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# WHAT HAVE HERBARIA EVER DONE FOR US? THE ROLE OF HERBARIA IN CONSERVATION ASSESSMENTS

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ABSTRACT. The world is entering a time of immense environmental upheaval, where experts increasingly are required to provide conservation assessments. A quantitative assessment of trends in range and abundance of flora is costly, requiring extensive field studies over a long period of time. Unfortunately, many plant species are known only from a few chance sightings or a handful of specimens. Specimen-based records provide information on the distribution of taxa through time and space, and a wealth of this knowledge can be found in the taxonomic collections and libraries of herbaria and museums. Conservation assessments are increasingly important, as lists of threatened species often form the primary source of information in the allocation of limited resources for conservation. One of the strengths of using herbarium data is that the results are built on current taxonomic expertise. Such data are derived directly from individual, verifiable records, which represent primary observations. Here we describe a number of techniques that are available for conservation assessments, including Red Listing of species.

*Key words:* extinction, decline, threat, herbarium data, conservation assessments, IUCN Red List criteria

## INTRODUCTION

Herbaria and other natural history collections often have been considered mainly the realm of taxonomic research, i.e., naming new species, revisions, monographs, checklists, and floras. Such collections, however, have a lot more to offer. Recent research has included the study of phenological response to climate change, confirmation of the existence of diseases in rodent populations prior to the outbreak in humans, changes in population structure and genetic diversity caused by habitat loss, and estimation of historical levels of environmental contaminants to provide a baseline for comparison with current levels (Graham et al. 2004, Suarez & Tsutsui 2004). The contributions of these institutes, however, have gone largely unnoticed by the public and the policymakers. This wide under-appreciation has resulted in insufficient financial support for maintenance and improvement of biological collections (Suarez & Tsutsui 2004).

Threatened species lists are fundamental in providing a global context for biodiversity degeneration (Hilton-Taylor 2000); and they are the primary source of information for the allocation of limited resources for conservation (Burgman 2002). Such information is a frequent requirement in legislation (Mace & Lande 1991). Quantitative assessment of trends in range and abundance is costly, requiring extensive field studies over a long period of time (Burgman et al. 2000). The vast majority of species, however, are only known from a handful of collections; thus these species often are excluded from conservation assessments; or at best, they are recorded as data deficient due to lack of information (McInerny et al. unpubl. data). If we cannot successfully monitor populations for the purpose of conservation assessments, it becomes nearly impossible to predict their decline or extinction with any certainty. Without such fieldwork, the status of a species may only be inferred from the information contained within the specimen-based collections (McInerny et al. unpubl. data); and such collections are estimated to contain ca. 2.5 billion specimens (Suarez & Tsutsui 2004). These records provide not only information on the distribution of taxa through time, and space (Ponder et al. 2001); they also represent primary verifiable observations and are built directly on current taxonomic expertise (Bachman et al. 2004). Even in cases where species are from well-studied groups, extinction and rediscovery raises concerns about how we know when a species is extinct, given the difficulty of effectively surveying and monitoring critically endangered species. According to McInerny et al. (unpubl. data), "Extinctions are most frequently asserted after subsequent investigation, and so uncertainty often surrounds the classification of a species

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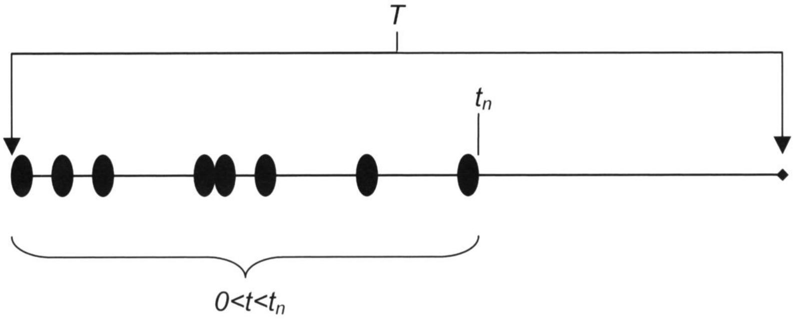

FIGURE 1. The Solow equation evaluates the probability that $n$ observations occurred before the last sighting during the period $t_7$.

as extinct. This necessitates acknowledgment of the probabilistic nature of any extinction statement." Making false extinction claims could undermine potential last-minute conservation action; and wider public support also could be undermined by conservationists "crying wolf" too frequently.

