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ORIGINAL PAPER

Achieving Target 2 of the Global Strategy for Plant Conservation: building a preliminary assessment of vascular plant species using data from herbarium specimens

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Abstract The Global Strategy for Plant Conservation calls for a preliminary assessment of the conservation status of all known plant species by the year 2010. To date insufficient progress has been made on meeting this target. New efforts to develop a preliminary list beyond using the full IUCN criteria in plant assessments are needed. Here we present an algorithm that provides a preliminary assessment of the conservation status of plant species using data from herbarium specimens. We use Hawaiian specimen data from the United States National Herbarium to calibrate the parameters of the algorithm and then use specimen data from the Arecaceae, Commelinaceae, Gesneriaceae and Heliconiaceae as examples of the application of the algorithm. The algorithm was calibrated to insure 95% accuracy in placing the Hawaiian plant species into previously and independently determined threatened categories. Our results indicate that 28% of the Hawaiian taxa, 27% of the species of Arecaceae, 45% of the species of Commelinaceae, 32% of the species of Gesneriaceae, and 35% of the species of Heliconiaceae are *Not Threatened* and will not need any further evaluation for the preliminary assessment. Species identified here as *Potentially Extinct* and *Potentially Threatened* can be further assessed by additional herbarium material and/or conservation specialists for final evaluation using other assessment strategies (e.g., regional and national lists, taxonomic expert assessment, etc.).

Keywords Conservation assessments · Database · Herbarium · Plant specimens · IUCN Red List · Threatened species

Introduction

Plants are universally recognized as a vital part of the world's biological diversity and an essential resource for the planet. At present, a complete inventory of the plants of the world has not been assembled (Nic Lughadha 2004; see also http://www.iplants.org/), but it is

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estimated that the total number of vascular plant species may be between 310,000 and 422,000 (Prance et al. 2000; Govaerts 2001). Of particular concern is the fact that many species are in danger of extinction and threatened by habitat transformation, over-exploitation, alien invasive species, pollution, and climate change (Krupnick and Kress 2005). One of the greatest challenges for the conservation community is to halt the destruction of plant diversity that is so essential to meet the present and future needs of humankind.

The importance of this challenge was recognized by the unanimous adoption in 2002 of the Global Strategy for Plant Conservation (GSPC) at the sixth meeting of the Conference of the Parties to the Convention on Biological Diversity (GSPC 2002). The most innovative element of the Global Strategy is the inclusion of 16 outcome-oriented targets aimed at achieving a series of measurable goals by the year 2010. The GSPC was the first initiative in which such targets have been adopted under the Convention.

One of the most ambitious and critical goals of the GSPC is Target 2: *a preliminary assessment of the conservation status of all known plant species, at national, regional and international levels*. Many of the 16 targets in the GSPC depend on knowing which plants are threatened, especially Target 5 (protection of 50% of the most important plant diversity areas), Target 7 (60% of the world's threatened species conserved in situ), and Target 8 (60% of threatened plant species in accessible ex situ collections). The information produced by a preliminary assessment is needed before a significant portion of the remaining targets of the GSPC can be implemented. Unfortunately to date insufficient progress has been made on meeting this target. For example, only 11,891 vascular plant taxa appear in the 2007 IUCN Red List of Threatened Species (IUCN 2008). To achieve Target 2, new approaches to developing a preliminary assessment are urgently needed (also, see Strahm 2003).

Data from specimens deposited in local, national, and international herbaria contain a wealth of information that can be used to develop a preliminary list of threatened species. Over 250 million plant specimens exist in more than 3,000 herbaria in over 150 countries (Holmgren and Holmgren 1998). Of those specimens, a small percentage has been inventoried with even a smaller percentage available online. As an example, of the approximately 5 million specimens in the collection at the U.S. National Herbarium, roughly 1.0 million specimens (20%) have been inventoried, and 200,000 records (4% of the total collection) are available online. Despite the millions of specimens found in the world's herbaria, many areas of the Earth, especially in the tropics, remain under-sampled because of difficulty of access and are not adequately represented in these collections (e.g., Myanmar; Kress et al. 2003). Even though herbarium specimens are subject to such sampling issues, the data contained in these collections are nonetheless extremely useful for conservation assessments (Krupnick and Kress 2005).

Spatial, temporal and abundance data for plant species can be obtained from herbarium records by recording (1) the number of verified specimens, (2) the breadth of the localities represented by the specimens, and (3) the range of collection dates of the specimens. An algorithm that incorporates such data (Fig. 1) can effectively place a species into one of three "Preliminary Red List Categories": *Potentially Extinct* (includes 2001 IUCN Red List Categories "Extinct" and "Extinct in the Wild"; see IUCN 2001); *Potentially Threatened* (includes "Critically Endangered," "Endangered," and "Vulnerable"); and *Not Threatened* (includes "Near Threatened" and "Least Concern"). Conservation assessments based on data from a subset of all available specimens in the world's herbaria (in this case specimens in the U.S. National Herbarium) can serve as a "first pass" to reduce the next stage of evaluation based on the assembled records from additional international, national, and regional herbaria. Conclusions on *Potentially Extinct* and *Potentially Threatened* species will remain provisional until further data are used to test

