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Where are the tropical plants? A call for better inclusion of tropical plants in studies investigating and predicting the effects of climate change

It is critical that we be able to accurately predict how different species will fare under anthropogenic climate change. Given their high diversity, importance in providing vital ecosystem services, and hypothesized climate sensitivity (Janzen 1967), this need is perhaps most poignant for tropical plant species. Unfortunately, tropical plants are poorly represented in studies investigating and predicting climate change impacts. For example, in a recent meta-analysis, Urban (2015) synthesized more than a hundred studies predicting species' extinction risks due to climate change. Included in these analyses were data for many tens of thousands of plant and animal species worldwide, including several thousand tropical plant species (it is not possible to discern the exact number of tropical plant species that were included due to a lack of specification about many species' identities or provenances in the original datasets). While the representation of tropical plants in Urban (2015) is a marked improvement over past syntheses (e.g., in their landmark study, Thomas et al. (2004) included just 172 tropical plant species, of which 163 were from the Brazilian Cerrado and 9 from the Amazon), it is still just a miniscule fraction of actual tropical plant biodiversity (Joppa et al. 2011a), especially considering that the included species were meant to represent all possible tropical biogeographic realms, habitat types, and plant life forms (Urban 2015).

Why are tropical plant species consistently underrepresented in studies investigating and predicting the effects of climate change? The simple answer is an extreme paucity of data. We still don't know enough about most tropical plant species to understand how their performance and distributions relate to climate, much less to make informed predictions about how these species will fare in the face of climate change (Feeley et al. 2012).

The information most commonly used to predict species' risks of extinction due to climate change is their geographic ranges, which in turn require maps of where the species occur and, ideally, where they do not occur. The data that are currently available for most tropical plant species are inadequate and simply do not allow such maps to be made. To help illustrate this lack of data, we can look at tropical South America, which is arguable the best-studied of all tropical realms. The Amazon Tree Diversity Network (ATDN)¹ recently conducted a study looking at the occurrences of tree species in over 1,100 census plots distributed throughout lowland Amazonia (ter Steege et al. 2013). Across all of their census plots, the ATDN found approximately 5,000 tree species. Of these species, more than 1,500 (approximately 1/3rd of the represented species) were recorded in just one or two plots each. At least for these species, there is obviously no way that the plot data alone can be used to map their geographic ranges or estimate their climatic niches. Furthermore, there are estimated to be more than 11,000 Amazonian tree species that are not included in any of the ATDN plots (ter Steege et al. 2013). Unless we greatly accelerate our inventory efforts, many of these species will never be discovered and named, much less have their distributions mapped, before they go extinct (Joppa et al. 2011b).

An alternative source of data for mapping plant species' ranges is herbarium or natural history collections. But here again, data from the tropics are woefully sparse. For tropical South America, nearly 2 million georeferenced plant collection records representing more than 50,000 species were available for download through the Global Biodiversity Information Facility (GBIF)² as of February 2014. Approximately 1/3rd of these species are represented by just one or two collections each (Feeley

1 <http://web.science.uu.nl/amazon/atdn/>

2 <http://www.gbif.org/>

2015a). There are certain to be several thousand more species that are not represented by any collections at all or that have yet to be properly identified (Bebber et al. 2010). If we extend these tallies beyond South America, the number of tropical plant species for which we have little or no information is truly daunting (Feeley and Silman, 2011).

Beyond just a lack of occurrence data, there are several additional challenges to predicting the fate of species under climate change that are magnified for tropical plants. For example, even if we are able to accurately map the current distributions of tropical plant species, these maps may provide relatively little insight into the ability of these species to tolerate rising temperatures. In temperate systems, species can, at least theoretically, extend their distributions to span the full range of tolerable temperatures. On the other hand, the ranges of tropical species are often truncated by an absence of suitable climates (Feeley and Silman 2010). In other words, we expect that an unknown number of tropical species are capable of tolerating even hotter temperatures than those that occur within their current realized distributions, but that these species are unable to express this tolerance since the species already occur in some of the hottest places on Earth. Rising temperatures will not necessarily force species with truncated niches to shift their ranges and may actually allow these species to expand their ranges as more areas become suitable (Feeley and Silman 2010, Lenoir and Svenning 2015). In order to predict the impacts of climate change on tropical species we will need better estimates of species' distributions and also better information about species' fundamental climate tolerances – this will require expanded collections/plot databases combined with physiological studies and experiments (Feeley 2015b).

Another complication that can make predicting the impacts of climate change on tropical plants difficult is the preponderance of species that rely on animals for pollination and/or seed dispersal (Howe and Smallwood 1982, Bawa 1990, Correa et al. 2015). Climate change can potentially disrupt these interspecific mutualistic interactions, and thereby have negative impacts on plant species even before the climate

itself becomes unsuitable (Bond 1994, Schweiger et al. 2010). While many temperate species will also be negatively affected by the disruption of mutualisms, there are simply a greater number and proportion of plants in the tropics that rely on animals to transport their pollen and seeds (Howe and Smallwood 1982). Also, unlike many of their temperate counterparts, tropical plant species typically lack compensatory reproductive mechanisms that can minimize the negative effects of disrupted mutualisms (Bond 1994). Unfortunately, the vast majority of species interactions remain so poorly characterized that the sensitivity of tropical plants to climate change will be impossible to predict even with better data on their distributions and climatic tolerances.

Tropical plants constitute one of the largest and most important components of terrestrial biodiversity and play vital roles in supporting ecosystem function and services. We cannot hope to predict the fate of these foundational species in the face of climate change or other anthropogenic disturbances if we do not know where they occur, much less their physiological tolerances and the sensitivities of the complex species interactions on which they depend (Feeley 2015b). Clearly we need more data. And we need it fast.

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