For the purpose of conservation assessments, we are mainly interested in trends in abundance and range. Natural history collections contain two main types of useful information for this purpose, the time and the place of collection (i.e., the collection event, Suarez & Tsutsui 2004). In some cases, other ecological information also is available. Firstly, the date of collections may be arranged as a binary record, as a time series. Several methods have been presented that provide a probabilistic basis for the extinction hypothesis based on such time series (Solow 1993a, 1993b; Burgman 1995; McCarthy 1998; Solow & Roberts 2003; McInerny et al. unpubl. data). Essentially these methods provide the probability that another collection will be made given the characteristics of a time series (McInerny et al. unpubl. data). Secondly, locality data allows use to determine both area of occupancy (AOO) and extent of occurrence (EOO). In addition, where satellite images are available, the current existence of the former location of a species may be ascertained, i.e., whether a former rain forest location has been cleared resulting in local extinction (Willis et al. 2003). This allows us to calculate the decline of a species. Methods that use such data potentially have wide application as indicators of threat.

Using the Malagasy orchid, *Angraecum sesquipidale,* as an example, we show how herbarium data can be used to make IUCN Red List assessments.

## Methods and Materials

### Statistical Models

### Inferring Threat and Extinction

Sightings of a species may be arranged as a binary record, with multiple sightings recorded as a single sighting for any single time unit; as the methods assume collections are independent of one another (McCarthy 1998). The sightings occur within the entire period, $T$, at ordered times, $t_1 < t_2 < \ldots < t_n$ (FIGURE 1). Higher probability values ($>\alpha$) infer, therefore, that extinction has not occurred, as the lack of sightings at the end of the record could happen by chance. Low probabilities ($<\alpha$) infer that extinction has occurred, as the sightings are unlikely to have occurred in the time period $0 \leq t \leq t_n$ given the magnitude of $T$, and/or $n$.

Increasing magnitude of p-values implies decreasing levels of threat (McCarthy 1998). This also allows us to prioritize conservation effort by ranking the p-values generated. In addition, if species were collected randomly and were not in decline, then one would expect uniform distribution; for example, species that are presumed extinct would have the lowest p-values (McCarthy 1998).

Several methods have been developed with this type of data in mind (Solow 1993a, 1993b; Burgman et al. 1995; McCarthy 1998; Solow & Roberts 2003; McInerny et al. unpubl. data). The methods differ in their usage. Some have been developed for use with limited data, some incorporate the type of decline a species is likely to go through, and others include collection effort or increase the comparability of results between different taxonomic groups of geographical regions.

### Using Locality Data to Measure Threat and Extinction

Locality data allows use of GIS (Geographical Information Systems) to determine area of occupancy (AOO), extent of occurrence (EOO), and number of subpopulations. Willis et al. (2003) used several methods to calculate these Red List parameters.