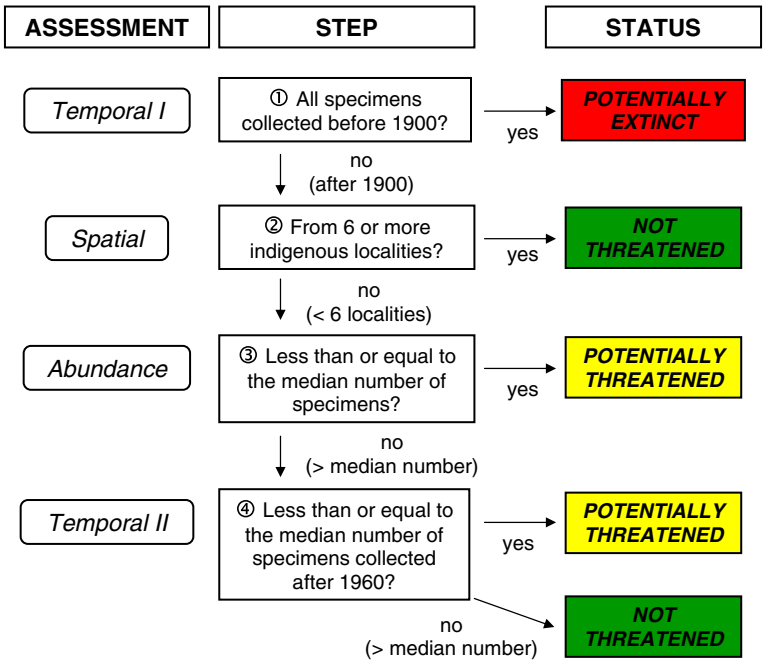

Fig. 1 Based on abundance, temporal, and spatial data, the preliminary conservation assessment algorithm can use herbaria specimens to generate preliminary conservation assessments for the world's flora (see "Results" for an explanation of each step)

conservation status. Species that are widespread, well-documented, and receive the *Not Threatened* designation in the initial assessment will not require additional re-evaluations and can be deemed fully assessed, eliminating a large number of vascular plant species from the need for any further evaluation.

Here we (1) describe how we developed the parameters of the conservation assessment algorithm using a known floristic dataset and (2) present the application of the algorithm using specimen data to four independent plant families. For each step of the algorithm an a priori cut-off value for abundance, spatial, and temporal assessment had to be calibrated. Specimen data from the well-documented Hawaiian flora were used to calibrate these cut-off values. The flora of Hawaii is taxonomically well-known (Wagner et al. 2005) and the conservation status of all vascular plants has been determined by an independent analysis (Wagner et al. 1999). In addition the Hawaiian specimens at the United States National Herbarium (US) have been fully inventoried and data are readily available for analysis. For these reasons, the Hawaiian flora serves as an ideal dataset with which to build the conservation assessment algorithm.

The Arecaceae, Commelinaceae, Gesneriaceae, and Heliconiaceae, four primarily tropical groups of plants were selected for application of the algorithm. Specimens of these three families have been fully inventoried at US and a taxonomic specialist for three families was readily available to resolve any ambiguities about the specimen data (Commelinaceae: R. Faden; Gesneriaceae: L. Skog and J. L. Clark; Heliconiaceae: W. J. Kress). In addition, the four families differ in the number of taxa and number of specimens (the Commelinaceae has an abundance of collections, and the Gesneriaceae has more species, while the Heliconiaceae has fewer species and collections, and the Arecaceae is comparatively under-collected),

which provides four widely different datasets to which the algorithm can be applied. Johnson and the IUCN/SSC Palm Specialist Group (1996) conducted a global assessment of the Arecaceae using the 1980 IUCN Red List Categories and Criteria; however, only species identified as the most threatened were listed. To our knowledge, no current, global conservation assessment currently exists for the other three families—the 2007 IUCN Red List of Threatened Species has only a partial assessment of each group of plants.

Methods

Specimen data included in the analyses consisted of family, genus, species epithet, author, infraspecific rank, infraspecific epithet, collector, collection number, collection date, country, division (state, province, or island), locality, and specimen sheet barcode and number. These data fields are a subset of the Darwin Core concept list and each field was necessary at a particular stage of the algorithm. Before analysis several editorial sweeps were performed on the data. All typographical errors in the scientific names were corrected. All specimens listed as "sp." and "indet", or without an epithet were removed from the analysis as were all known hybrids. Any specimen considered to be cultivated was also eliminated. Many historic collections did not contain collection year: if a specimen did not display a collection year, and it was collected during a known nineteenth-century expedition by collector "US Ex. Ex.," "H Mann," "W Hillebrand," "DD Baldwin," "GW Lichtenthaler," or "JD Smith," then the year "pre-1900" was added to the database. In cases where the locality division was absent from the collection label, "unknown" was inserted in that field. Unknown localities were not added to the total number of localities per taxon, except for cases where "unknown locality" was the only locality for the taxon. All naturalized species were removed.

The Hawaii database of 27,946 herbarium specimens was culled to 21,214 specimens representing 1,192 taxa (species and subspecies). Data from these specimens were used to develop the parameters of the algorithm.

Trials of the conservation assessment algorithm focused on the monocot families Arecaceae, Commelinaceae, and Heliconiaceae, and the dicot family Gesneriaceae. Editorial sweeps were performed as above, except that taxa were analyzed at the species level, and thus all subspecies within a given species were combined. The Arecaceae database of 10,976 specimens was culled to 5,726 specimens representing 839 species of the estimated 2,361 species in the family (Stevens 2001) after the editorial sweep. Likewise, the Commelinaceae database of 15,371 specimens was culled to 13,880 specimens representing 466 species of the estimated 652 species in the family (Stevens 2001). The Heliconiaceae database of 3,710 specimens was culled to 2,535 specimens representing 176 species of the estimated 215 species in the family (Kress et al. 1999). Finally, the Gesneriaceae database of 28,750 specimens was culled to 25,142 representing 1,542 species of the estimated 3,240 species in the family (Skog and Boggan 2007).

