Observed localities for three endangered, endemic Mexican ambystomatids (*Ambystoma altamirani*, *A. leorae*, and *A. rivulare*) from central Mexico

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ABSTRACT - The populations of ambystomatid salamanders around Mexico City are subject to a variety of threats, and some populations may be in decline. Three *Ambystoma* species found around Mexico City and in central Mexico are *A. altamirani*, *A. leorae*, and *A. rivulare*, and these three species are subject to a variety of conservation threats. We compiled a database of localities for these ambystomatid salamanders. The compiled observations of these three species of endangered salamanders suggest several patterns: 1) most localities for all three species are in the Estado de México, including several for *A. altamirani* within the borders of Mexico City; 2) there is little, if any, geographical overlap among these three species; 3) the relatively few documented sites for *A. leorae* and *A. rivulare* highlight their tenuous conservation status. Our hope is that this presentation of a map of documented locations of these three Mexican *Ambystoma* has created a starting point for future studies on these salamanders.

INTRODUCTION

The genus *Ambystoma* has several Mexican species that are of conservation concern (Frías-Alvarez et al., 2010; Wilson et al., 2013). The populations of *Ambystoma* located around Mexico City are subject to a variety of threats, and some populations may be in decline (e.g., *A. mexicanum*, Zambrano et al., 2007; Contreras et al., 2009). Many of these issues arise because of the expansion of Mexico City (Merlín-Uribe et al., 2013). This is particularly important because many of these species of *Ambystoma* are small, isolated, and show low genetic diversity (Parra-Olea et al., 2012; Sunny et al., 2014a,b), and thus may be prone to extinction. *Ambystoma* may also be subject to collection and removal for the international pet trade (e.g., Carpenter et al., 2014) or other uses (e.g., food, medicine; Griffiths et al., 2004).

Three of the species of *Ambystoma* found around Mexico City and central Mexico are *A. altamirani*, *A. leorae*, and *A. rivulare*. These three species used to be considered part of a separate genus, *Rhyacosiredon*, but they are now considered to be *Ambystoma* (Brandon, 1977; Reilly & Brandon, 1994). They are also likely relatively closely related, at least *A. altamirani* and *A. rivulare* (*A. leorae* not sampled; Weisrock et al., 2006; Recuero et al., 2010). According to Wilson et al. (2013), the Environmental Vulnerability Score (EVS) of *A. altamirani* is 13, *A. leorae* is 15, and *A. rivulare* is 13, primarily due to the limited geographic and ecological ranges. These are at the higher end of the intermediate vulnerability range (10-13) and in the high vulnerability range (> 14) (Wilson et al., 2013). According to the IUCN Red List the conservation status of *A. altamirani* is Endangered, *A. leorae* is Critically Endangered, and *A. rivulare* is Data Deficient (IUCN, 2015). According to the Mexican government (SEMARNAT, 2010), these three ambystomatid species are all classified as Threatened.

Populations of these three species of *Ambystoma* in central Mexico are endangered due to a variety of conservation threats. For example, *A. altamirani* and *A. rivulare* have both been shown to be infected with *Batrachochytrium dendrobatidis* (*A. leorae* was not tested; Frías-Alvarez et al., 2008). The introduction of fish to previously fishless habitats appears particularly damaging to *Ambystoma* populations in this region (e.g., Lemos-Espinal et al., 1999; Griffiths et al., 2004; Alcaraz et al., 2015). Pollution and lowered water quality is another potential threat to *Ambystoma* near Mexico City (e.g., Griffiths et al., 2004; Robles-Mendoza et al., 2009; Recuero et al., 2010), and many streams where these species are found are impacted by local residents (Lemos-Espinal et al., 1999).