Area of occupancy (AOO), according to the

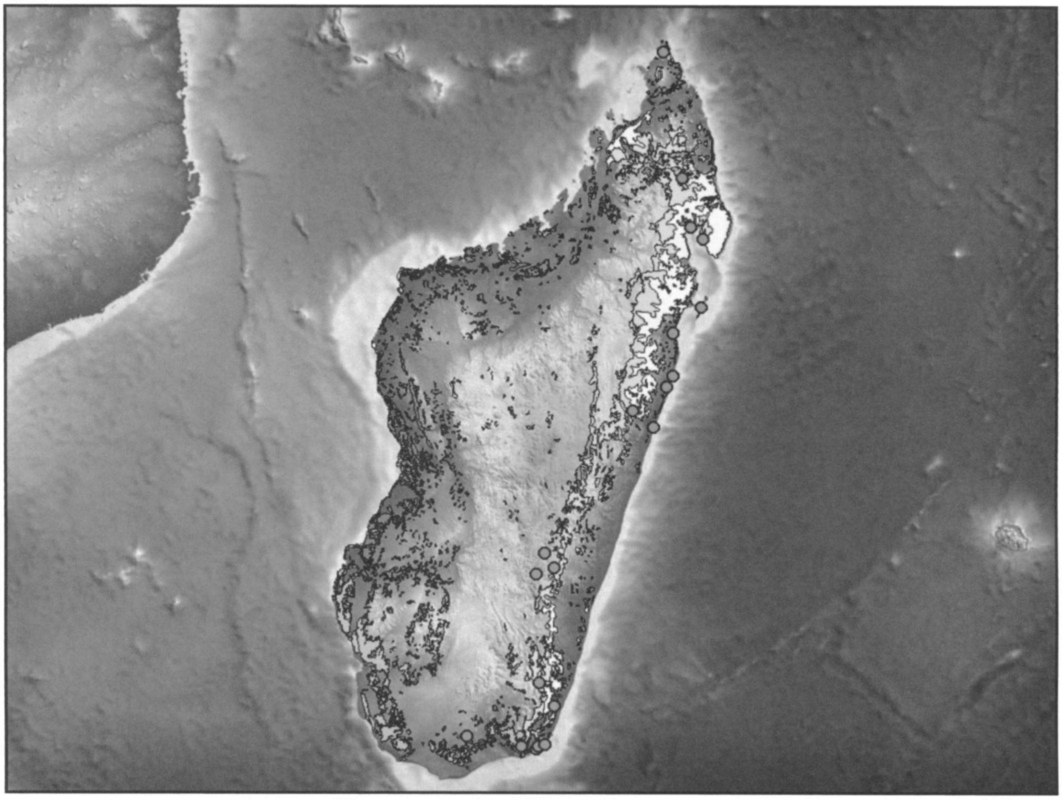

FIGURE 2. Distribution of georeferenced herbarium specimens of *Angraecum sesquepidale*. Collections are indicated as shaded circles, background is elevation with primary remaining vegetation highlighted (after Dupuy & Moat 1996).

IUCN (2001), is the number of occupied cells; however, no cell size is stated. Willis et al. (2003) calculated the cell size as a tenth of the maximum distance between any pair of points. This allows the construction of a grid that is appropriate to the geographical range of a species.

Extent of occurrence (EOO) is the shortest continuous imaginary boundary enclosing a set of points. Known as a convex hull, this is easily calculated within a GIS (Willis et al. 2003). According to the IUCN (2001), "This measure may exclude discontinuities or disjunctions within the overall distribution of taxa." This measure, however, is difficult to implement, as boundaries may be obscure (Willis et al. 2003). For example, island distributions may be obvious, but what do we do about mountain species?

Calculation of number of subpopulations requires good knowledge of the species biology. Such knowledge, as mentioned previous, is rarely available, since most species are only known from museum collections. Specimen locality data, however, may be used to calculate the number of contiguous cells, applying the same methods as for AOO or Rapoport's mean propinquity (Rapoport 1982). Rapoport's mean propinquity involves the construction of a minimum-spanning tree. From this, subpopulations are separated, where the limb distance is more than twice the mean limb distance (Willis et al. 2003).

## Application of Techniques

The statistical methods described here were applied to the Malagasy orchid, *Angraecum sesquepidale,* using data from 32 herbarium collections that represent 21 localities (FIGURE 2) (J. Hermans unpubl. data).