Results

Determining the parameters: the Hawaiian flora

Based on the empirically derived cut-off values calibrated by data on the Hawaiian flora (Fig. 1), the four steps of the final algorithm each with a specific query about the species under assessment are:

Step One—Temporal Assessment I. Query: Have all specimens of a given species been collected before 1 January 1900? This step provides a baseline assessment of extreme rarity and population decline since 1900. If a species was collected before 1900, and has not been collected since, the species is considered to be *Potentially Extinct*. The cut-off date of 1900 was selected because the last decade of the 1800s was a peak time in the description of new plant species (Kress and Krupnick 2005). In addition, about two-thirds of the currently accepted Hawaiian plant species were described before 1900 (Wagner et al. 2005). To select a cut-off date prior to 1900 proved to be too difficult as most Hawaiian collections from the 1800s did not have precise dates recorded on the collection labels; rather, a time frame of the collection is generally given (e.g., U.S. Exploring Expedition: 1838–1842). In this step, 22 Hawaiian taxa were identified as having all of their specimens collected before 1900, and thus these taxa were designated as *Potentially Extinct*.

Step Two—Spatial Assessment. Query: Are all of the specimens of a given taxon derived from six or more natural locations? Locality is defined here at the division level (i.e., state, providence, or island) depending on regional geography and nationally designated political boundaries. This step assesses spatial distribution and occurrence. If the answer to the query is yes, the species is apparently widespread and considered to be *Not Threatened*. A six-locality cut-off was selected in accordance with the 2001 IUCN Red List Categories and Criteria version 3.1 (i.e., *Vulnerable D2*; IUCN 2001). This value also minimized the number of known endangered Hawaiian taxa erroneously placed into the *Not Threatened* category by the algorithm while maximizing the number of species correctly placed in that category according to Wagner et al. (1999) (i.e., the six-locality value had the highest ratio of *Apparently Secure* taxa to *Endangered* taxa; see Fig. 2).

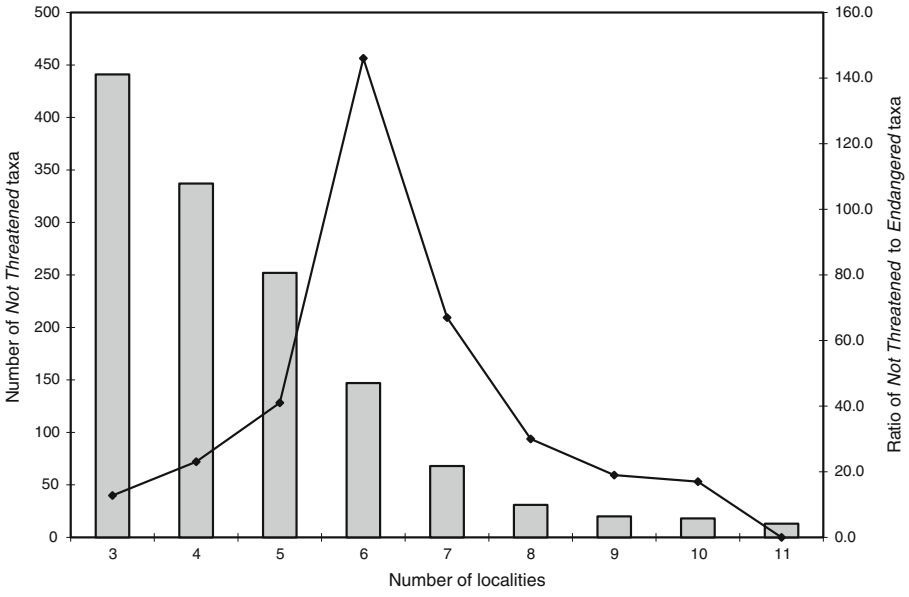

Fig. 2 *Bar Chart*: The number of Hawaiian taxa that are assessed by the algorithm as *Not Threatened* in Step Two based on the number of different localities (islands) for which specimens exist. *Line Chart*: The ratio of taxa that are assessed as *Not Threatened* to those that are identified by Wagner et al. (1999) as *Endangered*. A six-locality cut-off has the highest ratio of *Not Threatened* to *Endangered* taxa (146:1) when compared to all other cut-offs

Step Two identified 147 Hawaiian taxa that had specimens from six or more localities. These taxa were placed in the *Not Threatened* category. The remaining 1,023 Hawaiian taxa had specimens from five or fewer localities, and thus continue on to Step Three of the algorithm where additional data is necessary to ascertain an assessment category. One short-coming of Step two is that wide spread threatened species (such as the endangered *Sesbania tomentosa*, with collections from 10 localities) are identified here as *Not Threatened*.

Step Three—Abundance Assessment. Query: Is the species represented by less than or equal to the median number of specimens per species available for the region or taxon? As in Step One this step also assesses rarity. Empirical data are necessary to calibrate the cut-off value which will vary depending on the number of specimens available for the taxon or region under consideration. If the answer to the question is yes, the species is considered to be *Potentially Threatened*. The number of total specimens in the entire Hawaiian dataset, hence a reflection of the overall collecting effort and knowledge of the flora, is taken into account by using a rank statistic (the median number of specimens per species) as the cut-off value in Step Three. Our rationale for using this method is that collecting intensity should reflect both population abundance and population size, i.e., species with a small number of populations or small population sizes in general should be under-collected compared to species with many populations or large population sizes. Collection intensity, however, may also reflect a taxonomist's interest. A family or geographic area that has a high level of interest will have more available specimens than a family or area that has a low level of interest. Alternatively, a taxonomist may target rare species over common ones, and thus common species may be under-collected (see Ungricht et al. 2005). In addition, specimens from certain families may be more difficult to collect than specimens from other families (for instance, cacti and palms may be more difficult to collect than grasses) due to the plants habit; thus, certain families may be under-collected. For the Hawaiian flora, which has been intensively collected by botanists, the median number of specimens per taxon is 10. Therefore, 587 taxa with 10 or fewer specimens (an indication of possible rarity) are designated here as *Potentially Threatened*. The remaining 436 taxa (with more than 10 specimens each) continue on to Step Four.

