

Using species distribution models as a tool to discover new populations of *Phaedranassa brevifolia* Meerow, 1987 (Liliopsida: Amaryllidaceae) in Northern Ecuador

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ABSTRACT: *Phaedranassa brevifolia* Meerow (1987) is an endangered plant species endemic to Ecuador. Until recently, this species was only known by the type location and four other adjacent subpopulations in a restricted area of less than four km². We combined geo-referenced occurrences of this species and bioclimatic variables to generate a prospective species distribution model. Using the resulting map as a guide for field work, we found three new populations of *P. brevifolia*, increasing its geographic distribution to 16 km².

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Phaedranassa brevifolia was first described from a single specimen collected in 1978 in Northern Ecuador (Meerow 1987) in a habitat classified as Dry Montane Scrub, characterized by thorny dry forest (Valencia *et al.* 1999). The above-ground parts of this bulbous species consist of only one or two leaves approximately 12 cm in length (Meerow 1990), which are hard to locate among other shrubs. The reproductive biology of *P. brevifolia* is unknown, but the general phenological pattern of the genus is to flower once annually, before the wet season (N. Oleas, personal observations). Above-ground leaves are absent before flowering, which makes spotting individuals especially difficult during that time of the year. At flowering, each plant is a 39–56 cm stem or scape, with five to seven funnel-shaped to ventricose flowers (Meerow 1990) (Figure 1A). After an extensive survey in 1999, the species was found in the type location and another four nearby subpopulations located in an area of less than four km² (Figure 1B) (Oleas and Pitman 2003). One of the difficulties for finding new records of *P. brevifolia* is the small size of the plant.

Species Distribution Models (SDMs) can be used to identify areas where species might be potentially found (de Siqueira *et al.* 2009). The SDMs are a general set of simulations that forecast the ranges of species based on the relation between real field records and a set of environmental predictors (Guisan and Zimmermann 2000). The resulting model can be used to judge habitat suitability and hence predict the species' potential distribution, across large landscapes (Elith and Leathwick 2009), making them a valuable tool in biogeography and conservation biology. One of the challenges for modeling

the distribution of poorly-known species is that the models generally require a minimum of 20 records (Hernandez *et al.* 2006; Wisz *et al.* 2008) or more (Feeley and Silman 2011) in order to produce accurate models. However, for rare species, even SDMs generated with less than the optimal number of records may still be valuable if they can suggest areas that may have suitable habitats, and thereby help direct collecting efforts (de Siqueira *et al.* 2009). Ideally, new collections can then be incorporated back into the SDM in an iterative process such that each new record helps to improve the accuracy of range predictions and increase the likelihood of finding new populations (Guisan *et al.* 2006).

We used the geo-referenced data of the five known locations of *P. brevifolia* to develop a preliminary distribution model for the species (Figure 1C). The model was generated through a maximum entropy approach as implemented in the program MAXENT ver. 3.3.3a (Phillips *et al.* 2006) with the default settings, which have been shown to provide good results (Syfert *et al.* 2013). The settings included: 10000 maximum number of background points, crossvalidated replicate run, 500 maximum iterations, 0,00001 convergence threshold. MAXENT is appropriate for presence/absence data (Newbold *et al.* 2010) and is one of the most commonly-used method to generate SDMs. MAXENT has shown superior prediction accuracy compared to other methods (Elith *et al.* 2006) and is less sensitive to sample size than other SDMs (Hernandez *et al.* 2006; Pearson *et al.* 2007; Hernandez *et al.* 2008; Wisz *et al.* 2008). For our model, we used 19 bioclimatic variables derived from monthly temperature and rainfall values (www.worldclim.org, spatial resolution of 30 arc

second or $\sim 1 \text{ km}^2$) (Hijmans *et al.* 2005) as the underlying environmental surfaces. The bioclimatic variables include annual trends like mean annual temperature and annual precipitation, seasonality that takes into consideration the annual range of precipitation and temperature and extreme environmental conditions as temperature of the coldest and warmest month (Hijmans *et al.* 2005). The output of MAXENT is a continuous probability field which we transformed into a predicted suitable vs. unsuitable map based on thresholding with the cutoff set as the point of maximum training sensitivity plus specificity as suggested by Jiménez-Valverde *et al.* (2008). Maximum training sensitivity refers to minimize false negatives and specificity aims to reduce false positives. We assessed model performance with the receiver operating characteristic analysis (ROC) as the Area under the curve

(AUC) as implemented in MAXENT (Phillips *et al.* 2006). Our model had an AUC value of 0.9995, which indicates a better than random model performance (Manel *et al.* 2001; Franklin, 2009).

In July–December 2009, we searched previously unexplored areas predicted as suitable for the occurrence of the species according to the SDM map. We need to point out finding new records of *P. brevifolia* is not an easy task. Each sterile individual aboveground is only one leaf of 12 cm, which is difficult to distinguish, especially during the rainy season, when the vegetation is fuller. Furthermore, *P. brevifolia* habitat is located in one of the most deforested areas in Ecuador (Valencia *et al.* 1999), where agricultural practice includes setting up fire to clear the sites for agricultural purposes (N. Oleas, personal observations). Our species distribution model, based on the few available

