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Spatial distribution of dry forest orchids in the Cauca River Valley and Dagua Canyon: Towards a conservation strategy to climate change

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ABSTRACT

Epiphytic orchids are fundamental elements of the dynamics and composition of tropical ecosystems; there are an estimated 19,000 species worldwide, of which 85 occur in the dry forests of the basins of the Cauca and Dagua rivers in the Valle del Cauca Department in southwestern Colombia. These plants form the interface between the forest and the atmosphere and depend on aerial nutrient sources, rain, and water vapour for survival. This physiological dependence on the climate makes them especially sensitive to changes in the atmosphere and temperature, so they are ideal models for the study of climate change (CC). The objective of this study was to detect changes in the spatial distribution of seven orchid species in the tropical dry forest in the department of Valle del Cauca and their significance in terms of conservation planning for CC. A maximum entropy algorithm was used for modelling, and nine variables were analysed. Presence data for 30 municipalities came from 31 field trips, herbarium data, and the literature, and the current potential distribution was compared against the SRES-A2 scenario developed by the Intergovernmental Panel on Climate Change (IPCC) and modelled for the 2080–2100 time horizon. For the set of seven species, the results show an altitudinal increase under the future CC scenario compared to the present, but the responses vary amongst taxa, elevation, and location, depending on the degree of thermal specialization. Under the future CC scenario, the suitability of mid-mountain areas will increase at the expense of the basal areas where dry forest orchids are currently found, and the Cordillera Occidental will have a greater concentration of suitable areas than the Cordillera Central. Variables such as accessibility, land coverage, temperature, and water availability explain 88.6% of the model. A strategy to combat the impending loss of biodiversity due to CC is the establishment of Altitudinal Migration Corridors (AMCs) that connect the forest relics of the alluvial plain with the mid-mountain areas. Areas with a probability of species occurrence greater than $P = 0.75$ have been identified with MaxEnt software, and these areas constitute "thermal refugia", which, together with existing protected areas, form the backbone of this conservation strategy. Protection of xeric shrublands and the appropriate management of phorophytes would not only facilitate the dispersion processes of these orchids but also the survival of other flora and fauna in the dry forest of the Valle del Cauca River against CC.

1. Introduction

Epiphytes, i.e., plants that grow on other plants, represent 10% of all vascular flora (Kress, 1989; Benzing, 2008), and of the 27,614 vascular epiphytes in the world, 19,000 are orchids, an important floristic component of many tropical ecosystems (Zotz and Andrade, 2002; Zotz, 2013). Orchid epiphytes form the interface zone between the forest and the atmosphere, and these plants are physiologically dependent on atmospheric sources of nutrients and water, which are released as rain or water vapour (Nadkarni, 2010). Mycorrhizal fungi are essential for orchid mineral nutrition, especially during the seedling stage (Janos, 1993), and they are a key factor determining orchid establishment and survival because seed germination is dependent on interactions with specific mycorrhizal fungi (Rasmussen

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& Rasmussen 2008), although the degree of specificity varies among orchid species (Otero, Flanagan, Herre, Ackerman, & Bayman, 2007; Otero, Thrall, Clements, Burdon, & Miller, 2011; Valadares, Otero, Correa-Pereira, & Cardoso, 2015). All of these factors mean that orchids are particularly sensitive to changes in the atmosphere and, especially, temperature (Bellgard and Williams, 2011), so epiphytes are exceptionally useful as bioindicators for the monitoring of phenomena related to climate change (CC) both at the regional and global levels (Lugo and Scatena, 1992).

Orchid inventories in the Cauca River Valley in southwestern Colombia have documented 70 species, of which 48 (69%) are epiphytes, and there are an additional 15 species in the dry forest of Dagua Canyon (Reina-Rodríguez, Ospina-Calderón, Castaño, Soriano, & Otero, 2010). Originally, the populations of these species would have occupied broad expanses of this land. Orchid collections by Humboldt & Bonpland (1801); Justin Goudot (1843–1844); José Jerónimo Triana (1851–1853); J. von Warscewicz (1851); Isaac Farwell Holton (1853); F.C. Lehmann (1884–1900); Langlassè (1899); H. Pittier (1906); E.P. Killip (1917–1948) and J. Cuatrecasas (1943–1947), demonstrate the presence and abundance of orchids in this territory. In 1920, the German engineer Werner Hopp, who traveled in the Cauca River Valley, spoke *of millions of blooming Cattleyas* (Hopp, 1957). However, accelerated deforestation in this territory over the last 150 years, which has been caused by sugarcane agribusiness (Reina-Rodríguez & Otero 2011; Arcila-Cardona, Valderrama, & Chacón de Ulloa, 2012), has resulted in the loss of habitat, which may threaten the remaining populations through problems such as genetic drift and inbreeding (Li and Ge, 2006; Tremblay, Ackerman, & Zimmerman, 2005).

Middle elevations have been shown to have high species richness, which is also true for epiphytes (Wolf and Alejandro, 2003; Cardelus, Colwell, & Watkins, 2006; McCain, 2004). These areas have been important in the dispersal of flora and fauna, but they may become even more significant to conservation strategies against CC.