Step Four—Temporal Assessment II. Query: Is the species represented by less than or equal to the median number of specimens collected since 1 January 1960? This step assesses the decline of a species. The remaining taxa from Step Three each have a large number of specimens (more than the median number). If some of those specimens were collected within the last four decades (i.e., less than the median number since 1960), then the species may be in decline and is considered *Potentially Threatened*. Those taxa that have a large number of recently collected specimens (more than the median number) are considered to be *Not Threatened*. The rank statistic cut-off value (the median number of specimens per species collected after 1960) maximizes the number of Hawaiian species placed in the *Not Threatened* category while minimizing errors of misplacing endangered taxa into this category. For the Hawaiian flora, the median number of specimens per taxon collected after 1960 is 7, resulting in 253 taxa designated as *Potentially Threatened*; 183 taxa had greater than 7 specimens collected after 1960, and were designated *Not Threatened*.

As described above, the assessment algorithm was calibrated to approach 95% accuracy in placing endangered plant species from Hawaii in a preliminary threatened category. Of the 328 taxa listed as *Extinct*, *Potentially Extinct*, or *Endangered* in Wagner et al. (1999), 312 taxa (95.1%) were designated as *Potentially Extinct* or *Potentially Threatened* (and thus

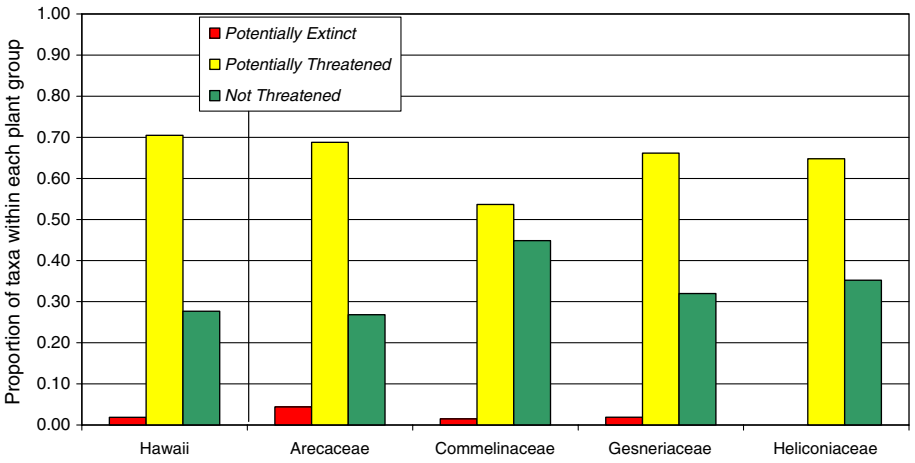

Fig. 3 The proportion of the Hawaiian flora and species of Arecaceae, Commelinaceae, Gesneriaceae, and Heliconiaceae that were assessed by the algorithm as *Potentially Extinct*, *Potentially Threatened*, and *Not Threatened* after an analysis of 68,336 specimens

requiring further evaluation) in our study. Of the 57 *Extinct* or *Possibly Extinct* Hawaiian taxa (Wagner et al. 1999), 15 were assessed as *Potentially Extinct* and 42 were assessed as *Potentially Threatened* in our analysis. Of the 271 *Endangered* Hawaiian taxa (Wagner et al. 1999), four were designated as *Potentially Extinct*, 251 were designated as *Potentially Threatened*, and 16 were designated as *Not Threatened* (i.e., "errors"). In summary, by using the parameters assigned for each step only about 4.9% (16 taxa) were erroneously assessed with the algorithm in comparisons to the designations of Wagner et al. (1999). Further, approximately 28% (330 taxa) of the Hawaiian taxa were identified as *Not Threatened*, and thus these taxa can be considered fully assessed, and will need no further evaluation (Fig. 3).

Applying the algorithm: Arecaceae, Commelinaceae, Gesneriaceae, and Heliconiaceae

In Step One of the algorithm, 37 species in the Arecaceae were identified as having all of their specimens collected before 1900, and thus these taxa were designated as *Potentially Extinct*. Among these species is *Corypha taliera*, listed in the 2007 Red List as *Extinct in the Wild*. In the Commelinaceae, 7 species were designated as *Potentially Extinct* (none are listed as *Extinct* in the 2007 Red List). In the Gesneriaceae, 29 species were designated as *Potentially Extinct*, including *Cyrtandra waiolani*, the only member of this family that is listed as *Extinct in the Wild* in the 2007 Red List. No Heliconiaceae species were designated as *Potentially Extinct* (none are listed as *Extinct* in the 2007 Red List).

In Step Two, 112 species in the Arecaceae had specimens from six or more localities and were thus assessed as *Not Threatened*. None of these species are listed in the 2007 Red List. In the Commelinaceae, 187 species were assessed as *Not Threatened*. None of these species are listed in the 2007 Red List either. In the Gesneriaceae, 274 species were assessed as *Not Threatened* (including five species listed as *Threatened* in the 2007 Red List: *Columnea katzensteiniae*, *C. manabiana*, *C. mastersonii*, *C. schimpffii*, and *Drymonia ecuadorensis*). In the Heliconiaceae, 49 species were assessed as *Not Threatened*. One of these species (*Heliconia obscura*) is listed as *Threatened* in the 2007 Red List.

The median number of specimens per species for the Arecaceae, Commelinaceae, Gesneriaceae, and Heliconiaceae are 3, 9, 4, and 5 specimens per species, respectively. Using a 3-specimen cut-off for Arecaceae in Step Three, 463 species were assessed as *Potentially Threatened*. Using a 9-specimen cut-of for Commelinaceae, 225 species were assessed as *Potentially Threatened*. Using a 4-specimen cut-off for Gesneriaceae, 749 species were assessed as *Potentially Threatened*. Using a 5-specimen cut-off for Heliconiaceae, 94 species were assessed as *Potentially Threatened*.