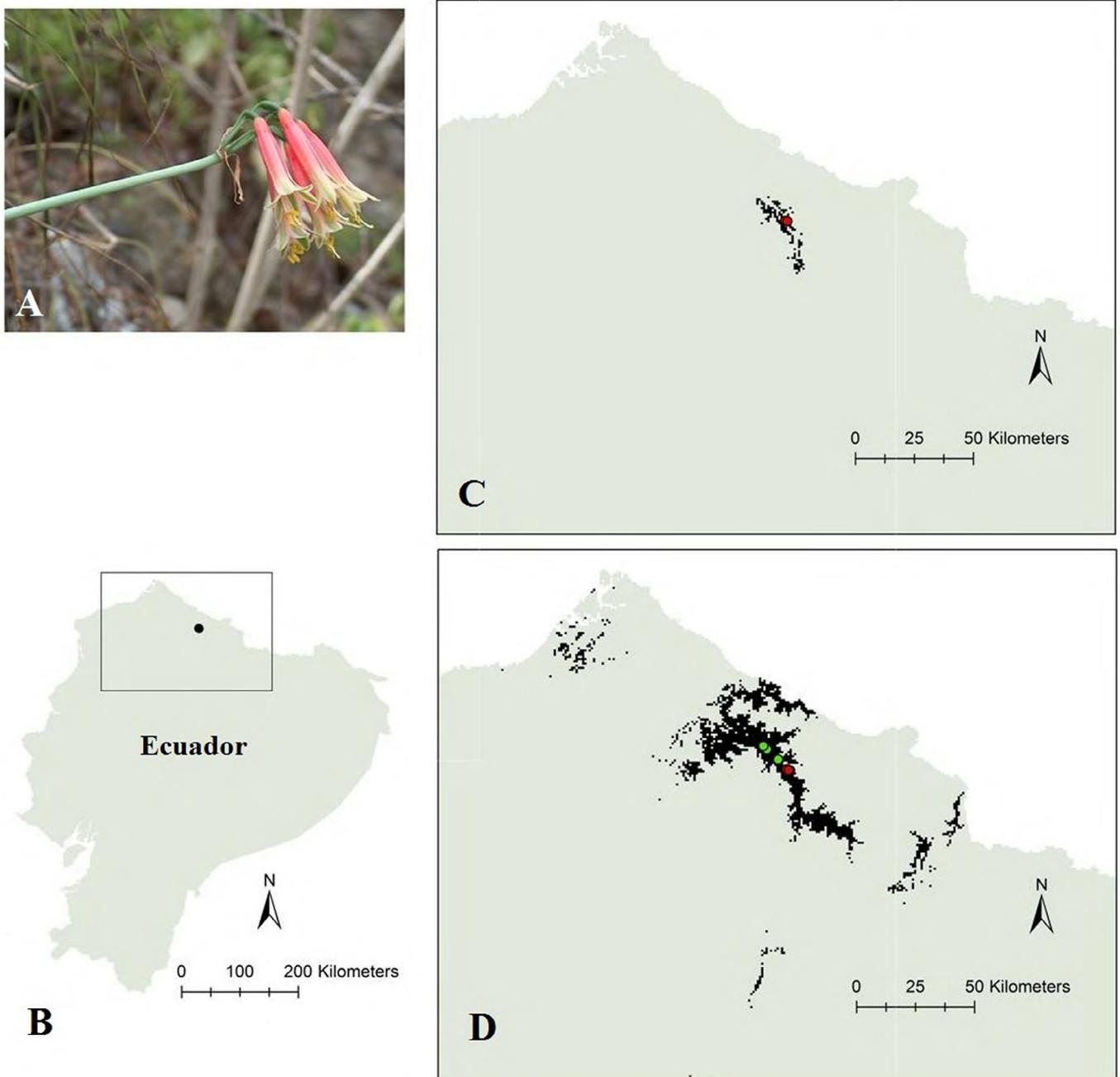


FIGURE 1. New records of *Phaedranassa brevifolia* (Amaryllidaceae). (A) *P. brevifolia* in the wild, (B) Map of Ecuador showing *P. brevifolia* distribution, (C) Species Distribution Model (black area) estimating potentially suitable areas based on the five previously known registers (red dots), (D) New records of the species (green dots) and Species Distribution Model of potentially suitable areas estimated with the combined dataset of new and old records (black area).

records before this study, suggested that the species could be found in adjacent areas to the west (Fig. 1C). The SDM increase the altitudinal range of *P. brevifolia* from 1200–1500 m to 800 to 1800 m. The habitat of *P. brevifolia* then would extend from Dry Montane Scrub habitats at the eastern portion of the geographic range to Wet Montane Scrub at the western part of the range. Within this area, we found three new locations expanding the known distribution of *P. brevifolia* to 16 km² to the west of the previously known range (Figure 1B). Botanical vouchers for these locations are deposited at the National Herbarium (QCNE) in Quito, Ecuador (Oleas # 1010, 1011, 1012). The conservation status of *P. brevifolia*, even with these new populations does not change. The previously reported five populations in Oleas and Pitman (2003) correspond to a very small area, with each record

separated by less than two km². Because of this, they can be considered one location or at most two, so that the total number of locations for *P. brevifolia* after incorporating the new populations is still just five. It is likely that there are more populations of *P. brevifolia* in the wild, but additional fieldwork is needed to find new populations. Thus, *P. brevifolia* is Endangered (EN) under the IUCN criteria B1ab (iii); C2a (i) (IUCN, 2001). Figure 1D shows a SDM including the new records found at the field; information that can be used to located new records of the species in the future.

Our experience supports the potential application of SDMs as a tool to guide the search for new populations of rare species, even when models are based on limited sample sizes. Indeed, the use of SDMs has the potential to decrease time and effort to direct field efforts

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