Given these multiple threats to ambystomatid salamanders in central Mexico, it is important to establish and carefully document the locations of the existing populations. This is to both identify the types of habitats where they currently occur, but also to identify, via these locations, the specific types of threats they

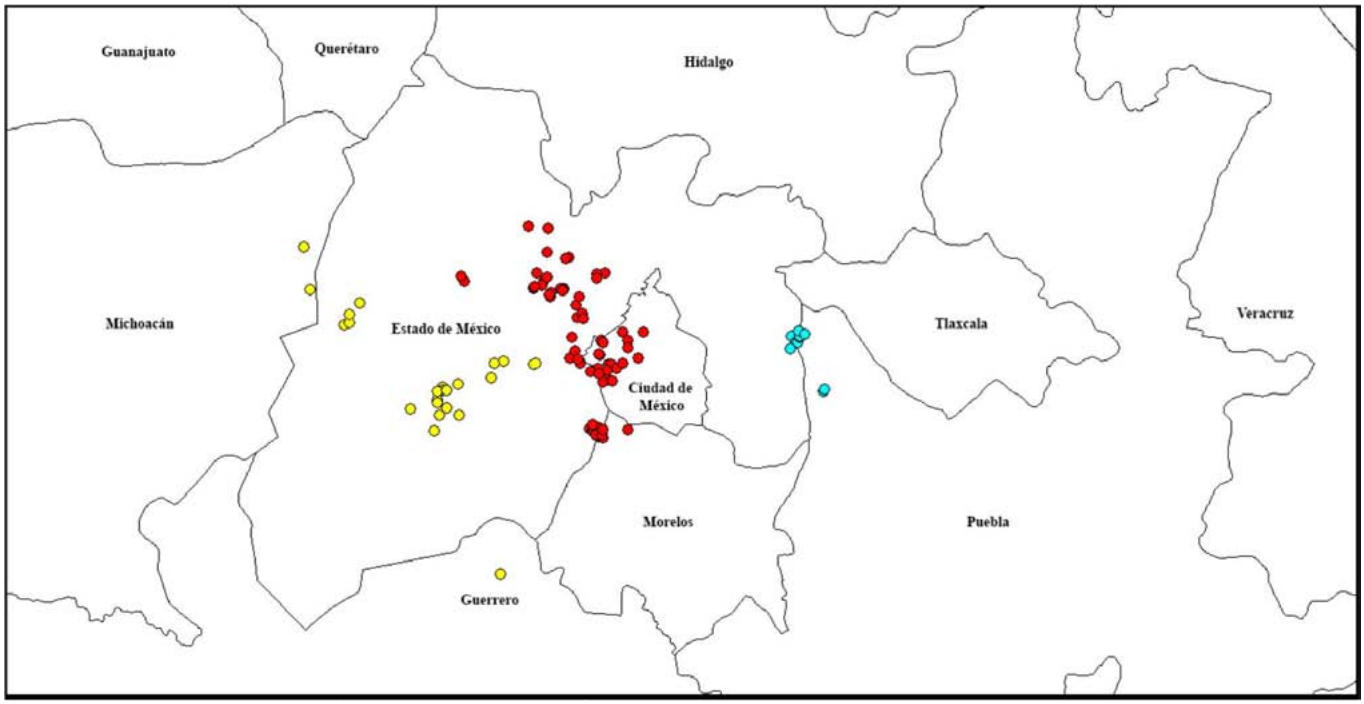

Figure 1. Map of the localities where *A. altamirani* (red circles), *A. leorae* (blue circles), and *A. rivulare* (yellow circles) were found and documented

may be likely to face. We therefore set out to compile a list of all documented localities for these ambystomatid salamanders, *A. altamirani*, *A. leorae*, and *A. rivulare*.

Previous research has documented habitat use for a few populations of these three species. *A. leorae* are found in pools along streams with a variety of substrates and well oxygenated water (Vega-López & Alvarez S., 1992; Sunny et al., 2014b; Monroy-Vilchis et al., 2015). Lemos-Espinal et al. (1999) reported most *A. leorae* were first seen in shaded sites. *A. rivulare* are found in slow-moving streams or in pools along streams (Bille, 2009). In the Arroyo Los Axolotes, Mexico, *A. altamirani* tend to use portions of the stream with grassy vegetation, muddy or sandy substrates, more oxygenated and faster flowing water, as well as sites containing more water (Lemos-Espinal et al., 2016). They can also be found in well-oxygenated pools along streams (Maldonado Koerdell, 1947), and are frequently found under rocks along streams (Lemos-Espinal et al., 1999).