In Step Four, 114 species of Arecaceae had the median number of 1 or fewer specimens collected after 1960 and were assessed as *Potentially Threatened*; the remaining 113 species were assessed as *Not Threatened*. Of the remaining 47 species of Commelinaceae, 25 had the median number of 7 or fewer specimens collected after 1960 and were assessed as *Potentially Threatened*; the remaining 22 species were assessed as *Not Threatened*. Of the remaining 490 species of Gesneriaceae, 303 had the median number of 6 or fewer specimens collected after 1960 and were assessed as *Potentially Threatened*; the remaining 187 species were assessed as *Not Threatened*. Of the remaining 33 species of Heliconiaceae, 20 species had the median number of 7 or fewer specimens collected after 1960 and were assessed as *Potentially Threatened*; the remaining 13 species were assessed as *Not Threatened*. The total number of errors (assessed here as *Not Threatened*, but as *Threatened* in the 2007 IUCN Red List) included 5 species of Arecaceae, no species of Commelinaceae, 19 species of Gesneriaceae, and 1 species of Heliconiaceae.

In total 27% (225 species) of the species of Arecaceae, 45% (209 species) of Commelinaceae, 32% (493 species) of the species of Gesneriaceae and 35% (62 species) of the species of Heliconiaceae were identified as *Not Threatened*, and thus these species will not require additional re-evaluations in this preliminary assessment (Fig. 3).

A comparison between this study and a field-based analysis of the endemic palms of Hawaii (Chapin et al. 2004) and the endemic palms of the West Indies (Zona et al. 2007) shows a high level of similarity (see Appendix I and Appendix II). The 10 Hawaiian *Pritchardia* species, which are identified here as *Potentially Threatened*, are listed as *Critically Endangered*, *Endangered*, or *Vulnerable* in Chapin et al. (2004). One species (*Pritchardia minor*) is identified here as *Not Threatened*, but *Endangered* in Chapin et al. (2004). Of the 66 West Indian palm species that are identified here as *Potentially Threatened*, Zona et al. (2007) listed 25 species as *Extinct*, *Critically Endangered*, *Endangered*, and *Vulnerable*, 28 species as *Least Concern*, and 13 as *Data Deficient*. Of the 27 West Indian palm species identified here as *Not Threatened*, Zona et al. (2007) identified 1 species as *Endangered* (*Desmoncus polyacanthos*), 22 as *Least Concern*, and 4 as *Data Deficient*. Thus, only two species (*Pritchardia minor* and *Desmoncus polyacanthos*) of 77 resulted in false positives in our analyses (identified here as *Not Threatened*, but listed elsewhere as *Endangered*).

Discussion

The conservation assessment algorithm makes use of temporal, spatial, and abundance data contained in herbarium specimens to provide a rapid and admittedly preliminary evaluation of the threatened status of a plant species. Although correction of some specimen data (e.g., taxon spelling check, removal of hybrids and cultivated records, etc.) is required before the analysis can be performed, core fields available in most international specimen databases are sufficient for the algorithm to be used (international biodiversity portals such as GBIF often lack the full set of fields necessary to perform the analysis using the algorithm).

Table 1 The percentage of species identified as *Potentially Extinct* (PE), *Potentially Threatened* (PT), and *Not Threatened* (NT) at each of the four steps of the assessment algorithm (see Fig. 1)

Region/family	Step 1 (PE, %)	Step 2 (NT, %)	Step 3 (PT, %)	Step 4 (PT, %)	Step 4 (NT, %)
Hawaii	1.9	12.3	49.2	21.2	15.4
Arecaceae	4.4	13.3	55.2	13.6	13.5
Commelinaceae	1.5	40.1	48.3	5.4	4.7
Gesneriaceae	1.9	17.8	48.6	19.6	12.1
Heliconiaceae	0.0	27.8	53.4	11.4	7.4

Faulty data can mistakenly be incorporated into the analysis so it is critical that information is verified before use. The strength of our approach is that the method quickly and accurately identifies those species that are *not threatened*, i.e., species that are widespread and common, and, hence, can be eliminated from any further analysis. The species that are labeled as *potentially extinct* or *potentially threatened* can then be subjected to further analysis if necessary.

Our assessment reveals some interesting differences among the various plant family and regional databases (Fig. 3; Table 1). Compared to the Hawaiian flora and the other three plant families, the Commelinaceae has the largest percentage of species (45%) identified as *Not Threatened*. In Step Two of the algorithm (asking whether specimens were collected from six or more native localities), 40% of the species of Commelinaceae and 28% of the species of Heliconiaceae were identified as *Not Threatened*, compared to 12% of the Hawaiian taxa, 13% of the species of Arecaceae, and 18% of the species of Gesneriaceae (Table 1). Whether such a large number of widespread Commelinaceae species is characteristic of the family or a reflection of collection intensity (or a combination of the two) warrants further study.

Previous studies have used data from herbarium specimens to detect rarity (MacDougall et al. 1998) and decline (Burgman et al. 1995; Hedenäs et al. 2002; Case et al. 2007), but the methods employed in these studies would not be appropriate or would be too difficult to scale-up to examine a database as large as entire plant families (however, see Ungricht et al. 2005). Certain limitations to using herbarium records for conservation assessments do exist (see Golding 2004). For example, when assessing temporal data, a small number of recently collected specimens may only indicate a drop in collection effort, and not a decline in population size. Using the algorithm presented here, however, those species will be placed in the *Potentially Threatened* category, and therefore receive additional future analysis. Further, geo-referenced locality data from herbarium labels, which have recently been used to estimate area of occupancy (AOO) (Randrianasolo et al. 2002; Willis et al. 2003; Hernández and Navarro 2007), are unfortunately relatively depauperate for museum specimens with the majority of historic specimens containing no such information.

If the estimate of 350,000 species of vascular plants is used as a baseline of the number of species on Earth and the average of the median number of specimens per species needed to make a preliminary assessment is around 6 (as demonstrated here), then data from a minimum of 2.1 M herbarium specimens will be needed to provide at least the first stage of the assessment called for by Target 2. This number is simply a minimal estimate and a greater number of specimens will provide a more comprehensive conservation assessment.

