impacts. Changes in status in these taxa over a short period such as the 10 year period used here, invokes the precautionary principle where downgrading of a species is seldom done unless conservation measures are being highly effective in mitigating threats and enabling the recovery of the species.

In summary, the data indicate that the current classification systems for threatened flora do not adequately reflect the current threat processes, or the impact of conservation measures. Firstly, the criteria thresholds of such classification systems do not provide a quick response or early warning (sensu Hellawell, 1991), and secondly they allow the possibility to classify species using low quality data that obscure an accurate picture of general conservation patterns.

However, we believe that objective threat classification systems should play an important role in reporting biodiversity changes. They provide a systematic way to complement or add information to other monitoring techniques, for example they are fundamental to pinpoint and measure the effect of long-term, major stressors on species conservation. They are fundamental inventory tools able to show which are the major threats to the biota over time (see for example Wilcove et al., 1998). They can also be used to triage biological properties with the endangerment process (Sjostrom and Gross, 2006) or for assigning priorities for preventive conservation and species recovery (Prugh et al., 2010), or to report taxonomic activity.

4.2. Threat classification and threat analysis

This analysis has shown that when a threat is reported for Western Australian, Spanish or Californian plants, there is a 0.83 chance that this threat will be related to human pressures. Not surprisingly, this trend was also found in other studies (Araújo, 2003; Burgman et al., 2007; Messick, 1997).

More specifically, the most common threat class reported in the results (HnSS) combines threat types reporting risk derived from public works (transportation and housing in all regions) and natural resource exploitation (such as mining for California and Western Australia, and logging for California) or land use change related to agricultural exploitation in Spain. In spite of this shared pattern among the three territories, the results report differences in threat class distribution as well. HnS are not so frequent in California and Spain (examples are non-native plant impacts in California: 7.4%, and fire for both territories: 2.4% and 5% respectively, see Table S1 in online Supplementary materials) but extraordinarily frequent in WA (difference with statistical significance, see Table 3). Thus, lack of habitat, altered fire regime, the impact of weeds and pathogens represent up to 65% of all reported threat types for the WA flora (see Table S1 in online materials). In contrast, the HnSnS class is more common in California and Spain than in WA. This class includes threats derived from the effect of grazing (herbivory and trampling) and recreational use (vehicle or foot traffic) on public use land.

The non-human related class, nHnSnS (non-human, non-stochastic, and non-space related) includes threat types such as narrow habitat requirements, natural competition, predation or hybridization in California and Spain. The non-human, stochastic, and non-space related class (nHnSnS) represents drought and increased temperature, and lack of pollinators or dispersal, in Western Australia.

The HSS and nHnSS classes do not include any threat types due to there being few possibilities for a threat being classified as stochastic and human related, because most threats related to human factors have a human timeframe as well.

One important conclusion can be drawn from this analysis: the most frequently reported threats in California and Spain are related to population density rather than human presence alone (63.6% in California and 35.2% in Spain) in agreement with ideas expressed in previous works (Araújo, 2003). Thus human population density-dependent actions such as trampling, road infrastructures, urban sprawl and grazing, often due to increases in human populations in rural environments, are examples of this type of
threat. Western Australia in contrast, with just 2 million people, has a low population density but high impacts due to a concentration of that population in the species-rich southwest Mediterranean region, and associated ‘industrial’ large-scale approaches to clearing for agriculture in this region. This has led to, or exacerbated, threat types not modulated by human abundance but human presence: lack of habitat, habitat fragmentation, alteration of fire regimes (too frequent fires or prescribed burning at ecologically inappropriate times), the effects of pathogens, or weeds/pests (summing up 60.9% in total). Those threats will be especially conspicuous in more pristine environments where non-subsistence human activity is recent (<200 years for WA) and linked to post-European occupation of the landscape.