## RESULTS AND DISCUSSION

Based on Solow (1993a), Solow & Roberts (2003), and McInerny et al. (unpubl. data), p-values range from 0.60 to 0.77. These values are high, particularly if compared with other species of Malagasy orchids (Cribb et al., this issue). Application of GIS-based methods gave the fol-

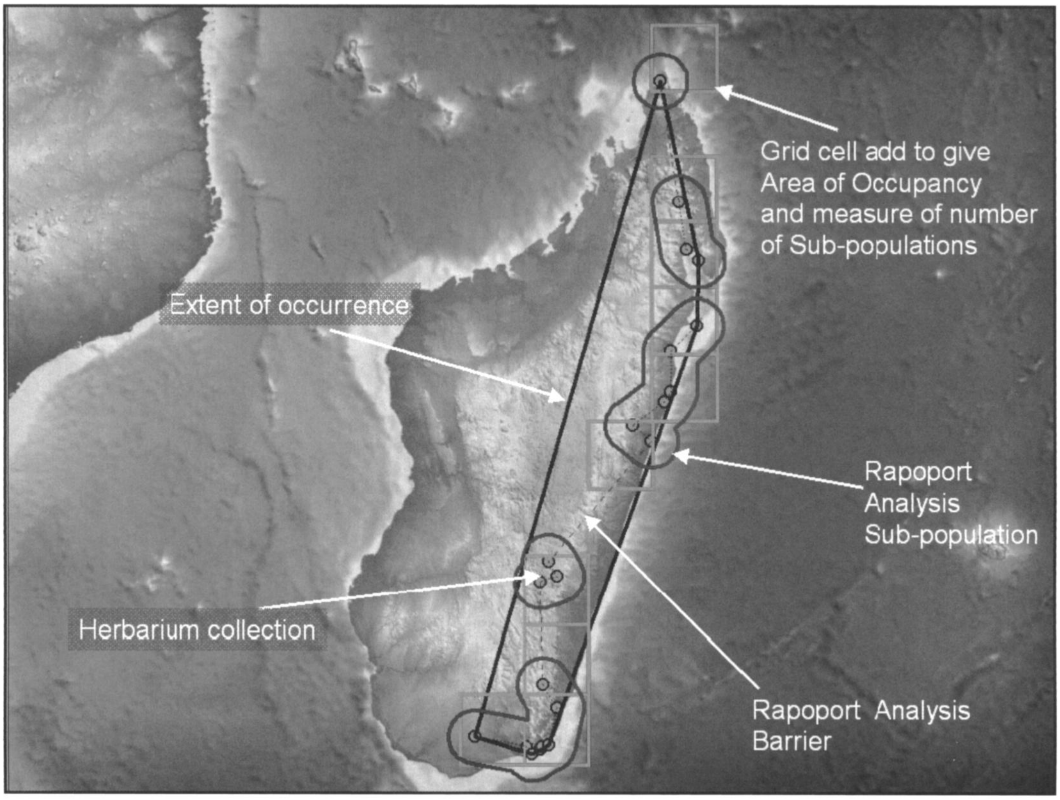

FIGURE 3. Application of GIS-based techniques to the herbarium data of *Angraecum sesquepidale.*

lowing results (FIGURE 3): EOO = 225,493 km$^2$; AOO = 186,197 km$^2$ and three subpopulations (Grid Adjacently); and Rapoport Analysis = five subpopulations. The results suggest that *Angraecum sesquepidale* should be classified under the IUCN Red List category as a species of Least Concern.

## CONCLUSIONS

Natural history collections such as herbaria offer a unique opportunity, using the methods described here, to rapidly assess the conservation status of much of the world's species, since many are only known from these collections. Such assessments will allow the prioritization of our limited conservation funds and also will prevent the undermining of potential conservation action for species on the brink of extinction.

Some may consider the results of these techniques to be only preliminary assessments for IUCN Red Listing; but, as pointed out here, most species are only known from this material and data. In addition, with so many species becoming threatened, funding to study them in sufficient detail to make a full assessment is highly unlikely. A further benefit is that these methods are a way of standardizing assessments, thus making species more comparable for prioritizations.

The IUCN Red List criteria are themselves not without criticism. Willis et al. (2003) pointed out two examples. Firstly, the projected continuing decline criterion, according to the IUCN (2001), only requires a yes or no answer! Secondly, regarding the fragmentation criterion, the IUCN (2001) stated that habitat data can be used in "certain circumstances," but no justification was given or guidance offered on when habitat data should be applied.

Application of the statistical methods described here for inferring species decline from museum specimens can aid our understanding of the probability of a taxon being threatened and can help maintain public confidence in conservation.

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