We believe that such data currently exist at the major herbaria of the world and, if properly distributed among the world's plant species, could be easily mobilized. The conservation algorithm assessment could then be automated and quickly compiled.

We also believe that the assessment should not stop with this first sweep of the data. The widespread *Not Threatened* species, which according to the four trials presented here may represent approximately one-quarter to one-third of the world's flora, will be set aside from further analysis. Because the algorithm presented here is intended to provide preliminary assessments, more focused specimen collections, such as those found in national and regional herbaria, can then be used to make new refined assessments on the remaining species. Species that have been categorized as *Potentially Extinct* and *Potentially Threatened* can serve as the basis for the next stage of the conservation assessment based on the same stepwise algorithm but using a different suite of specimens. Alternative or complementary assessments using expert knowledge, data from plant specialist groups, and fieldwork can assist in the final assessment.

What do we need to proceed with achieving Target 2? The first stage is to mobilize the millions of specimen records that currently exist in herbaria around the world. The second stage is to analyze as many species as this mega-database will allow. These two stages should be carried out by taxonomists in an international consortium of botanical institutes. The third stage, after identifying all of the *Not Threatened* species, is to enlist assistance from IUCN, other conservation organizations, and local herbaria to provide a more focused assessment of the *Potentially Threatened* species. The fourth stage would be to convene a panel of expert taxonomists for a final assessment of the list of threatened species. Unfortunately completing this agenda by 2010 appears unlikely. However, it is not unfeasible that the preliminary assessment could be finished within 5 years after the process is initiated.

Target 2 is a lofty but necessary goal that can only be achieved through cooperative efforts by botanists, conservationists, and institutions working in conjunction with the Global Partnership for Plant Conservation to complete this critical preliminary inventory and assessment.

Acknowledgments We thank Chris Tuccinardi for assistance with each of the specimen databases; Robert Faden for assistance with the Commelinaceae specimen database; John Boggan, John L. Clark, Laurence Skog for assistance with the Gesneriaceae specimen database; and Ida Lopez for assistance with the Heliconiaceae specimen database. Brian Boom provided an informal review of an earlier version of this manuscript.

Appendices

Appendix I The 22 taxa of Hawaiian endemic *Pritchardia* palms with the current global Red List status, three previous conservation assessments, and this assessment

Taxon	1996 Red List status[a]	Wagner et al. (1999) assessment[b]	Chapin et al. (2004) assessment[c,d]	2007 Red List status[c,e]	This assessment[f]
P. affinis Becc.	E	E	CR	CR	PT
P. arecina Becc.	Not listed	AS	CR	Not listed	Not assessed
P. aylmer-robinsonii St. John	E	E	CR	CR	Not assessed

Appendix I continued

Taxon	1996 Red List status[a]	Wagner et al. (1999) assessment[b]	Chapin et al. (2004) assessment[c,d]	2007 Red List status[c,e]	This assessment[f]
P. beccariana Rock	Not listed	AS	EN	Not listed	PT
P. forbesiana Rock	Not listed	R	CR	EN	PT
P. glabrata Becc. & Rock	Not listed	V	CR	EN	Not assessed
P. hardyi Rock	Not listed	R	EN	CR	Not assessed
P. hillebrandii (Kuntze) Becc.	Not listed	AS	EN	Not listed	PT
P. kaalae Rock	E	E	CR	CR	PT
P. lanaiensis Becc. & Rock	Not listed	V	EN	EN	PT
P. lanigera Becc.	Not listed	R	CR	EN	Not assessed
P. limahuliensis St. John	Not listed	E	CR	CR	Not assessed
P. lowreyana Rock ex Becc.	Not listed	AS	CR	VU	Not assessed
P. martii H. Wendl.	Not listed	AS	VU	Not listed	PT
P. minor Becc.	Not listed	AS	EN	Not listed	NT
P. munroi Rock	E	E	CR	CR	Not assessed
P. napaliensis St. John	E	E	CR	CR	PT
P. perlmanii Gemmill	Not listed	E	EN	EN	Not assessed
P. remota (Kuntze) Becc.	E	E	VU	EN	PT
P. schattaueri Hodel	E	E	CR	CR	PT
P. viscosa Rock	E	E	CR	CR	Not assessed
P. waialealeana Read	Not listed	AS	DD	VU	Not assessed

[a] Global assessment of Johnson & the IUCN/SSC Palm Specialist Group (1996); E, endangered

[b] E, endangered; V, vulnerable; R, rare; AS, apparently secure

[c] CR, critically endangered; EN, endangered; VU, vulnerable; DD, data deficient

[d] Assessments using version 3.1 of the IUCN Red List Categories & Criteria (IUCN 2001)

[e] Assessments (IUCN 2008) use version 2.3 of the IUCN Red List Categories & Criteria (IUCN 1994)

[f] PT, potentially threatened; NT, not threatened; not assessed, no specimen data were available for analysis

Appendix II The 121 taxa of West Indian palms with the current global Red List status, two previous conservation assessments, and this assessment

Taxon	1996 Red List status[a]	2007 Red List status[b,c]	Zona et al. (2007) assessment[b,d]	This assessment[e]
Acoelorrhaphe wrightii (Griseb. & H. Wendl.) H. Wendl. ex Becc.	nt	Not listed	LC	NT
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	nt	Not listed	LC	NT
Aiphanes minima (Gaertn.) Burret	Not listed	Not listed	LC	NT
Attalea crassispatha (Mart.) Burret	E	CR	CR	PT