MATERIALS AND METHODS

We collected locality records for these three species using the following sources: (1) by our own field work and using a GPS unit (Garmin eTrex Venture; accuracy < 15 meters) to record the location (n = 41); (2) literature records in Monroy-Vilchis et al. (2015) and Vega-López and Álvarez (1992) (n = 2); and (3) a data base provided by the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (National Commission for the Understanding and Use of Biodiversity; CONABIO) (n = 90). Due to conservation concerns, we do not report specific locality data in this paper. Researchers with a legitimate need for specific locality data can contact the correspondence author. We used the locality data to draw a dot distributional map showing each locality record for the three studied species using the program Biótica 5.0.4.1 by CONABIO which is a free access program found at http://www.conabio.gob.mx/biotica5/documents/DescargaBiotica.php.

RESULTS

A. altimirani were found in 94 sites in the Distrito Federal (n = 20), Estado de México (n = 68), and Morelos (n = 6) (Fig. 1). The altitudinal range of sites where *A. altimirani* have been found is from 2450 m to 3487 m. *A. leorae* were found in 12 sites in the Estado de México (n = 7) and Puebla (n = 5) (Fig. 1). The altitudinal range of sites where we documented *A. leorae* ranged from 2525 m to 3750 m. We documented *A. rivulare* from 27 sites in Guerrero (n = 1), Estado de México (n = 25), and Michoacán (n = 1) (Fig. 1). *A. rivulare* were found at elevations between 2720 m and 3180 m.

DISCUSSION

Our distributional observations of these three species of endangered salamanders suggests several patterns. First, most sites we documented for all three species are in the Estado de México, including several for *A. altamirani* within the borders of the Mexico City metropolitan area (see Fig. 1). This observation reinforces the concern about the potential effects of an expanding Mexico City on the long-term prognosis of these populations (see Monroy-Vilchis et al., 2015), especially in light of studies showing the continued loss of natural areas near Mexico City (García-Romero, 2002; Merlín-Uribe et al., 2013). Second, there does not appear to be much, if any, geographical overlap among these three species. This suggests that

while many of their habitat requirements may be similar (e.g., *A. altimirani*: Taylor & Smith, 1945, Maldonado Koerdell, 1947, Brandon & Altig, 1973, Lemos-Espinal et al., 1999, 2016; *A. leorae*: Sunny et al., 2014a, Monroy-Vilchis et al., 2015; *A. rivulare*: Brandon & Altig, 1973, Bille, 2009) and thus effective conservation efforts might be similar, they must be addressed in a species-by-species manner. For example, a single reserve or natural area is unlikely to provide coverage for all three species. The disjunctive species distributions also raise questions about why they do not co-occur given their use of relatively similar habitats. Answering such questions would be useful in helping to determine what might happen if these species are forced together by shifting habitats with climate change or with changes in habitats as urban and agricultural land use expands in central Mexico. Third, the relatively few sites where we documented *A. leorae* and *A. rivulare* highlight the tenuous conservation status of these species. This concern is especially high for *A. leorae* (see also Sunny et al., 2014a,b).

Finally, our hope is that by presenting a summary of the documented locations of these three Mexican *Ambystoma* we have created a starting point for future studies on these salamanders. In particular, we hope that others will continue to try to fill in additional locations so that we have a better and more complete understanding of the populations and distributions of these species. In addition, it is hoped that regular monitoring of these sites for salamanders will allow for the detection of any population or range declines, or loss of suitable habitat. We hope our results will also serve as a basis for exploring ways to conserve existing populations and localities by establishing where these salamanders are known to exist.

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