Threat analysis is fundamental for understanding the conservation of species, improving the accuracy of listing assessments in the future, and assigning more informative threat classifications. Expert opinion has been used extensively for Red listing, with increasing use of observational data on populations and trends. Although demographic and distribution status are clearly stated in the form of criteria in current threat classification systems, there is little reference to the causes or origin of these factors. Thus, we may have quantitative temporal data on species demography and occupancy, but little may be known about the types of threat underpinning these trends. As a consequence, we show that although classification results are equal and in practice any flora could be classified according to the same IUCN criteria, the inconsistencies produced in reporting threat types and their effects make current classifications highly idiosyncratic and less comprehensive than expected.

In addition, ranking threats according to expert opinion, and limiting the number of threats for some of this analysis (see Section 2), produced other issues. For example, the effect of a widespread threat to a larger proportion of the threatened flora may be underestimated in preference to more immediate threats. This is demonstrated in the WA study where only the top four threats for each species were used in the assessment. For example, Phytophthora dieback in the WA flora, is a well-known, pervasive, and highly threatening factor to much of the (common and rare) flora of the biodiverse Southwest Floristic Region (Burbidge et al., 1977). However, the listing indicates just a small proportion of taxa are directly threatened by what has now been termed the ‘biological bulldozer’ (Table S1 in online Supplementary material). This apparent under-reporting may be due to a bias that often arises with expert opinion, or more likely the longer term and more insidious nature of this threat process compared to some other threats which are having current and obvious impacts on the flora.

Efforts should be made to produce a more systematic approach to assess threats for Red listing that allow comparison between different areas and precise identification of threat factors. Two main actions are recommended:

1. Implementation of a world-wide classification system of threat types. Results of Red Data List and Books provide a useful and reasonably robust starting point together with the Threat Classification Scheme of IUCN.

2. The development of a method to report not only the diversity but the intensity of threats, such that, as pressures increase and threats compound, a species will shift into a higher threat class. It is important here to focus not just on the effect of the threat on the species, but to measure the trend of the threat itself. For example, rather than just measuring the effect of grazing on a particular threatened species, it is more informative for conservation planning and for Red listing classification to report on the risk and probable consequence of changes in livestock numbers in an area.

4.3. Threat types and category movements

WA differs from the other territories on class HnSS being negatively associated with plants that experience no change in IUCN categories over those years. So plants that remained in the same conservation status from 2000 to 2008 are less frequently affected by threats related to humans, predictable and involving space loss (i.e. accidental destruction, clearing or mining), than the average threatened plant in WA.

More significantly, we found that Spanish plants that experience a movement across categories due to conservation reasons will, on average, have a mild upgrading, and this upgrading will have a larger probability than expected of being associated with human-related threats (right bottom Fig. 3). We consider this a clear example of human activities being directly linked with an overall pattern of a worsening in conservation status for the vascular flora.

Region considered is a major factor on the two original hypotheses, probably because of the effect of the large amount of plants experiencing no movement at all in the three areas. However, it has been shown that upgrading was particularly associated with conservation reasons in both WA and Spain. Our second hypothesis hold true for Spanish plants where threat related to human activities were linked with positive increases in the classification.

The fact that our work has found that only in the Spanish case there is a link between intensification of risk and anthropogenic activities, does not mean that WA or California are free of negative human effect upon their floras, rather this result is a consequence of both, the knowledge (monitoring) level associated with the floras, and the way these are used to derive a classification status. Both factors combined may explain why other reasons producing a conservation status change, i.e. increasing flora knowledge, or simply no change at all in conservation data, are predominant in the California, Spain and Western Australia Red Lists. These results are even more disturbing if we acknowledge that the three studied regions are some of the most active and innovative in plant conservation methods and application of resources throughout the world. Here we show that only by linking assessment and evaluation approaches between regions will we be able to accurately measure and assess real changes in plant conservation status and plan more effective global responses. These conclusions indicate that current or near-future attempts of Red List assessments and threatened flora evaluations will be problematic, because in our point of view larger time frames are required to accurately measure biodiversity losses using present threat classification techniques.

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Appendix A. Supplementary material

Detailed classification and selection methods and further results (Appendix S1) are available as online supplementary material. Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2012.07.008.

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