Appendix II continued

Taxon	1996 Red List status[a]	2007 Red List status[b,c]	Zona et al. (2007) assessment[b,d]	This assessment[e]
Bactris cubensis Burret	Not listed	Not listed	LC	PT
Bactris jamaicana L. H. Bailey	Not listed	VU	DD	PT
Bactris plumeriana Mart.	Not listed	Not listed	LC	PT
Calyptronoma occidentalis (Sw.) H. E. Moore	Not listed	Not listed	LC	NT
Calyptronoma plumeriana (Mart.) Lourteig	Not listed	Not listed	LC	NT
Calyptronoma rivalis (O. F. Cook) L. H. Bailey	V	Not listed	LC	NT
Coccothrinax acunana León	Not listed	Not listed	VU	PT
Coccothrinax alexandri León	Not listed	Not listed	VU/EN[f]	PT
Coccothrinax argentata (Jacq.) L. H. Bailey	nt	Not listed	DD	NT
Coccothrinax argentea (Lodd. ex J. A. & J. H. Schultes) Sarg. ex Becc.	Not listed	Not listed	LC	PT
Coccothrinax baracoensis Borhidi & Muñiz	Not listed	Not listed	DD	Not assessed
Coccothrinax barbadensis (Lodd. ex Mart.) Becc.	Not listed	Not listed	DD	NT
Coccothrinax bermudezii León	Not listed	Not listed	EN	PT
Coccothrinax borhidiana Muñiz	E	CR	CR	Not assessed
Coccothrinax boschiana Mejía & García	Not listed	Not listed	VU	PT
Coccothrinax camagueyana Borhidi & Muñiz	Not listed	Not listed	CR	Not assessed
Coccothrinax clarensis León	Not listed	Not listed	LC/DD/DD[f]	PT
Coccothrinax concolor Burret	Not listed	Not listed	DD	PT
Coccothrinax crinita (Griseb. & H. Wendl.) Becc.	E/R[f]	Not listed	CR/EN[f]	PT
Coccothrinax cupularis (León) Muñiz & Borhidi	Not listed	Not listed	DD	PT
Coccothrinax ekmanii Burret	Not listed	DD	DD	PT
Coccothrinax elegans Muñiz & Borhidi	Not listed	Not listed	LC	Not assessed
Coccothrinax fagildei Borhidi & Muñiz	Not listed	Not listed	VU	Not assessed
Coccothrinax fragrans Burret	Not listed	Not listed	DD	PT
Coccothrinax garciana León	Not listed	Not listed	VU	PT
Coccothrinax gracilis Burret	Not listed	Not listed	DD	PT
Coccothrinax guantanamensis (León) Muñiz & Borhidi	Not listed	Not listed	LC	PT
Coccothrinax gundlachii León	Not listed	LC	LC	PT
Coccothrinax hioramii León	Not listed	Not listed	LC	PT
Coccothrinax inaguensis Read	R	DD	DD	NT
Coccothrinax jamaicensis Read	Not listed	Not listed	LC	NT
Coccothrinax leonis Muñiz & Borhidi	Not listed	Not listed	EN	Not assessed
Coccothrinax litoralis León	Not listed	Not listed	LC	PT
Coccothrinax macroglossa (León) Muñiz & Borhidi	Not listed	Not listed	LC	Not assessed
Coccothrinax microphylla Borhidi & Muñiz	Not listed	Not listed	VU	Not assessed

Appendix II continued

Taxon	1996 Red List status[a]	2007 Red List status[b,c]	Zona et al. (2007) assessment[b,d]	This assessment[e]
Coccothrinax miraguama (Kunth) Becc.	nt	Not listed	LC/LC/VU/LC[f]	NT
Coccothrinax moaensis (Borhidi & Muñiz) Muñiz	Not listed	Not listed	EN	Not assessed
Coccothrinax montana Burret	Not listed	Not listed	DD	Not assessed
Coccothrinax munizii Borhidi	Not listed	Not listed	LC	Not assessed
Coccothrinax muricata León	Not listed	Not listed	LC	PT
Coccothrinax nipensis Borhidi & Muñiz	Not listed	Not listed	VU	Not assessed
Coccothrinax orientalis (León) Muñiz & Borhidi	Not listed	Not listed	LC	PT
Coccothrinax pauciramosa Burret	I	VU	VU	PT
Coccothrinax proctorii Read	Not listed	Not listed	DD	Not assessed
Coccothrinax pseudorigida León	Not listed	Not listed	EN	PT
Coccothrinax pumila Borhidi & J. A. Hernández	Not listed	Not listed	DD	Not assessed
Coccothrinax rigida (Griseb. & H. Wendl.) Becc.	Not listed	Not listed	DD	PT
Coccothrinax salvatoris León	Not listed	Not listed	LC/EN[f]	PT
Coccothrinax saxicola León	Not listed	Not listed	LC	PT
Coccothrinax scoparia Becc.	Not listed	Not listed	DD	PT
Coccothrinax spissa L. H. Bailey	Not listed	Not listed	DD	PT
Coccothrinax trinitensis Borhidi & Muñiz	Not listed	Not listed	DD	Not assessed
Coccothrinax victorini León	Not listed	Not listed	CR	Not assessed
Coccothrinax yunquensis Borhidi & Muñiz	Not listed	Not listed	VU	Not assessed
Coccothrinax yuraguana (A. Rich.) León	Not listed	Not listed	LC	PT
Colpothrinax wrightii Griseb. & H. Wendl. ex Voss	V	VU	EN	PT
Copernicia baileyana León	nt	LC	LC	PT
Copernicia berteroana Becc.	I	Not listed	DD	PT
Copernicia brittonorum León	R	VU	CR	PT
Copernicia cowellii Britt. & Wilson	Not listed	Not listed	EN	PT
Copernicia curbeloi León	Not listed	Not listed	VU	PT
Copernicia curtissii Becc.	Not listed	Not listed	LC	PT
Copernicia ekmanii Burret	E	EN	EN	PT
Copernicia fallaensis León	Not listed	Not listed	CR	PT
Copernicia gigas Ekman ex Burret	Not listed	VU	VU	PT
Copernicia glabrescens H. Wendl. & Becc.	Not listed	Not listed	LC/VU[f]	PT
Copernicia hospita Mart.	nt	Not listed	LC	PT
Copernicia humicola León	Not listed	Not listed	DD	PT
Copernicia longiglossa León	Not listed	Not listed	DD	PT
Copernicia macroglossa H. Wendl. & Becc.	nt	Not listed	LC	PT
Copernicia molineti León	Not listed	Not listed	DD	PT

Appendix II continued

Taxon	1996 Red List status[a]	2007 Red List status[b,c]	Zona et al. (2007) assessment[b,d]	This assessment[e]
Copernicia rigida Britt. & Wilson	Not listed	LC	LC	PT
Copernicia roigii León	Not listed	Not listed	LC	PT
Copernicia yarey Burret	Not listed	Not listed	LC/VU[f]	PT
Copernicia x burretiana León	Not listed	Not listed	CR	Not assessed
Copernicia x occidentalis León	Not listed	Not listed	CR	Not assessed
Copernicia x shaferi Dahlgren & Glassm.	Not listed	Not listed	CR	Not assessed
Copernicia x sueroana León	Not listed	Not listed	EN	Not assessed
Copernicia x textilis León	Not listed	Not listed	EN	Not assessed
Copernicia x vespertilionum León	Not listed	Not listed	EN	Not assessed
Desmoncus polyacanthos Mart.	nt	Not listed	EN	NT
Euterpe broadwayi Becc. ex Broadway	Unknown	Not listed	LC	NT
Gastrococos crispa[g] (Kunth) H. E. Moore	nt	Not listed	LC	PT
Gaussia attenuata (O. F. Cook) Becc.	E	VU	LC	PT
Gaussia princeps H. Wendl.	Not listed	Not listed	LC	PT
Gaussia spirituana Moya & Leiva	Not listed	EN	EN	Not assessed
Geonoma interrupta (Ruiz & Pavon) Mart.	Not listed	Not listed	LC	NT
Geonoma undata Klotzsch	Not listed	Not listed	DD	NT
Hemithrinax compacta (Griseb. & H. Wendl.) Gómez	Not listed	Not listed	VU	PT
Hemithrinax rivularis León	V/V[f]	Not listed	EN/EN[f]	PT
Prestoea acuminata (Willd.) H. E. Moore	Not listed	Not listed	LC	NT
Pseudophoenix ekmanii Burret	E	CR	VU	PT
Pseudophoenix lediniana Read	V	CR	CR	Not assessed
Pseudophoenix sargentii H. Wendl. ex Sarg.	R	Not listed	LC	NT
Pseudophoenix vinifera (Mart.) Becc.	Not listed	Not listed	VU	PT
Reinhardtia paiewonskiana Read, Zanoni & Mejía	Not listed	Not listed	EN	PT
Roystonea altissima (Mill.) H. E. Moore	Not listed	Not listed	LC	NT
Roystonea borinquena O. F. Cook	Not listed	Not listed	LC	PT
Roystonea lenis León	Not listed	VU	VU	PT
Roystonea maisiana (L. H. Bailey) Zona	Not listed	Not listed	VU	Not assessed
Roystonea oleracea (Jacq.) O. F. Cook	nt	Not listed	LC	NT
Roystonea princeps (Becc.) Burret	Not listed	LR/nt	LC	PT
Roystonea regia (Kunth) O. F. Cook	nt	Not listed	LC	NT
Roystonea stellata León	Ex/E	EN	EX	PT
Roystonea violacea León	R	Not listed	EN	PT
Sabal causiarum (O. F. Cook) Becc.	nt	Not listed	LC	NT
Sabal domingensis Becc.	Not listed	Not listed	LC	Not assessed
Sabal maritima (Kunth) Burret	Not listed	Not listed	LC	PT
Sabal palmetto (Walt.) Lodd. ex J. A. & J. H. Schultes	nt	Not listed	LC	NT
Sabal yapa Wright ex Becc.	Not listed	Not listed	LC	PT

Appendix II continued

Taxon	1996 Red List status[a]	2007 Red List status[b,c]	Zona et al. (2007) assessment[b,d]	This assessment[e]
Syagrus amara (Jacq.) Mart.	Not listed	Not listed	LC	NT
Thrinax ekmaniana (Burret) Borhidi & Muñiz	E	CR	VU	Not assessed
Thrinax excelsa Lodd. ex Griseb.	Not listed	Not listed	LC	NT
Thrinax morrisii H. Wendl.	nt	Not listed	LC	NT
Thrinax parviflora Sw.	Not listed	Not listed	LC/LC[f]	NT
Thrinax radiata Ledd. ex J. A. & J. H. Schultes	nt	Not listed	LC	NT
Zombia antillarum (Desc.) L. H. Bailey	nt	Not listed	VU/DD[f]	PT

[a] Global assessment of Johnson & the IUCN/SSC Palm Specialist Group (1996); Ex/E, possibly extinct; E, endangered; V, vulnerable; R, rare; I, indeterminate; nt, not threatened

[b] EX, extinct; CR, critically endangered; EN, endangered; VU, vulnerable; LR/nt, lower risk: near threatened; LC, least concern; DD, data deficient

[c] Assessments (IUCN 2008) use version 2.3 of the IUCN Red List Categories & Criteria (IUCN 1994)

[d] Assessments using version 3.1 of the IUCN Red List Categories & Criteria (IUCN 2001)

[e] PT, potentially threatened; NT, not threatened; not assessed, no specimen data were available for analysis

[f] Subspecies and varieties were assessed separately; a composite assessment is indicated in the table

[h] Listed as *Acrocomia crispa* (Kunth) C. F. Baker ex Becc. in Zona et al. (2007)

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