Climate change projections for Colombia indicate that the current ecosystem ranges will be displaced by up to 500 m, which would impact 23% of the country (Gutiérrez-Rey, 2002). Specifically, in Valle del Cauca, there will be a 2.8 °C increase in temperature and a 20% decrease in precipitation (Gutiérrez-Rey, 2002). Important areas for conservation have been defined at the country level or in large biomes (Leach, Zalat, & Gilbert, 2013; Bambach, Meza, Gilabert, & Miranda, 2013; Trisurat, Shrestha, & Kjelgren, 2011; Warren et al., 2013). However, few studies have focused on local and subregional scales (Schroth et al., 2009; Alvarado-Solano & Otero 2015), and even fewer have modelled tropical orchid distributions.

Our research question focused on whether CC will affect the spatial distribution patterns of epiphytic orchids in the department of Valle del Cauca. In other words, the objective of the study was to determine the potential changes in the spatial distributions of these orchids. In terms of regional planning, the results may contribute to the design of biological corridors along altitudinal migration routes as part of a conservation strategy against potential biodiversity loss in the southwestern Colombian Tropical Dry Forest (TDF) due to CC. In this study, seven TDF orchid species (Appendix A) were evaluated under the assumption that increasing temperatures would produce an altitudinal migration effect towards suitable sites that would fulfil their ecological requirements. Specifically, this paper identifies areas that are considered to be potential refugia or regional "thermal niches" for the orchid flora of the TDF in 30 municipalities of Valle del Cauca as well as their overlap with existing protected areas.

2. Materials and methods

2.1. Study area

The inter-Andean valleys of the Cauca and Dagua rivers in southwestern Colombia are located between 5°0′9.17″ and 3°5′39.17″ north latitude and 75°42′12.87″ and 77°32′12.87″ west longitude. These valleys have a combined area of 775,318 ha, between 800 and 1700 m above sea level. The dominant land covers are agricultural and silvopastoral systems, and only 10,716 ha of the Cauca Valley (1.76%) (Arcila-Cardona et al., 2012) and 2867 ha of the Dagua River Basin (0.36%) (IAvH, 2015) are covered by native forests. The Cauca River crosses the study area from south to north, and is bounded by the central and western mountains. The annual average rainfall is 1760 mm in the south and 1650 mm in the north with peaks in April and November and minimums in January and July. However, in some locations of the piedmont, the average rainfall is 963 mm (CVC, 2010). The average temperature is 24.5 °C; the average annual evaporation is 1354 mm/year, and the average relative humidity is 76% (IDEAM, 2015).

2.2. Sources of locality information

Data were collected from the alluvial plain of the Cauca and Dagua rivers in 30 municipalities of the Valle del Cauca Department, southwestern Colombia, which has a population of 4,061,554 representing 8.4% (DANE, 2005) of the country's population.

The data in this study include 123 records of seven epiphytic orchids, which were used to model the current and potential future species distributions under the effects of CC. Over 600 effective working hours were used to collect the primary information from 31 field trips and several web resources: W3Tropicos of the Missouri Botanical Garden (http://www.tropicos.org/Home.aspx); the virtual herbarium of the Institute of Natural Sciences of Bogotá (http://www.biovirtual.unal.edu.co/ICN); the Jany Renz Swiss Orchid Foundation (http://orchid.unibas.ch); the Natural History Museum of Paris (http://coldb.mnhn.fr); and, the New York Botanical Garden (http://sciweb.nybg.org/science2/hcol/allvasc/index.asp). Additionally, geographic information was extracted from the botanical specimens deposited at three departmental herbaria (CUVC: Universidad del Valle Herbaria, VALLE: Universidad Nacional Herbaria and TULV: Botanical Garden Juan María Céspedes Herbaria) and the Botanical Institute of Barcelona (BC); personal communications with Silverstone-Sopkin P., A. Niessen, J. Uribe, and A. Castaño; and the scientific literature (Guarín, 1981; Ortiz, 1995; Viveros-Bedoya, Velez-Nauer, & Rodríguez-Molina, 2001; Ortiz and Uribe, 2007; Misas, 2005; Calderón-Sáenz, 2007; Kolanowska, Perez-Escobar, Parra-Sanchez, & Szlachetko, 2011; Reina-Rodríguez et al., 2010; Reina-Rodríguez & Otero, 2011).

2.3. Climate projections and environmental context

The climate information was obtained from the archives of the IPCC, Worldclim (Graham and Hijmans, 2006: http://www.worldclim.org/bioclim.htm), the Geodata Portal of King's College of London (http://www.policysupport.org/waterworld) and the Joint Research Centre (http://bioval.jrc.ec.europa.eu/products/gam/index.htm). Other variables of interest, such as the topographic wetness index (TWI), were estimated using the System for Automated Geoscientific Analyses (SAGA) software (http://www.saga-gis.org). The habitat type was derived from the digital ecosystem map produced by the Regional Autonomous Corporation of Valle del Cauca (CVC) (2010). Using geographic information systems, the original categories were reclassified into five habitat types that accounted for the height and composition of the tree and shrub species: LS: Lateritic shrubland; XS: Xerophytic shrubland; FdnF: