MESOAMERICAN SALAMANDERS
(AMPHIBIA: CAUDATA) AS A CONSERVATION FOCAL GROUP

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"Conservation is not merely a question of morality, but a question of our own survival".
His Holiness the Dalai Lama (2004)

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Summary

Salamanders constitute the second largest order of amphibians in the world. The 762 species occurring globally are organized into nine families, of which eight are found in the Western Hemisphere. The 308 species of Mesoamerican salamanders are arranged in four families, only two of which have representatives occurring significantly south of the US-Mexican border. Those two families are the Ambystomatidae, with 18 Mesoamerican species, and the Plethodontidae, with 287 species. Most of the Mesoamerican salamanders are endemic to either Mexico or Central America or to Mesoamerica in general. The largest number of endemic species belong to the genera *Ambystoma*, *Bolitoglossa*, *Chiropterotriton*, *Nototriton*, *Oedipina*, *Pseudoeurycea*, and *Thorius*. The greatest amount of salamander diversity is found in Mexico, followed in order by that in Guatemala, Costa Rica, Honduras, Panama, Nicaragua, El Salvador, and Belize. The amount of endemicity in Central America ranges in order from highest to lowest in Costa Rica, Nicaragua, Guatemala, Honduras, Panama, El Salvador, and Belize. Most species of Mesoamerican salamanders occupy conservation priority level one, amounting to 244 species and 88.4% of the 276 Mexican and Central American endemic species. These 244 species constitute a key conservation focal group for Mesoamerica based on several criteria. Most of the priority level one species are in the Mesa Central, Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur, Sierra de Los Tuxtlas, Western and Eastern Nuclear Central American Highlands, Isthmian Central American Highlands, and the Highlands of Eastern Panama. The significance of the biodiversity resource represented by Mesoamerican salamanders is not emphasized outside of a small cadre of conservation herpetologists and systematists working in the region. Nonetheless, these salamanders are threatened currently by the destructive activities of humans and potentially endangered by the possibility of the invasion of their habitats by the chytrid fungus *Batrachochytrium salamandrivorans*. Our conclusion is that Mesoamerican salamanders should be recognized as a conservation focal group for several reasons outlined herein. In addition, we suggest that these salamanders become the subject of a scientific congress tasked with promptly preparing a plan for protecting the diversity and endemicity of these amphibians for perpetuity.

Resumen

Las salamandras constituyen el segundo orden más grande de anfibios en el mundo. Las 762 especies que ocurren a nivel mundial están organizadas en nueve familias, de las cuales ocho se encuentran en el hemisferio occidental. Las 308 especies de salamandras mesoamericanas están distribuidas en cuatro familias, solo dos de las cuales tienen representantes que se encuentran significativamente al sur de la frontera de México y Estados Unidos. Esas dos familias son Ambystomatidae, con 18 especies mesoamericanas, y Plethodontidae, con 287 especies. La mayoría de las salamandras mesoamericanas son endémicas de México o Centroamérica o de Mesoamérica en general. La mayor cantidad de especies endémicas pertenece a los géneros *Ambystoma*, *Bolitoglossa*, *Chiropterotriton*, *Nototriton*, *Oedipina*, *Pseudoeurycea* y *Thorius*. La mayor diversidad de salamandras se encuentra en México, seguido en orden por Guatemala, Costa Rica, Honduras, Panamá, Nicaragua, El Salvador y Belice. La cantidad de endemismo varía en orden de mayor a menor en Costa Rica, Nicaragua, Guatemala, Honduras, Panamá, El Salvador y Belice. La mayoría de las especies de salamandras mesoamericanas ocupan el nivel de prioridad de conservación uno, con un total de 244 especies y el 88.4% de las 276 especies endémicas de México y Centroamérica. Estas 244 especies constituyen un grupo de enfoque de conservación clave para Mesoamérica basado en varios criterios. La mayoría de las especies del nivel de prioridad de conservación uno, están ubicadas en la Mesa Central, la Sierra Madre Occidental, la Sierra Madre Oriental, la Sierra Madre del Sur, la Sierra de Los Tuxtlas, las tierras altas de Centroamérica nuclear occidental y oriental, las tierras altas del Istmo de Centroamérica y las tierras altas del este de Panamá. En términos generales, la importancia del recurso de biodiversidad representado por las salamandras mesoamericanas no es tomado en cuenta fuera de un pequeño grupo de herpetólogos y taxónomos interesados en la conservación del grupo en la región. No obstante, estas salamandras están actualmente amenazadas por las actividades destructivas de los humanos y potencialmente amenazadas por la posibilidad de la invasión de sus hábitats por el hongo quítrido *Batrachochytrium salamandrivorans*. Nuestra conclusión es que las salamandras mesoamericanas deberían ser promovidas como un grupo de enfoque de conservación por varias razones. Adicionalmente, sugerimos que estas salamandras se conviertan en el tema de un congreso científico que aborde la preparación de un plan para la protección de la diversidad y endemismo de estos anfibios para la perpetuidad lo más pronto posible.

Keywords: Biodiversity decline, Caudata, conservation priority levels, Mexico, Central America

Palabras Claves: Caudata, diminución de la biodiversidad, América Central, México, niveles prioritarios de conservación

Introduction

Salamanders globally comprise the second largest order of amphibians, after anurans and before caecilians. The Amphibian Species of the World (ASW) website (Frost 2020; accessed 28 October 2020) lists 8,234 species of amphibians, of which anurans comprise 7,259 taxa or 88.2%. Caecilians make up 2.6% of the order, with 213 species. Salamanders constitute 762 species or 9.3% of the total. Nine salamander families are recognized at the ASW website. Of these nine families, four are restricted to the Western Hemisphere, i.e., Ambystomatidae, Amphiumidae, Rhyacotritonidae, and Sirenidae. Four of the other five have representatives in both hemispheres. Only the family Hynobiidae is restricted in distribution to the Eastern Hemisphere. Of the four bi-hemispheric families, the distribution of two of them, the Cryptobranchidae and the Proteidae, is limited to North America north of the Mexican border. The distribution of the other two, the Plethodontidae and the Salamandridae, penetrates far beyond the US-Mexican border (Plethodontidae) or only slightly so (Salamandridae).

This paper comprises an essay that attempts to make a case for the recognition of the Mesoamerican salamander fauna as a conservation focal group to exemplify the survival issues facing the Mesoamerican herpetofauna as a whole. We support this proposed designation based on the outstanding level of endemism and susceptibility to anthropogenic environmental pressures exhibited by the Mesoamerican caudates.

Methods

We have based our approach in this paper on that adopted in a series of papers published since 2013 that utilized the Environmental Vulnerability Score (EVS) originated by Wilson and McCranie (2003) for initial use in determining the conservation status of the members of the Honduran herpetofauna. In 2013, three of us published two papers that applied the EVS to the Mexican herpetofauna (Wilson et al., 2013a, b). The methodology in these two papers then was applied to the Central American herpetofauna (Johnson, et al., 2015). Two years later, Johnson et al. (2017) introduced the concept of conservation priority levels, which were determined by combining the EVS levels of the endemic members of the Mexican herpetofauna with their physiographic distribution; two years after, Mata-Silva et al. (2019) applied the same methodology to the Central American herpetofauna. Finally, García-Padilla et al. (2020) identified the conservation priority level one amphibians and reptiles in Mesoamerica as those most in need of critical care. The present paper picks up from where García-Padilla et al. (2020) left off, identifying the Mesoamerican salamander fauna as a conservation focal group, and completes a lengthy examination of the conservation status of the Mesoamerican herpetofauna through six papers published between 2013 and the present year, culminating in the present paper.

We find it necessary to point out that our approach to evaluating the conservation status of the hugely important Mesoamerican herpetofauna, has been dependent on use of the EVS measure (Wilson et al., 2013a, b; Johnson, 2015). Thus, we have eschewed the use of the more broadly applied and globally utilized IUCN methodology for the reasons that are stipulated by Wilson et al. (2013b: 107), as follows: "The EVS provides several advantages for assessing the conservation status of amphibians and reptiles. First, this measure can be applied as soon as a species is named, because the information necessary for its application generally is known at that point. Second, calculating the EVS is economical because it does not require expensive, grant-supported workshops, such as those undertaken for the Global Amphibian Assessment (sponsored by the IUCN). Third, the EVS is predictive, as it measures susceptibility to anthropogenic pressure and can pinpoint taxa with the greatest need of immediate attention and continued scrutiny. Finally, it is simple to calculate and does not "penalize poorly known species." In addition, we make no use of the SEMARNAT system of conservation assessment, since it is applicable only to the Mexican herpetofauna and has proved of little use even in the work we have accomplished on the herpetofaunas of various states in Mexico in what we have called the Mexican Conservation Series (as elucidated, for example, in Ramírez Bautista et al., 2020).

Our definition of Mesoamerica is the same as that adopted at the Mesoamerican Herpetology website (mesoamericanherpetology.com), i.e., "the region extending from the northern border of Mexico to the eastern border of Panama." This also is the definition used in the volume *Conservation of Mesoamerican Amphibians and Reptiles* (Wilson, et al., 2010).

Salamander Diversity In Mesoamerica

Of the eight salamander families with representatives in the Americas, only four have distributions extending into Mesoamerica. These families are the Ambystomatidae, Plethodontidae, Salamandridae, and Sirenidae. Two of these families, however, the Salamandridae and Sirenidae, occur only in extreme northeastern Mexico, and are represented by only one (Salamandridae) or two species (Sirenidae), as indicated in the taxonomic list at the *Mesoamerican Herpetology* website (accessed 28 October 2020). Thus, most of the Mesoamerican salamanders belong to the families Ambystomatidae and Plethodontidae. Of the total of the 305 total species in these two families in Mesoamerica (mesoamericanherpetology.org; accessed 28 October 2020), 18 belong to the Ambystomatidae (5.9%), whereas 287 are placed in the Plethodontidae (94.1%).

The 18 ambystomatid salamanders occupying Mesoamerica are limited in distribution to Mexico north of the southern rim of the Mexican Plateau (Vitt and Caldwell, 2009). The 18 ambystomatids comprise 48.6% of the 37 species in the entire family (Frost, 2020; accessed 28 October 2020). The 287 Mesoamerican plethodontids make up 58.6% of a total of 490 in the entire family, and 59.7% of the 481 species occurring in the Western Hemisphere (Frost, 2020; accessed 28 October 2020).

All 18 of the Mesoamerican ambystomatid salamanders belong to the genus *Ambystoma*, 54.5% of the 33 species in the entire genus. The only other genus in this family is *Dicamptodon*, with four species, limited in distribution to the Pacific Northwest of North America, from southwestern British Columbia in Canada to northern Idaho and extreme western Montana, as well as south to Pacific central California (Frost 2020; accessed 28 October 2020).

The 287 Mesoamerican plethodontids are placed in 17 genera (mesoamericanherpetology.org; accessed 28 October 2020), including *Aneides* (one species), *Aquiloeurycea* (six species), *Batrachoceps* (one species), *Bolitoglossa* (102 species), *Bradytriton* (one species), *Chiropterotriton* (23 species), *Cryptotriton* (seven species), *Dendrotriton* (eight species), *Ensatina* (one species), *Isthmura* (seven species), *Ixalotriton* (two species), *Nototriton* (20 species), *Nyctanolis* (one species), *Oedipina* (38 species), *Parvimolge* (one species), *Pseudoeurycea* (39 species), and *Thorius* (29 species). Interestingly, six of these 17 genera contain only single species in Mesoamerica, in some cases because the genus is monospecific (*Bradytriton*, *Nyctanolis*, and *Parvimolge*), in other cases because only a single species of a multi-specific genus ranges into Mesoamerica (*Aneides*, *Batrachoceps*, and *Ensatina*).

Only a single species of salamandrid salamanders occurs in Mesoamerica, in fact only in northeastern Mexico (to extreme northeastern Hidalgo), i.e., *Notophthalmus meridionalis*. Two species of sirenid salamanders, *Siren intermedia* and *S. lacertina*, are found in extreme northeastern Mexico.

Broad patterns of distribution of Mesoamerican Salamanders

The 308 Mesoamerican salamander species exhibit several broad patterns of distribution, as discussed by Wilson et al. (2017). These patterns and the number of taxa that illustrate them are outlined in Table 1. Of the nine distributional patterns for Mesoamerican amphibians and reptiles identified by Wilson et al. (2017), only five apply to Mesoamerican salamanders. These patterns are as follows:

(1) MXEN = species endemic to Mexico
(2) CAEN = species endemic to Central America
(3) MXUS = species distributed only in Mexico and the United States
(4) MXCA = species distributed only in Mexico and Central America
(5) CASA = species distributed only in Central America and South America

In general, most Mesoamerican salamanders exhibit the MXEN and CAEN patterns, i.e., they are species endemic to either Mexico or Central America. Of the 308 species involved, 133 or 43.2% are endemic to Mexico, whereas 144 or 46.8% are endemic to Central America. The total for these two portions of Mesoamerica is 277 species or 89.9% of the total for Mesoamerica. The remaining 31 species occur in Mexico and the United States (seven species or 2.3%), Mexico and Central America (19 species or 6.2%), or Central America and South America (five species or 1.6%). Combining the MXEN, CAEN, and MXCA species produces a figure of 296 species endemic to Mesoamerica or 96.1%. Thus, only 12 species or 3.9% occur also outside of Mesoamerica in the United States (seven species or 2.3%) or South America (five species or 1.6%).

Endemism among the Mesoamerican Salamanders

As noted above, the overall endemicity of Mesoamerican salamanders is stunning at 96.1% (Table 1). Also noteworthy is that 12 of the 20 genera of these amphibians are endemic to either Mexico (*Aquiloeurycea*, *Chiropterotriton*, *Isthmura*, *Ixalotriton*, *Parvimolge*, and *Thorius*), Central America (*Nototriton*), or Mesoamerica in general (*Bradytriton, Cryptotriton*, *Dendrotriton*, *Nyctanolis,* and *Pseudoeurycea*). The other eight genera in Mesoamerica have representatives in either the United States (*Ambystoma*, *Aneides*, *Batrachoceps*, *Ensatina*, *Notophthalmus*, and *Siren*) or South America (*Bolitoglossa* and *Oedipina*). The 12 endemic Mesoamerican genera collectively contain 144 species or 46.8% of the 308 total species distributed in Mesoamerica. The largest genus of salamanders in Mesoamerica is *Bolitoglossa*, with 102 species. According to Frost (2020; accessed 28 October 2020) this genus contains 136 species, indicating that 34 of the currently recognized species are restricted in distribution to South America and *Bolitoglossa* constitutes the only genus of salamanders occurring within this southern continent, other than *Oedipina*.

At the specific level, and as noted above, 296 of the 308 Mesoamerican salamanders or 96.1% are endemic to this region. The largest number of endemic Mesoamerican species belongs to the genera *Ambystoma* (17 species), *Bolitoglossa* (102 species), *Chiropterotriton* (23 species), *Nototriton* (20 species), *Oedipina* (36 species), *Pseudoeurycea* (39 species), and *Thorius* (29 species) for a total of 266 species or 86.4% of the overall total of 308 species (Table 1).

Country distribution and endemism of Mesoamerican Salamanders

Although the distribution of Mesoamerican salamanders among the eight nations of Mesoamerica has no biological significance, this information does have conservation significance, since it is governments of countries that draw up conservation plans. Therefore, the data on country distribution of these salamanders is placed in Table 2.

These data indicate that the greatest diversity is found in Mexico. This country harbors members of all four of the Mesoamerican families of salamanders, three of which occur nowhere else in Mesoamerica (i.e., in Central America). Mexico also contains the highest number of genera (18 of 20 or 90.0%) and species (158 of 308 or 51.3%). The next highest number of genera (8 of 20 or 40.0%) and species (64 of 308 or 20.8%%) is found in Guatemala, followed by the number in Costa Rica (3 of 20 genera or 15.0% and 52 of 308 species or 16.9%). Honduras and Panama exhibit an intermediate amount of diversity compared to the other countries in Central America, with, respectively, five of 20 genera or 25.0% and 42 of 308 species or 13.6% and two of 20 genera or 10.0% and 32 of 308 species or 10.4%. The other three Central American countries have either five species (Belize and El Salvador) or 10 species (Nicaragua), which amount to 1.6 or 3.2% of the total, respectively; the number of genera is either two (Belize and El Salvador) or three (Nicaragua).

At the country level, endemism ranges from 0% in Belize to 84.2% in Mexico. Intermediate figures are, in ascending order, 20.0% in El Salvador, 28.1% in Panama, 59.5% in Honduras, 59.4% in Guatemala, 60.0% in Nicaragua, and 63.5% in Costa Rica. Thus, the figures for country-level endemism are greater than 50% in Honduras, Guatemala, Nicaragua, Costa Rica, and Mexico. The total number of species endemic at the country level amounts to 245, which is 79.5% of the 308 species of salamanders found in Mesoamerica.

Table 1. Summary of distributional categories for the Mesoamerican salamander species, by genera. The abbreviations are as follows: MXEN = species endemic to Mexico; CAEN = species endemic to Central America; MXUS = species distributed only in Mexico and the United States; MXCA = species distributed only in Mexico and Central America; and CASA = species distributed only in Central America and South America.

Genera	No. of Species	MXEN (1)	CAEN (2)	MXUS (3)	MXCA (4)	CASA (5)
Ambystoma	18	17	—	1	—	—
Aneides	1	—	—	1	—	—
Aquiloeurycea	6	6	—	—	—	—
Batrachoceps	1	—	—	1	—	—
Bolitoglossa	102	10	76	—	13	3
Bradytriton	1	—	—	—	1	—
Chiropterotriton	23	23	—	—	—	—
Cryptotriton	7	1	6	—	—	—
Dendrotriton	8	2	6	—	—	—
Ensatina	1	—	—	1	—	—
Isthmura	7	7	—	—	—	—
Ixalotriton	2	2	—	—	—	—
Nototriton	20	—	20	—	—	—
Nyctinolis	1	—	—	—	1	—
Oedipina	38	—	35	—	1	2
Parvimolge	1	1	—	—	—	—
Pseudoeurycea	39	35	1	—	3	—
Thorius	29	29	—	—	—	—
Notophthalmus	1	—	—	1	—	—
Siren	2	—	—	2	—	—
Totals	308	133	144	7	19	5

Table 2. Distribution of the native salamander species of Mesoamerica by country. Asterisk signifies a species endemic to a given country.

Taxa	Mexico	Belize	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Caudata: Ambystomatidae (1 genus, 18 species)								
Ambystoma altamirani	+*							
Ambystoma amblycephalum	+*							
Ambystoma andersoni	+*							
Ambystoma bombypellum	+*							
Ambystoma dumerilii	+*							
Ambystoma flavipiperatum	+*							
Ambystoma granulosum	+*							
Ambystoma leorae	+*							
Ambystoma lermaense	+*							
Ambystoma mavortium	+							
Ambystoma mexicanum	+*							
Ambystoma ordinarium	+*							
Ambystoma rivulare	+*							
Ambystoma rosaceum	+*							
Ambystoma silvense	+*							
Ambystoma subsalsum	+*							
Ambystoma taylori	+*							
Ambystoma velasci	+*							
Subtotals	**18/17**							
Caudata: Plethodontidae (17 genera, 280 species)								
Aneides lugubris	+							
Aquiloeurycea cafetlera	+*							
Aquiloeuryces cephalica	+*							
Aquiloeurycea galeanae	+*							
Aquiloeurycea praecellens	+*							
Aquiloeurycea quetzalensis	+*							
Aquiloeurycea scandens	+*							
Batrachoseps major	+							
Bolitoglossa alberchi	+*							
Bolitoglossa alvaradoi							+*	
Bolitoglossa anthracina								+*
Bolitoglossa aurae							+*	
Bolitoglossa aureogularis							+*	
Bolitoglossa biseriata								+
Bolitoglossa bramei							+	+
Bolitoglossa carri					+*			
Bolitoglossa cataguana					+*			
Bolitoglossa celaque					+*			
Bolitoglossa centenorum			+*					
Bolitoglossa cerroensis							+*	
Bolitoglossa chinanteca	+*							
Bolitoglossa chucantiensis	+*							+*
Bolitoglossa coaxtlahuacana	+*							
Bolitoglossa colonnea							+	+
Bolitoglossa compacta							+	+
Bolitoglossa conanti			+		+			
Bolitoglossa copia								+*
Bolitoglossa copinhorum					+*			
Bolitoglossa cuchumatana			+*					
Bolitoglossa cuna								+*
Bolitoglossa daryorum			+*					

Taxa	Mexico	Belize	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Bolitoglossa decora					+*			
Bolitoglossa diaphora					+*			
Bolitoglossa diminuta							+*	
Bolitoglossa dofleini		+	+		+			
Bolitoglossa dunni			+		+			
Bolitoglossa engelhardti	+		+					
Bolitoglossa epimela							+*	
Bolitoglossa eremia			+*					
Bolitoglossa flavimembris	+		+					
Bolitoglossa flaviventris	+		+					
Bolitoglossa franklini	+		+					
Bolitoglossa gomezi							+	+
Bolitoglossa gracilis							+*	
Bolitoglossa hartwegi	+		+					
Bolitoglossa heiroreias			+	+	+			
Bolitoglossa helmrichi			+*					
Bolitoglossa hermosa	+*							
Bolitoglossa huehuetenanguensis			+*					
Bolitoglossa indio						+*		
Bolitoglossa insularis						+*		
Bolitoglossa jacksoni			+*					
Bolitoglossa jugivagans								+*
Bolitoglossa kamuk							+*	
Bolitoglossa kaqchikelorum			+*					
Bolitoglossa la			+*					
Bolitoglossa lignicolor							+	+
Bolitoglossa lincolni	+		+					
Bolitoglossa longissima					+*			
Bolitoglossa macrinii	+*							
Bolitoglossa magnifica								+*
Bolitoglossa marmorea							+	+
Bolitoglossa medemi								+
Bolitoglossa meliana			+*					
Bolitoglossa mexicana	+	+	+		+			
Bolitoglossa minutula							+	+
Bolitoglossa mombachoensis						+*		
Bolitoglossa morio			+*					
Bolitoglossa mulleri	+		+					
Bolitoglossa nigrescens							+*	
Bolitoglossa ninadormida			+*					
Bolitoglossa nussbaumi			+*					
Bolitoglossa nympha			+		+			
Bolitoglossa oaxacaensis	+*							
Bolitoglossa obscura							+*	
Bolitoglossa occidentalis	+		+		+			
Bolitoglossa odonnelli			+*					
Bolitoglossa omniumsanctorum			+*					
Bolitoglossa oresbia					+*			
Bolitoglossa pacaya			+*					
Bolitoglossa pesrubra							+*	
Bolitoglossa phalarosoma								+
Bolitoglossa platydactyla	+*							
Bolitoglossa porrasorum					+*			
Bolitoglossa psephena			+*					
Bolitoglossa pygmaea								+*
Bolitoglossa riletti	+*							
Bolitoglossa robinsoni							+*	
Bolitoglossa robusta							+	+
Bolitoglossa rostrata	+		+					
Bolitoglossa rufescens	+	+	+		+			
Bolitoglossa salvinii			+	+				
Bolitoglossa schizodactyla							+	+
Bolitoglossa sombra							+	+
Bolitoglossa sooyorum							+*	
Bolitoglossa splendida							+*	
Bolitoglossa striatula					+	+	+	
Bolitoglossa stuarti	+		+					
Bolitoglossa subpalmata							+*	
Bolitoglossa suchitanensis			+*					
Bolitoglossa synoria				+	+			
Bolitoglossa taylori								+
Bolitoglossa tenebrosa			+*					
Bolitoglossa tica							+*	
Bolitoglossa tzultacaj			+*					
Bolitoglossa veracrucis	+*							
Bolitoglossa xibalba			+*					
Bolitoglossa yucatana	+	+						
Bolitoglossa zacapensis			+*					
Bolitoglossa zapoteca	+*							
Bradytriton silus			+*					
Chiropterotriton arboreus	+*							
Chiropterotriton aureus	+*							
Chiropterotriton casasi	+*							
Chiropterotriton ceronorum	+*							
Chiropterotriton chico	+*							
Chiropterotriton chiropterus	+*							
Chiropterotriton chondrostega	+*							
Chiropterotriton cieloensis	+*							
Chiropterotriton cracens	+*							
Chiropterotriton dimidiatus	+*							
Chiropterotriton infernalis	+*							
Chiropterotriton lavae	+*							
Chiropterotriton magnipes	+*							
Chiropterotriton melipona	+*							
Chiropterotriton miquihuanus	+*							
Chiropterotriton mosauri	+*							
Chiropterotriton multidentatus	+*							
Chiropterotriton nubilis	+*							
Chiropterotriton orculus	+*							
Chiropterotriton perotensis	+*							
Chiropterotriton priscus	+*							
Chiropterotriton terrestris	+*							
Chiropterotriton totonacus	+*							
Cryptotriton alvarezdeltoroi	+*							
Cryptotriton monzoni			+*					
Cryptotriton nasalis					+*			
Cryptotriton necopinus					+*			

Taxa	Mexico	Belize	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Cryptotriton sierraminensis			+*					
Cryptotriton veraepacis			+*					
Cryptotriton xucaneborum			+*					
Dendrotriton bromeliacius			+*					
Dendrotriton chujorum			+*					
Dendrotriton cuchumatanus			+*					
Dendrotriton kekchiorum			+*					
Dendrotriton megarhinus	+*							
Dendrotriton rabbi			+*					
Dendrotriton sanctibarbarus					+*			
Dendrotriton xolocalcae	+*							
Ensatina eschscholtzii	+							
Isthmura bellii	+*							
Isthmura boneti	+*							
Isthmura corrugata	+*							
Isthmura gigantea	+*							
Isthmura maxima	+*							
Isthmura naucampatepetl	+*							
Isthmura sierraoccidentalis	+*							
Ixalotriton niger	+*							
Ixalotriton parvus	+*							
Nototriton abscondens							+*	
Nototriton barbouri					+*			
Nototriton brodiei			+*					
Nototriton costaricense							+*	
Nototriton gamezi							+*	
Nototriton guanacaste							+*	
Nototriton lignicola					+*			
Nototriton limnospectator					+*			
Nototriton major							+*	
Nototriton matama							+*	
Nototriton mime					+*			
Nototriton nelsoni					+*			
Nototriton oreadorum					+*			
Nototriton picadoi							+*	
Nototriton picucha					+*			
Nototriton richardi							+*	
Nototriton saslaya						+*		
Nototriton stuarti			+*					
Nototriton tapanti							+*	
Nototriton tomamorum					+*			
Nyctanolis pernix	+		+					
Oedipina alfaroi							+	+
Oedipina alleni							+	+
Oedipina altura							+*	
Oedipina berlini							+*	
Oedipina capitalina					+*			
Oedipina carablanca							+*	
Oedipina chortiorum			+		+			
Oedipina collaris						+	+	+
Oedipina complex								+
Oedipina cyclocauda						+	+	+
Oedipina elongata	+	+	+		+			
Oedipina fortunensis								+*
Oedipina gephyra					+*			
Oedipina gracilis							+	+
Oedipina grandis							+	+
Oedipina ignea			+		+			
Oedipina kasios					+*			
Oedipina koehleri						+*		
Oedipina leptopoda					+*			
Oedipina maritima								+*
Oedipina motaguae			+*					
Oedipina nica						+*		
Oedipina nimaso							+*	
Oedipina pacificensis							+	+
Oedipina parvipes								+
Oedipina paucidentata							+*	
Oedipina petiola					+*			
Oedipina poelzi							+*	
Oedipina pseudouniformis						+	+	
Oedipina quadra					+*			
Oedipina salvadorensis				+*				
Oedipina savagei							+*	
Oedipina stenopodia			+*					
Oedipina stuarti					+*			
Oedipina taylori			+	+	+			
Oedipina tomasi					+*			
Oedipina tzutujilorum			+*					
Oedipina uniformis							+*	
Parvimolge townsendi	+*							
Pseudoeurycea ahuitzotl	+*							
Pseudoeurycea altamontana	+*							
Pseudoeurycea amuzga	+*							
Pseudoeurycea anitae	+*							
Pseudoeurycea aquatica	+*							
Pseudoeurycea aurantia	+*							
Pseudoeurycea brunnata	+		+					
Pseudoeurycea cochranae	+*							
Pseudoeurycea conanti	+*							
Pseudoeurycea exspectata			+*					
Pseudoeurycea firscheini	+*							
Pseudoeurycea gadovi	+*							
Pseudoeurycea goebeli	+		+					
Pseudoeurycea juarezi	+*							
Pseudoeurycea kuautli	+*							
Pseudoeurycea leprosa	+*							
Pseudoeurycea lineola	+*							
Pseudoeurycea longicauda	+*							
Pseudoeurycea lynchi	+*							
Pseudoeurycea melanomolga	+*							
Pseudoeurycea mixcoatl	+*							
Pseudoeurycea mixteca	+*							
Pseudoeurycea mystax	+*							
Pseudoeurycea nigromaculata	+*							
Pseudoeurycea obesa	+*							
Pseudoeurycea orchileucos	+*							
Pseudoeurycea orchimelas	+*							
Pseudoeurycea papenfussi	+*							
Pseudoeurycea rex	+		+					
Pseudoeurycea robertsi	+*							
Pseudoeurycea ruficauda	+*							
Pseudoeurycea saltator	+*							

Taxa	Mexico	Belize	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Pseudoeurycea smithi	+*							
Pseudoeurycea tenchalli	+*							
Pseudoeurycea teotepec	+*							
Pseudoeurycea tlahcuiloh	+*							
Pseudoeurycea tlilicxitl	+*							
Pseudoeurycea unguidentis	+*							
Pseudoeurycea werleri	+*							
Thorius adelos	+*							
Thorius arboreus	+*							
Thorius aureus	+*							
Thorius boreas	+*							
Thorius dubitus	+*							
Thorius grandis	+*							
Thorius hankeni	+*							
Thorius infernalis	+*							
Thorius insperatus	+*							
Thorius longicaudus	+*							
Thorius lunaris	+*							
Thorius macdougalli	+*							
Thorius magnipes	+*							
Thorius maxillabrochus	+*							
Thorius minutissimus	+*							
Thorius minydemus	+*							
Thorius munificus	+*							
Thorius narismagnus	+*							
Thorius narisovalis	+*							
Thorius omiltemi	+*							
Thorius papaloae	+*							
Thorius pennatulus	+*							
Thorius pinicola	+*							
Thorius pulmonaris	+*							
Thorius schmidti	+*							
Thorius smithi	+*							
Thorius spilogaster	+*							
Thorius tlaxiacus	+*							
Thorius troglodytes	+*							
Subtotals	**137/116**	**5/0**	**64/38**	**5/1**	**42/25**	**10/6**	**52/33**	**32/9**
Caudata: Salamandridae (1 genus, 1 species)								
Notophthalmus meridionalis	+							
Subtotals	**1/0**							
Caudata: Sirenidae (1 genus, 2 species)								
Siren intermedia	+							
Siren lacertina	+							
Subtotals	**2/0**							
Totals (17 genera, 301 species)	**158/133**	**5/0**	**64/38**	**5/1**	**42/25**	**10/6**	**52/33**	**32/9**

Conservation priority levels among Mesoamerican Salamanders

Johnson et al. (2017) and Mata-Silva et al. (2019) presented the concept of conservation priority levels, a simple means of assessing the conservation significance of the endemic herpetofauna in Mexico and Central America, respectively, by combining data on their physiographic distribution and EVS group categorization, which resulted in the employment of 18 priority groupings for Mexico and 14 for Central America. These groupings were divided into six high priority levels, eight medium priority levels, and four low priority levels (the last with no such representatives in Central America). We extracted the data on the conservation priority categorizations for the endemic salamander species occurring in Mexico as well as Central America and placed them in Table 3, but excluded from consideration the 19 species common to both areas and priority levels with no salamander representation (i.e., levels six, nine, 11, 12, 13, 14, 15, 16, 17, and 18. As such, eight priority levels remain for placement of Mesoamerican endemic salamanders. There are a total of 276 salamanders endemic to either Mexico (with 132 species) or Central America (with 144 species). The majority of both the Mexican (116 species) and Central American species (128 species) occupy priority level one for a total of 244 for both regions, which amounts to 88.4% of the total number of species of 276. The number of species in the next largest priority level (two) declines sharply to 15. The numbers for levels three, four, five, seven, eight, and ten are five, three, one, four, two, and two, respectively (Table 3). These numbers add up to 32 or 11.6% of the total. Thus, almost nine of every ten endemic species in Mesoamerica occupy priority level one, and as such, are restricted to a single physiographic region, and have a high EVS.

In our opinion, salamanders can be viewed as comprising a key conservation focal group based on several criteria, including: (1) the highest level of overall endemicity of any herpetofaunal group in Mesoamerica (96.1%); (2) a huge representation of endemic salamander species in montane regions in Mesoamerica (233 species in nine montane regions or 95.5% of 244 endemic species); (3) the highest proportion of endemic salamander species with a high EVS (268 of 276 species or 97.1%); and also (4) a high proportion of salamander species occupying conservation priority level one (values noted above). Most of the Mesoamerican salamanders are placed in the family Plethodontidae; i.e., 287 of 308 species or 93.2%. The next largest representation (5.8%) involves the 18 species allocated to the family Ambystomatidae, occurring no farther south than the Mexican Plateau. Finally, a very few species are placed in the families Salamandridae (one) and Sirenidae (two). Of the 308 species of salamanders occurring in Mesoamerica, most are endemic to either Mexico (132 species) or Central America (144 species) or to Mesoamerica as a whole (19 species); the total is 295 or 95.8% of the entire Mesoamerican salamander count of 308 (Table 3). These numerical data are from Wilson et al. (2017), as updated at the Mesoamerican Herpetology website (mesoamericanherpetology.com; accessed 28 October 2020).

Most species of priority level one species of Mesoamerican salamanders are distributed in montane regions (García-Padilla et al., 2019). The data in that paper have been extracted and placed in Table 4, indicating the following: 233 species of these creatures or 95.5% of the 244 total priority level one salamanders occur in the following montane regions (Mesa Central—17; Sierra Madre Occidental—2, Sierra Madre Oriental—60; Sierra Madre del Sur—29; Sierra de Los Tuxtlas—3; Western Nuclear Central American Highlands—39; Eastern Nuclear Central American Highlands—36; Isthmian Central American Highlands—45; and Highlands of Eastern Panama—2); relatively few priority level one salamander species occupy the lowland regions (11 species or 4.5% of the total of 244, as distributed in the following regions—Caribbean Lowlands of Eastern Guatemala and Northern Honduras—2; Caribbean Lowlands from Nicaragua to Panama—7; Pacific Lowlands from Southeastern Guatemala to Northwestern Costa Rica—1; and Pacific Lowlands from Central Costa Rica through Panama—1). Of the nine montane regions, two (Sierra Madre Occidental and Highlands of Eastern Panama) harbor only two species each. The remainder contain 3 to 60 species. Three of these seven regions are restricted to Mexico, including the Mesa Central, Sierra Madre Oriental, and Sierra Madre del Sur regions, one overlaps Mexico and Central America (Western Nuclear Central American Highlands), and the final three (Eastern Nuclear Central American Highlands, Isthmian Central American Highlands, and Highlands of Eastern Panama) are limited to Central America. The three Mexico-only regions, i.e., Mesa Central, Sierra Madre Oriental, and Sierra Madre del Sur, support 17, 60, and 29 species, respectively, for a total of 106 species. The Mexico-Central America region (Western Nuclear Central American Highlands) contains 39 species. Finally, the Central America-only regions, i.e, Eastern Nuclear Central American Highlands, and Isthmian Central American Highlands, have 36 and 45 species, respectively, for a total of 81 species. It is either likely or assured that new species will be discovered and described from most or all the nine montane regions. In fact, we are aware that new species are undergoing description presently from the Western Nuclear Central American Highlands region and are likely to be found in time in the Sierra Madre Oriental, Sierra Madre del Sur, Western Nuclear Central American Highlands, Isthmian Central American Highlands, and Highlands of Eastern Panama regions, all which regions are the subject of study by some of our herpetological colleagues. The five lowland regions (Atlantic Lowlands from Tamaulipas to Tabasco, Caribbean Lowlands of Eastern Guatemala and Northern Honduras, Caribbean Lowlands from Nicaragua to Panama, Pacific Lowlands from Southeastern Guatemala to Northwestern Costa Rica, and Pacific Lowlands from Central Costa Rica through Panama) are less likely to be sites of significant new salamander species discoveries, but might still prove to produce novelties.

The genera of priority level one Mesoamerican salamanders tend to have distributions restricted to montane regions or groups of montane regions of Mesoamerica, as follows:

Ambystoma (nine species in the Mesa Central, one species in the Sierra Madre Occidental).
Aquiloeurycea (five species in the Sierra Madre Oriental).
Bolitoglossa (one species in the Sierra Madre Oriental, six species in the Sierra Madre del Sur, 20 species in the Western Nuclear Central American Highlands, 15 species in the Eastern Nuclear Central American Highlands, 27 species in the Isthmian Central American Highlands, two species in the Highlands of Eastern Panama).
Chiropterotriton (18 species in the Sierra Madre Oriental).
Cryptotriton (five species in the Western Nuclear Central American Highlands and one species in the Eastern Nuclear Central American Highlands).
Dendrotriton (seven species in the Western Nuclear Central American Highlands and one species in the Eastern Nuclear Central American Highlands).
Isthmura (one species in the Sierra Madre Occidental, two species in the Sierra Madre Oriental, and one species in the Sierra Madre del Sur).
Ixalotriton (two species in the Western Nuclear Central American Highlands).
Nototriton (two species in the Western Nuclear Central American Highlands, nine species in the Eastern Nuclear Central American Highlands, and nine species in the Isthmian Central American Highlands).
Oedipina (two species in the Western Nuclear Central American Highlands, 10 species in the Eastern Nuclear Central American Highlands, nine species in the Isthmian Central American Highlands, two species in the Caribbean lowlands of eastern Guatemala and northern Honduras, five species in the Caribbean Lowlands from Nicaragua to Panama, one species in the Pacific Lowlands from Southeastern Guatemala to Northwestern Costa Rica, and one species in the Pacific Lowlands from Central Costa Rica to Panama).
Parvimolge (one species in the Sierra Madre Oriental).
Pseudoeurycea (four species in the Mesa Central, 14 species in the Sierra Madre Oriental, two species in the Sierra de Los Tuxtlas, 13 species in the Sierra Madre del Sur, and one species in the Western Nuclear Central American Highlands).
Thorius (19 species in the Sierra Madre Oriental, one species in the Sierra de Los Tuxtlas, and nine species in the Sierra Madre del Sur).

Most of these priority level one salamander species belong to the family Plethodontidae and are distributed in montane regions throughout Mesoamerica. Many of the genera to which these priority level one salamander species belong are also endemic to Mesoamerica, including *Aquiloeurycea* (Mexico only), *Chiropterotriton* (Mexico only), *Cryptotriton* (Mexico and Central America), *Dendrotriton* (Mexico and Central America), *Isthmura* (Mexico only), *Ixalotriton* (Mexico only), *Nototriton* (Central America only), *Parvimolge* (Mexico only), *Pseudoeurycea* (Mexico and Central America), and *Thorius* (Mexico only). Thus, there is a plethora of these taxa that could be featured as flagship genera and species of montane regions throughout Mesoamerica in efforts to highlight the need for the conservation of the herpetofauna of these regions.

Table 3. Conservation priority list of endemic salamander species in Mexico and Central America based on the EVS categorization and the range of physiographic occurrence (data from Johnson et al., 2017, and Mata-Silva et al., 2019 [as updated with data from mesoamericanherpetology.com; accessed 28 October 2020]). Species common to Mexico and Central America not included.

Priority Levels	Mexico	Central America	Totals
One (High EVS in One Region)	116	128	244
Two (High EVS in Two Regions)	5	10	15
Three (High EVS in Three Regions)	3	2	5
Four (High EVS in Four Regions)	1	2	3
Five (High EVS in Five Regions)	—	1	1
High EVS Species Totals	125	143	268
Seven (Medium EVS in One Region)	4	—	4
Eight (Medium EVS in Two Regions)	1	1	2
Ten (Medium EVS in Four Regions)	2	—	2
Medium EVS Species Totals	7	1	8
Sum Totals	***132***	***144***	***276***

Tables 4. Distributional summary of priority level one salamander species in Mesoamerica, among 21 physiographic regions (first 14 in Mexico, remainder in Central America, with WN, CGU, and YP represented in both regions). Abbreviations are as follows: BC = Baja California and Adjacent Islands; SD = Sonoran Desert Basins and Ranges; NB = Northern Plateau Basins and Ranges; MC = Mesa Central; EL = Subhumid Extratropical Lowlands of Northeastern Mexico; SC = Pacific Lowlands from Sonora to Western Chiapas, including the Balsas Basin and Central Depression of Chiapas; OC = Sierra Madre Occidental; OR = Sierra Madre Oriental; TT = Atlantic Lowlands from Tamaulipas to Tabasco; LT = Sierra de Los Tuxtlas; SU = Sierra Madre del Sur; YP – Yucatan Platform; WN = Western Nuclear Central American Highlands; CGU = Pacific lowlands from eastern Chiapas to south-central Guatemala; HN = eastern nuclear Central American highlands; CRP = Isthmian Central American highlands; EP = highlands of eastern Panama; GH = Caribbean lowlands of eastern Guatemala and northern Honduras (area includes associated Caribbean islands); NP = Caribbean lowlands from Nicaragua to Panama (area includes associated Caribbean islands); GCR = Pacific lowlands from southeastern Guatemala to northwestern Costa Rica; and CP = Pacific lowlands from central Costa Rica through Panama (area includes associated Pacific islands).

Families	Physiographic Regions																				
	BC	***SD***	***NB***	***MC***	***EL***	***SC***	***OC***	***OR***	***TT***	***LT***	***SU***	***YP***	***WN***	***CGU***	***HN***	***CRP***	***EP***	***GH***	***NP***	***GCR***	***CP***
Ambystoma andersoni				+																	
Ambystoma bombypellum				+																	
Ambystoma dumerilii				+																	
Ambystoma flavipiperatum				+																	
Ambystoma granulosum				+																	
Ambystoma leorae				+																	
Ambystoma lermaense				+																	
Ambystoma mexicanum				+																	
Ambystoma silvense							+														
Ambystoma taylori				+																	
Ambystomatidae (10 species)	—	—	—	***9***	—	—	***1***	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aquiloeurycea cafetalera								+													
Aquiloeurycea galaenae								+													
Aquiloeurycea praecellens								+													
Aquiloeurycea quetzalanensis								+													
Aquiloeurycea scandens								+													
Bolitoglossa anthracina																+					
Bolitoglossa aurae																+					
Bolitoglossa aureogularis																+					
Bolitoglossa bramei																+					
Bolitoglossa carri															+						
Bolitoglossa cataguana															+						
Bolitoglossa celaque															+						
Bolitoglossa centenorum													+								
Bolitoglossa cerroensis																+					
Bolitoglossa chinanteca								+													
Bolitoglossa chucantiensis																	+				
Bolitoglossa coaxtlahuacana											+										
Bolitoglossa compacta																+					
Bolitoglossa conanti															+						
Bolitoglossa copia																+					
Bolitoglossa copinhorum															+						

Families	Physiographic Regions																			
Bolitoglossa cuchumatana													+							
Bolitoglossa cuna																			+	
Bolitoglossa daryorum													+							
Bolitoglossa decora															+					
Bolitoglossa diaphora															+					
Bolitoglossa diminuta																+				
Bolitoglossa dunni															+					
Bolitoglossa epimela																+				
Bolitoglossa eremia													+							
Bolitoglossa gomezi																+				
Bolitoglossa gracilis																+				
Bolitoglossa heiroreias															+					
Bolitoglossa helmrichi													+							
Bolitoglossa hermosa											+									
Bolitoglossa huehuetenanguensis													+							
Bolitoglossa indio																			+	
Bolitoglossa insularis															+					
Bolitoglossa jacksoni													+							
Bolitoglossa jugivagans																+				
Bolitoglossa kamuk																+				
Bolitoglossa kaqchikelorum													+							
Bolitoglossa la													+							
Bolitoglossa longissima															+					
Bolitoglossa macrinii											+									
Bolitoglossa magnifica																+				
Bolitoglossa marmorea																+				
Bolitoglossa meliana													+							
Bolitoglossa minutula																+				
Bolitoglossa mombachoensis															+					
Bolitoglossa nigrescens																+				
Bolitoglossa ninadormida													+							
Bolitoglossa nussbaumi													+							
Bolitoglossa oaxacensis											+									
Bolitoglossa obscura																+				
Bolitoglossa omniumsanctorum													+							
Bolitoglossa oresbia															+					
Bolitoglossa pacaya													+							
Bolitoglossa pesrubra																+				
Bolitoglossa porrasorum															+					
Bolitoglossa psephena													+							
Bolitoglossa pygmaea																+				
Bolitoglossa riletti											+									
Bolitoglossa robinsoni																+				
Bolitoglossa robusta																+				
Bolitoglossa sombra																+				
Bolitoglossa sooyorum																+				
Bolitoglossa splendida																+				
Bolitoglossa subpalmata																+				
Bolitoglossa suchitanensis													+							
Bolitoglossa synoria															+					
Bolitoglossa taylori																	+			
Bolitoglossa tenebrosa													+							
Bolitoglossa tica																+				
Bolitoglossa tzultacaj													+							
Bolitoglossa xibalba													+							
Bolitoglossa zacapensis													+							
Bolitoglossa zapoteca											+									
Chiropterotriton arboreus								+												
Chiropterotriton aureus								+												

Families	Physiographic Regions																				
Chiropterotriton casasi				+																	
Chiropterotriton ceronorum				+																	
Chiropterotriton chiropterus								+													
Chiropterotriton chondrostega								+													
Chiropterotriton cieloensis								+													
Chiropterotriton cracens								+													
Chiropterotriton dimidiatus								+													
Chiropterotriton infernalis								+													
Chiropterotriton lavae								+													
Chiropterotriton magnipes								+													
Chiropterotriton melipona								+													
Chiropterotriton miquihuanus								+													
Chiropterotriton mosaueri								+													
Chiropterotriton multidentatus								+													
Chiropterotriton nubilus								+													
Chiropterotriton orculus								+													
Chiropterotriton perotensis				+																	
Chiropterotriton priscus								+													
Chiropterotriton terrestris								+													
Chiropterotriton totonacus				+																	
Cryptotriton alvarezdeltoroi													+								
Cryptotriton monzoni													+								
Cryptotriton necopinus															+						
Cryptotriton sierraminensis													+								
Cryptotriton veraepacis													+								
Cryptotriton xucaneborum													+								
Dendrotriton bromeliacius													+								
Dendrotriton chujorum													+								
Dendrotriton cuchumatanus													+								
Dendrotriton kekchiorum													+								
Dendrotriton megarhinus													+								
Dendrotriton rabbi													+								
Dendrotriton sanctibarbarus															+						
Dendrotriton xolocalcae													+								
Isthmura corrugata								+													
Isthmura gigantea								+													
Isthmura maxima											+										
Isthmura sierraoccidentalis							+														
Ixalotriton niger													+								
Ixalotriton parvus													+								
Nototriton abscondens																+					
Nototriton barbouri															+						
Nototriton brodiei													+								
Nototriton costaricense																+					
Nototriton gamezi																+					
Nototriton guanacaste																+					
Nototriton lignicola															+						
Nototriton limnospectator															+						
Nototriton major																+					
Nototriton matama																+					
Nototriton mime															+						
Nototriton nelsoni															+						
Nototriton oreadorum															+						
Nototriton picadoi																+					
Nototriton picucha															+						
Nototriton richardi																+					
Nototriton saslaya															+						
Nototriton stuarti													+								
Nototriton tapanti																+					
Nototriton tomamorum															+						

Families	Physiographic Regions																				
Oedipina altura															+					
Oedipina berlini															+					
Oedipina capitalina														+						
Oedipina carablanca																		+		
Oedipina chortiorum														+						
Oedipina collaris																		+		
Oedipina cyclocauda																		+		
Oedipina fortunensis															+					
Oedipina gephyra														+						
Oedipina gracilis																		+		
Oedipina grandis															+					
Oedipina kasios														+						
Oedipina koehleri														+						
Oedipina leptopoda														+						
Oedipina maritima																		+		
Oedipina motaguae																	+			
Oedipina nica														+						
Oedipina nimaso															+					
Oedipina pacificensis																				+
Oedipina paucidentata															+					
Oedipina petiola														+						
Oedipina poelzi															+					
Oedipina quadra																	+			
Oedipina salvadorensis																			+	
Oedipina savagei															+					
Oedipina stenopodia												+								
Oedipina taylori														+						
Oedipina tomasi														+						
Oedipina tzutujilorum												+								
Oedipina uniformis															+					
Parvimolge townsendi							+													
Pseudoeurycea ahuitzotl										+										
Pseudoeurycea altamontana			+																	
Pseudoeurycea amuzga										+										
Pseudoeurycea anitae										+										
Pseudoeurycea aquatica							+													
Pseudoeurycea aurantia							+													
Pseudoeurycea cochranae										+										
Pseudoeurycea conanti										+										
Pseudoeurycea expectata												+								
Pseudoeurycea firscheini							+													
Pseudoeurycea juarezi							+													
Pseudoeurycea kuautli										+										
Pseudoeurycea lineola							+													
Pseudoeurycea longicauda			+																	
Pseudoeurycea lynchi							+													
Pseudoeurycea melanomolga							+													
Pseudoeurycea mixcoatl										+										
Pseudoeurycea mixteca										+										
Pseudoeurycea mystax										+										
Pseudoeurycea naucampatepetl							+													
Pseudoeurycea nigromaculata							+													
Pseudoeurycea obesa							+													
Pseudoeurycea orchileucos							+													
Pseudoeurycea orchimelas									+											
Pseudoeurycea papenfussi							+													
Pseudoeurycea robertsi			+																	
Pseudoeurycea ruficauda							+													
Pseudoeurycea saltator							+													
Pseudoeurycea tenchalli										+										

Families	Physiographic Regions																				
Pseudoeurycea teotepec											+										
Pseudoeurycea tlahcuiloh											+										
Pseudoeurycea tlilicxitl				+																	
Pseudoeurycea unguidentis											+										
Pseudoeurycea werleri										+											
Thorius adelos								+													
Thorius arboreus								+													
Thorius aureus								+													
Thorius boreas								+													
Thorius dubitus								+													
Thorius grandis											+										
Thorius hankeni											+										
Thorius infernalis											+										
Thorius insperatus								+													
Thorius longicaudus											+										
Thorius lunaris								+													
Thorius macdougalli								+													
Thorius magnipes								+													
Thorius maxillabrochus								+													
Thorius minutissimus											+										
Thorius minydemus								+													
Thorius munificus								+													
Thorius narismagnus										+											
Thorius narisovalis											+										
Thorius omiltemi											+										
Thorius papaloae								+													
Thorius pennatulus								+													
Thorius pinicola											+										
Thorius pulmonaris								+													
Thorius schmidti								+													
Thorius smithi								+													
Thorius spilogaster								+													
Thorius tlaxiacus											+										
Thorius troglodytes								+													
Plethodontidae (234 species)	—	—	—	8	—	—	1	60	—	3	29	—	39	—	36	45	2	2	7	1	1
Totals (244 species)	—	—	—	17	—	—	2	60	—	3	29	—	39	—	36	45	2	2	7	1	1

Conservation significance of Mesoamerican Salamanders

Even though salamanders constitute a hugely important biodiversity resource in Mesoamerica, which is expected to continue to be the source of significant taxonomic novelty, this status is not recognized generally outside the enclave of conservation herpetologists or conservation biologists at most, and, therefore, the matter does not rise to the level of becoming the focus of conservation action plans anywhere in Mesoamerica, as judged by the conservation literature published to date.

Nonetheless, several important studies have appeared recently, the results of which impinge on the conservation importance of Mexican salamanders. The most consequential deal with the potential threat imposed by the chytrid fungus *Batrachochytrium salamandrivorans* (*Bsal*) on Mexican salamanders, which fungus has been documented to be responsible for the recent decline in European salamander populations (Gray et al. 2015; Spitzen-van der Sluijs et al. 2016; Stegen et al. 2017; Basanta et al. 2019). Their work is of immense importance, since *Bsal* has yet to be reported from Mexico or the USA. Basanta et al. (2019) used ecological modeling methods to identify "areas moderately to highly suitable for the establishment of *Bsal* with high salamander diversity as potential hotspots for surveillance" (Basanta et al. 2019: 1). They noted that Mexico has the second-highest salamander species diversity in the world (second only to the USA) and found (pg. 4) that "areas from the Sierra Madre Oriental (SMO), Trans-Mexican Volcanic Belt (TVB), Sierra Madre del Sur (SMS), Mexican Gulf and Yucatan Peninsula were the most suitable areas for *Bsal*." Of high significance is that three of these five areas (Sierra Madre Oriental, Trans-Mexican Volcanic Belt, and Sierra Madre del Sur) are precisely those areas we have identified above as harboring the highest levels of Mexican salamander diversity. The lowland regions, although supporting limited salamander diversity, do provide possible ports of entry for *Bsal* with foreign origins and access to populations of non-susceptible lowland anurans that could act as carriers and transmission vectors of *Bsal* to highly susceptible [salamander] species (Basanta et al. 2019: 8). These authors concluded (pg. 9) that their study, which integrated ecological niche modeling of *Bsal* and salamander distribution in Mexico, "found high overlap between them." They further concluded (pg. 9) that "the areas most suitable for *Bsal* in Mexico are Central and Southern Mexico, which coincide with the highest salamander richness areas and with the largest number of endemic and threatened species." Moreover, they "identified 13 areas as potential hotspots for population risk with both high salamander diversity and areas that are moderately to highly suitable for *Bsal*." These 13 potential hotspots (in which five or more salamander species occur) are in the Trans-Mexican Volcanic Belt, Los Tuxtlas in Veracruz, Sierra Madre del Sur in Guerrero and Oaxaca, and the Sierra Madre in Chiapas (pg. 5). The most important conclusion of the Basanta et al. (2019) study is obvious. What steps should be taken to prevent and/or limit the spread of *Bsal* in Mexico? The authors opine that wildlife trade presents the potential risk of introducing *Bsal* to naïve regions in Mexico. Furthermore, "areas with high salamander diversity have climatic conditions that appear to be suitable for the establishment of *Bsal* should an introduction occur. Considering the latter, the risk of *Bsal* arrival is critically important, and it is essential to monitor these areas where species loss would be considerable" (Basantal et al. 2019: 8). These authors also noted (pg. 9) that "the combined effects of *Bd* [*B. dendrobatidis*] and *Bsal* together [sic] in amphibian population are *unknown* [emphasis ours], but [they] can only assume that they could dramatically affect the amphibian populations that are already threatened by habitat loss." Finally, they stated that "conservation efforts for amphibians in Mexico should focus on preventing the arrival of *Bsal* and its transmission among populations. Amphibian trade restrictions are being implemented in the USA, Canada and the European Union, and Mexico *should not be the exception* [emphasis ours]. As the country with the second-highest salamander species diversity, Mexico is potentially at risk of facing dramatic declines upon the arrival of an emerging pathogen such as *Bsal*. If *Bsal* is detected in Mexico, immediate management actions to prevent its spread, such as restricting site-level access, especially in hotspots, should be considered."

The Basanta et al. (2019) study is a powerful prescriptive piece of work that seems destined to morph into an important tale of missed opportunities that if applied in time and with sufficient diligence could have averted a major ecological travesty. There are several reasons we think that one day those people who know what could have been avoided and care deeply that these things did not occur will look back and ask, "What might have happened if we had taken the steps prescribed by Basanta et al. (2019) in a timely fashion?" These reasons are as follows:

1. *Batrachochytrium dendrobatidis* (*Bd*) initially was reported to cause amphibian mortality by Berger et al. (1998) in species occurring in rain forests of Australia and Central America. In the ensuing two decades after that publication appeared, *Bd* has assumed a global presence and has become a major environmental threat to the continued existence of anuran amphibians on the planet. Subsequent studies have concluded that *Bd* either originated in Africa (Weldon et al. 2004) and spread through traffic in African clawed frogs (*Xenopus laevis*) or on the Korean Peninsula (New York Times, 2018-05-10) and also spread by trade in frogs (O-Hanlon et al. 2018). In addition, *Lithobates catesbeianus* is a North American anuran that is thought to be a carrier of the disease chytridiomycosis and is widely introduced into localities outside its native range for use as a food source and frequently escapes captivity to become established in these areas. The work we have done thus far with our Mexican Conservation Series has demonstrated that the American Bullfrog has been introduced into six of the

Mexican states (Coahuila, Hidalgo, Nayarit, Nuevo León, Puebla, and Tamaulipas) in 11 entries in this series published to date. Thus, it is clear that *Bd* is the culprit in the creation of a disease that has achieved global impact among populations of anuran amphibians and that humans have ably facilitated the spread of chytridiomycosis.

2. *Batrachochytrium salamandrivorans* is a chytrid fungus described as a new species by Martel et al. (2013), just eight years ago, and at the same time identified as capable of causing lethal chytridiomycosis in amphibians and to have been shown already to be responsible for "die-offs of native salamander species in Europe" (Basanta et al. 2019: 1). This fungus has decimated populations of the Fire Salamander (*Salamandra salamandra*) in the Netherlands (Martel et al. 2013). Thus far, the fungus has not been reported in the Western Hemisphere, but there is significant concern that it might eventually manage to become established there. Investigative work undertaken with North American species of salamanders has shown that this fungus can kill *Taricha granulosa* and that *Notophthalmus viridescens* is a susceptible *Bsal* host species. The introduction of *Bsal* into populations of *S. salamandra* in Europe is thought to have occurred relatively recently because of the pet trade in the Japanese Fire-bellied Newt (*Cynops pyrrhogaster*). The potential for the introduction of *Bsal* into North America is serious enough that the U.S. Fish and Wildlife Service issued a directive on 12 January 2016 prohibiting the importation of salamanders to reduce the threat posed by *Bsal*. This step, while certainly worthwhile, might not be sufficient to stem the potential for the establishment of *Bsal* in North America, especially inasmuch as wild frogs that can coexist with *Bsal* infections (Basanta et al. 2019: 2) have been shown to act as carriers of this fungus and potential vectors for transmission. Therefore, trade in these wild frogs also would have to be prohibited. The United States and Mexico contain the largest and the second-largest salamander faunas in the world, respectively. The global salamander fauna currently stands at 762 species (Frost, 2020; accessed 28 October 2020). North America is home to 208 species, as indicated at AmphibiaWeb.org (accessed 31 October 2020); this figure is 27.3% of the global figure. Only seven species of resident salamanders in the US occur in Mexico (mesoamericanherpetology.com; accessed 28 October 2020), which means that 201 species (96.6%) are endemic to the United States. The figure for Mesoamerica is 308 species (mesoamericanherpetology.com; accessed 28 October 2020), which is 40.4% of the total for the world. Mexico harbors 159 species of salamanders or 20.9% of the world total, of which 133 (83.6%) are endemic to the country. The number of salamander species in Central America is 168, of which 144 or 85.7% are endemic to this region (mesoamericanherpetology.com; accessed 28 October 2020). As impressive as these figures are, they do not account for the salamander species that have yet to be described from the Western Hemisphere. The potential for ecological disaster in the form of spreading *Bsal* to the United States and/or Mesoamerica and the infection of the many susceptible salamander species in these regions is incalculable presently, but appears substantial given the poor track record the human species has for dealing with such threats in advance of their manifestation, let alone after such has occurred.

3. As noted above, North America is the largest repository of salamander species in the world. The threat posed, therefore, by the introduction of *Bsal* into the United States is massive and has prompted a call for action by several workers in this country (Gray et al. 2015). These authors concluded the following about this threat: "All evidence suggests that we are at a critical time of action to protect global amphibian biodiversity by swift policy actions to prevent the translocation of *Bsal*… *Bsal*'s potential effects are broad taxonomically, geographically, ecologically, and across a variety of ecosystem services. Hence, response to the threat of *Bsal* calls for a cooperative effort across nongovernmental organizations, government agencies, academic institutions, zoos, the pet industry, and concerned citizens to avoid the potential catastrophic effects of *Bsal* on salamanders outside of the pathogen's endemic regions. Communication, collaboration, and expedited action are key to ensure that *Bsal* does not become established in North America and decimate wild salamander populations." These authors ended their report with the most pertinent question applicable, viz. "Will sufficient policy action occur before it is too late?" It appears to us to be likely that we will know the answer to this seminal question sooner rather than later.

4. Another recent study of the North American threat was prepared by Yap et al. (2015) and is entitled "Averting a North American biodiversity crisis." These authors prepared a salamander *Bsal* vulnerability model, which predicted the sites of major vulnerability to be located in the southeastern and northwestern sectors of the U.S. Yap et al. (2015) also posited that the most likely means of *Bsal* introduction into the U.S. is through international salamander trade. They determined the most likely routes for introduction by identifying the five most active ports (in order of importance, Los Angeles, CA, Tampa, FL, New York, NY, Atlanta GA, and San Francisco, CA) and indicated, frighteningly enough, that these ports "were located within or near the predicted salamander vulnerability zones" and collectively "accounted for more than 98% of all U.S. salamander imports" (Yap et al. 2015: 482). They concluded that "Immediate efforts are required to monitor zones of salamander *Bsal* high vulnerability… New studies on the basic biology of *Bsal* and on host-pathogen dynamics should also be a priority. Future studies should incorporate

new data on transmission, susceptibility, and other potentially influential variables (e.g., species life-history traits, host microbiome, or co-occurring pathogens) to better understand the complex disease system. In the interim, the trade industry should take preventive measures from protocols that have been developed for the detection of *Bsal*… and the treatment of infected individuals" (Yap et al. 2015: 482). As of 2017, however, *Bsal* has not been detected in a survey of pet salamanders in the US (Klocke et al. 2017).

5. If the threat to salamander populations by *Bsal* were not bad enough, this threat might not have to reach North America directly from imported salamanders from overseas. Nguyen et al. (2017: 554) reported that *Bsal* has been found on wild small-webbed fire-bellied toads (*Bombina microdeladigitora*) from Vietnam, which have been imported recently into Germany. Thus, these authors concluded that "this finding suggests that the installment of measures to mitigate the *Bsal* threat through the amphibian trade should not be limited to urodeles but should equally take anurans into account." Thus, the threat posed to salamanders by *Bsal* could be magnified tremendously given that anurans can act as agents for transmission of this chytrid fungus, making the problem several times more difficult to address.
6. Decimation of amphibian populations by chytrid fungi is a relatively recently understood phenomenon, which has proved important enough to have generated an extensive "cottage industry" of research into amphibian diseases, reports of which are now a regular feature of *Herpetological Review*, the official bulletin of the Society for the Study of Amphibians and Reptiles. Of significance is the fact that the December 2018 issue included a study entitled "Earliest record of *Batrachochytrium dendrobatidis* in amphibian populations of Baja California, Mexico" (Santos Barrera and Peralta García, 2018). This report indicated that *Bd* infection was detected in populations of *Rana draytonii*, the California Red-legged Frog, beginning three years (2018). This paper also noted that two additional anuran species, *Hyliola cadaverina* and *Anaxyrus californicus*, have populations at a nearby locality infected at a high level (over 80%) with *Bd*. The scientific approach to this ecological disaster essentially has been limited to watching (i.e., documenting) its spread, both geographically and taxonomically, as well as studying the biological features of the fungus. Most likely, the same situation will obtain for *Bsal*.
7. Whereas the spread of chytrid fungi of the genus *Batrachochytrium* among amphibian populations across the globe is especially alarming due to its rapidity and degree of scientific documentation, it is especially important to note that all the other environmental threats to amphibian (and reptile) species continue to develop apace. One of most dangerous outgrowths of the anthropocentric worldview is the idea that "our role is to conquer and subdue wild nature and use it for our own purposes" (Wilson and Lazcano 2019: 26). Humans continue to work on this ill-conceived purpose through two principal means: (a) by increasing the numbers of us on the planet by practicing unregulated population growth; and (b) by improving our ability to access resources from the natural world, send them through our economic systems (i.e., use and abuse them), and discharge them out the other end as unreclaimed and unreclaimable resources (= garbage). Human population growth continues apace and is monitored by, among other agencies, the Population Reference Bureau (prb.org). Every year, this organization produces a summary of statistics concerning population growth and related matters called the World Population Data Sheet (WPDS); the most recent version of this data sheet is for 2020. One of the pieces of data available on this sheet is the rate of natural increase or percentage growth rate, which can be used to calculate the population doubling time. If the percentage growth is divided into 70, the result approximates the doubling time in years. In Mesoamerica, the percentage growth rate ranges from 0.8% in Costa Rica to 1.8% in Nicaragua, which produces a range in doubling times from 87.5 to 38.9 years (2020 WPDS). The average for this part of the world is 1.2% for a doubling time of 58.3 years. Therefore, in this period or by 2078, the population of the region will have grown from the current level of 179 million to 358 million. In that same period, the impact of the human population on the amount of arable land in Mesoamerica will double, increasing from 618 people per square kilometer of arable land to 1,236 (2020 WPDS). In addition, the percentage of the population living in urban settings also will increase from the current figure of 69 to a higher figure. Consequently, more and more people living in urban settings will come to depend for subsistence on fewer and fewer people attempting to farm increasingly stressed croplands. From a conservation perspective, these trends portend for greater and greater pressure on the remnant natural habitats to support populations of organisms other than *Homo sapiens*, including the incredibly important endemic species in the herpetofauna.
8. The eight countries of Mesoamerica present a study of contrasts in terms of population, environmental, and economic data. The mid-2020 population figures range from 400,000 for Belize to 127,800,000 for Mexico. The growth rate ranges from 0.8% (doubling time of 87.5 years) in Costa Rica to more than double that figure in Nicaragua (1.8% with a doubling time of 38.8 years). The percentage of urbanization ranges from 45 in Belize to 73 in Costa Rica and Mexico. The population per square kilometer of arable land ranges from 439 in Nicaragua to 2,096 in Guatemala. The GNI per capita PPP 2018 ranges from $5,350 in Honduras to $29,340 in Panama (2020 WPDS). Rates of deforestation also vary considerably in Mesoamerica, with the proportion of remaining forest cover ranging from 21% in El Salvador to 63% in Belize

(wikipedia.org; accessed 02 November 2020). As noted by González Rodríguez (2017: 27), "The rate of deforestation in Mexico is one of the most intense on the planet: according to the Geography Institute of UNAM, each year we lose 500 thousand hectares of forests and jungles. This situation places a great variety of plants and animals at risk of extinction, as well as many communities that over the generations have found a means of life in this ecosystem, to such an extent that they have learned to take advantage of it without destroying it. This also places us in fifth place in deforestation globally." This level of deforestation equates to a loss of 2.5% of forest cover per year. At this rate of deforestation in Mexico, it is expected that the entirety of this country's forests will disappear in just 40 years. These realities do not seem to faze the people in government, who do what they do without compunction.

9. In addition to the threat posed by *Bsal* and the habitat modification and destruction resulting from deforestation and its concomitant forms of anthropogenic abuse (agriculturalization and urbanization), information is accruing that serious declines in salamander populations appear to be resulting from climate alteration in upland settings in Mexico and Central America due to alteration of moisture conditions because of lowland and premontane deforestation (Rovito et al. 2009). These authors reported on studies of salamander faunas at various sites in southern Mexico and northern Central America that demonstrated population declines in terrestrial salamander species as opposed to those inhabiting arboreal bromeliads. Rovito et al. (2009: 3235) concluded that, "The results of [their] study point to widespread and severe declines of upland salamanders at multiple sites in Guatemala and Mexico, including the most intensively-studied salamander transect in the neotropics [that on Volcán Tajumulco in the Department of San Marcos in southwestern Guatemala]. Although the causes of these declines are not yet well understood, the drastic reductions in salamander numbers and changes in community composition in this region indicate that the salamander populations of many upland species need protection. Until the forces causing these declines are identified, however, an effective conservation strategy cannot be devised. Protecting habitat, although important, is insufficient to conserve populations of many of these species. Furthermore, other recent studies have also provided evidence of declining salamander populations in the neotropics [Lips et al. 2006; Whitfield et al. 2007]. The global amphibian crisis, usually discussed in terms of frogs, clearly involves Middle American salamanders as well." They further noted (Rovito et al. 2009: 3235) that "Species of cloud forest salamanders that can still be found rely at least in part on bromeliads. Bromeliads depend on cloud water deposition and are predicted to be particularly vulnerable to climate change…Therefore, if climate change is in part responsible for the declines [they] observed, arboreal salamander species that are presently not in decline may soon suffer the same fate at the fully terrestrial species." This report raises the specter that environmental threats of great importance can arise from locales significantly remote from the habitats in which these salamanders live.

For the reasons elaborated above, it is our opinion that Mesoamerican salamanders should be promoted as a conservation focal group because they are the best exemplars of high rates of endemicity among the members of the Mesoamerican herpetofauna. In addition, they are highly susceptible to environmental damage through human action, due to the threat posed most egregiously by a potential *Bsal* infection and the actual and increasing impact of deforestation. In our view, a conservation focal group is one that contains species of sufficient diversity and endemicity to be used for publicizing the conservation issues facing such groups in general. Salamanders in Mesoamerica are primarily land-bound creatures heavily dependent on intact forest for their survival and reproduction (only 21 of 308 species or 6.8% are not members of the family Plethodontidae). Deforestation is a current and increasing threat to these amphibians, with *Bsal* infection a threat likely to emerge in the near future. Significant steps to protect populations of these flagship species should be implemented immediately by relevant conservation agencies.

A Comprehensive Plan to Salvage the Mesoamerican Salamander Fauna

In this study, we have documented several distinctive features of the Mesoamerican salamander fauna, including that:

1. This fauna is significantly large and diverse, consisting of 308 species in 20 genera of four families.
2. The two largest families are the Ambystomatidae, represented by 18 species in the genus *Ambystoma*, distributed most extensively in the Mesa Central, including its southern rim, and the Plethodontidae, with 287 species in 17 genera, distributed principally in the various montane regions of Mexico and Central America.
3. This salamander fauna is decidedly endemic, with an overall proportion of 96.1%. This fauna consists of 132 endemic Mexican species, 144 endemic Central American species, and 19 species endemic to Mesoamerica in general.
4. The majority of the 295 endemic Mesoamerican species are allocated to the conservation priority level one, indicating that each is restricted to one of the 21 recognized physiographic regions and have a high EVS value.
5. The Mesoamerican salamander fauna is gravely threatened by the potential specter of an invasion by the chytrid fungus *Batrachochytrium salamandrivorans* into the Western Hemisphere

in either North America north of Mexico, Mesoamerica, or both. This fauna is severely imperiled presently by widespread destruction of their habitat by humans. These potential or actual threats are, or will be, advancing at an exponential rate consonant with the increase in the human population and its insatiable appetite for consuming the planetary resource base.

6. Given the reality of these threats, there is no time like the present to devise and implement a comprehensive multi-national plan for salvaging of this globally significant salamander fauna. Such a plan for Mesoamerica could use the plan outlining research, monitoring, and management strategies developed for the United States by Campbell Grant et al. (2015).
7. Our initial suggestion is that a Mesoamerican-based herpetological group such as the Red Mesoamericana y del Caribe para la Conservación de Anfibios y Reptiles convene a congress for the express purpose of devising an action plan for reclaiming the Mesoamerican salamander fauna for perpetuity. Congressional participants should include professional herpetologists, especially those specializing in the study of salamander biology, conservation herpetologists, especially those specializing in the conservation of the Mesoamerican herpetofauna, conservation biologists representing global conservation organizations, specialists in environmental education, and government officials representing environmental ministries.
8. We also suggest that the program for the congress be based on an exploration of the conservation imperatives facing the various segments of the Mesoamerican salamander fauna from its principal montane regions, including the Sierra Madre Oriental, Sierra Madre Occidental, Mesa Central (including Trans-Mexican Volcanic Belt), Sierra Madre del Sur, Western and Eastern Nuclear Central American Highlands, Isthmian Central American Highlands, and Highlands of Eastern Panama. The program should also include a presentation on the steps being taken at the governmental level in the various Mesoamerican countries to assure a future for salamander faunas present in those countries. Finally, presentations should be made on how best to explain to local groups about the conservation significance and environmental threats facing the members of the Mesoamerican salamander fauna and to enlist their aid in developing and implementing programs for protecting these creatures.
9. Finally, plans for the publication of the results of the congress should be formulated for swift dissemination and implementation of a comprehensive plan for the perpetual protection of the Mesoamerican salamander fauna.

Conclusions

A. Salamanders constitute the second largest order of amphibians globally, with 762 species or 9.3% of the total size of the class. These 762 species are arranged into nine families, of which eight are represented in the Western Hemisphere.
B. The salamanders of Mesoamerica are partitioned into four families, including the Ambystomatidae, Plethodontidae, Salamandridae, and Sirenidae. Representatives of only two of these families, the Ambystomatidae and Plethodontidae, extend very far into Mesoamerica. The Mesoamerican species of the family Ambystomatidae extend only to the southern edge of the Mesa Central, whereas those of the family Plethodontidae extend the length and breadth of Mesoamerica from northern Mexico to southern Panama and on into northern South America.
C. The salamander fauna of Mesoamerican comprises 308 species, 305 of which belong to the two families Ambystomatidae (with 18

species) and Plethodontidae (with 287 species). All 18 of the Mesoamerican ambystomatid salamanders belong to the genus *Ambystoma*. The 287 Mesoamerican plethodontid salamanders are allocated to 17 genera, including *Aneides* (one species), *Aquiloeurycea* (six species), *Batrachoceps* (one species), *Bolitoglossa* (102 species), *Bradytriton* (one species), *Chiropterotriton* (23 species), *Cryptotriton* (seven species), *Dendrotriton* (eight species), *Ensatina* (one species), *Isthmura* (seven species), *Ixalotriton* (two species), *Nototriton* (20 species), *Nyctanolis* (one species), *Oedipina* (38 species), *Parvimolge* (one species), *Pseudoeurycea* (39 species), and *Thorius* (29 species). The mean number of species per genus among these salamanders is 16.9, thus six of the 17 genera contain more than this number and the remaining 11 genera fewer than this number. The largest genus of plethodontid salamanders in Mesoamerica is *Bolitoglossa*, with 102 species or 35.5% of the 287 total species in the family Plethodontidae.

D. Of the nine broad patterns of distribution established by Wilson et al. (2017), five apply to Mesoamerican salamanders, including the MXEN, CAEN, MXUS, MXCA, and CASA patterns. Generally, many Mesoamerican salamanders exhibit the MXEN and CAEN patterns, i.e., 277 species or 89.9% of the 308 species illustrate these two patterns. Adding the 19 MXCA species to this figure produces a total of 296 species endemic to Mesoamerica or 96.1%. This stunning figure is the highest by far for any herpetofaunal group in Mesoamerica. Also worth noting is that 12 of the 20 genera of salamanders in this region are endemic either to Mexico (six genera), Central America (one genus), or to both areas (five genera).

E. The largest number of endemic species belongs to *Ambystoma* (17 species), *Bolitoglossa* (99 species), *Chiropterotriton* (23 species), *Nototriton* (20 species), *Oedipina* (36 species), *Pseudoeurycea* (39 species), and *Thorius* (29 species).

F. At the country level, the highest salamander diversity occurs in Mexico, followed in decreasing order by that in Guatemala, Costa Rica, Honduras, Panama, Nicaragua, El Salvador, and Belize. At this same level, the amount of endemicity ranges from 0% in Belize to 84.2% in Mexico, with intermediate values, in ascending order, of 20.0% in El Salvador, 28.1% in Panama, 59.5% in Honduras, 59.4% in Guatemala, 60.0% in Nicaragua, and 63.5% in Costa Rica.

G. Of the eight conservation priority levels that apply to Mesoamerican salamanders, the majority of both the Mexican and Central American endemic species occupy priority level one, those species occupying single physiographic regions with high EVS values. This figure consists of 244 species or 88.4% of the 276 Mexican and Central American endemic species. These priority level one species comprise a key conservation focal group, based on the following criteria: (1) the highest level of overall endemicity of any herpetofaunal group in Mesoamerica; (2) a huge representation of endemic species in montane regions in Mesoamerica; (3) the highest proportion of endemic salamander species with high EVS values; and (4) a high proportion of salamander species occupying conservation priority level one.

H. Most of the priority level one species of salamanders in Mesoamerica inhabit the following montane regions: Mesa Central, Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur, Sierra de Los Tuxtlas, Western Nuclear Central American Highlands, Eastern Nuclear Central American Highlands, Isthmian Central American Highlands, and the Highlands of Eastern Panama. The same conclusion applies to the genera including the priority level one Mesoamerican species. *Ambystoma* occurs mostly in the Mesa Central, *Aquiloeurycea* and *Chiropterotriton* in the Sierra Madre Oriental, *Cryptotriton*, *Dendrotriton*, and *Ixalotriton* in the nuclear Central American Highlands, and *Parvimolge* in the Sierra Madre Oriental. The remaining genera are more broadly distributed in the montane regions of Mesoamerica, especially *Bolitoglossa*, *Isthmura*, *Nototriton*, *Oedipina*, *Pseudoeurycea*, and *Thorius*. Given the large number of endemic Mesoamerican species of *Bolitoglossa* in Mesoamerica, it is not surprising that it is the most broadly distributed genus with representation in the Sierra Madre Oriental, Sierra Madre del Sur, Western and Eastern Nuclear Central American Highlands, Isthmian Central American Highlands, and the Highlands of Eastern Panama.

I. Salamanders constitute a biodiversity resource of great importance in Mesoamerica, which is expected to grow in significance with time. This status, however, is not generally recognized outside the group of conservation herpetologists working in this region of the world. Thus, it perhaps should come as no surprise that these salamanders face grave threats to their continued survival with the potential arrival of the chytrid fungus *Batrachochytrium salamandrivorans* from the Old World. This threat appears to be very real and likely relatively immediate, as another testimony to the inability of humans to set aside their anthropocentrism in the interests of protecting an immensely interesting and evolutionarily significant group of amphibians. Since this fungus is established already in locales in the Eastern Hemisphere, it will fall to governments throughout the portions of the Americas inhabited by salamanders to guarantee that it does not become established in the Western Hemisphere. Whether this protection will be manifested on a continuing basis remains to be seen, but now is the time for protective measures to be enacted on a continuing and sufficiently extensive basis.

J. Whereas the chytrid fungus *Batrachochytrium salamandrivorans* poses a tremendous threat to the hugely significant Mesoamerican salamander fauna, which has a great potential to decimate populations of the largely endemic species comprising this fauna, all the other environmental threats that impinge on these creatures are still operating, especially habitat decimation and climate change. The means by which humans are delivering ills on these creatures are fundamentally two in number, i.e., unregulated human population growth and the concomitant increase in the process of turning the planetary resource base into unreclaimed refuse.

K. The major conclusion of this paper is that Mesoamerican salamanders ought to be promoted as a conservation focal group because they provide the most significant example of the high rates of endemicity among the members of the Mesoamerican herpetofauna that are exceedingly threatened by environmental damage through human action, both potential in the case of *Bsal* and through habitat modification and destruction.

Recommendations

A. The importance of the salamander fauna as the most significantly endemic component of the Mesoamerican herpetofauna, which is under severe threat due to human actions, needs to be emphasized, so we recommend that herpetologists whose research in centered in Mexico and/or Central America point out this importance whenever the opportunity might present itself at conferences and other gatherings.

B. We recommend principally that a congress should be arranged to explore the challenges facing herpetologists, conservation biologists, and governmental representatives, in an attempt to develop programs for the perpetual protection of the highly significant Mesoamerican salamander fauna.

C. An additional recommendation is to establish the proposed congress as soon as possible, since the threats facing the Mesoamerican salamander fauna are advancing at an exponential rate commensurate with the increase of the human populations in Mexico and Central America. Time is clearly of the essence.

D. Given that such a congress can be arranged, the principal outcome of the congress should involve the publication of a book involving a summary of the current state of knowledge of the biology of these creatures and the conservation imperatives with which they are faced and conclude with a detailed plan for their future salvation.

Acknowledgments

EGP thanks Haydée Morales Flores and his family for their support and companionship. We all extend our gratitude to the following people who supplied us with the outstanding images we included in this paper: Matthieu Berroneau, Claudio Contreras-Koob, César Halla García Mayoral, Pablo Garrido Szegedi, Valeria Mas, Andrés Novales, Jesús Ernesto Pérez Sánchez, Todd Pierson, Louis W. Porras, Javier Sunyer, Bruno Enrique Téllez Baños, and Enrique Vázquez Arroyo-Guerrero Jaguar. Also, we all gratefully thank Louis W. Porras, Aurelio Ramírez-Bautista, and Javier Sunyer for their perceptive reviews of this paper.

“The most dangerous worldview is the worldview of those who have not viewed the world”.

Alexander Von Humboldt

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Apendix

Isthmura maxima (Parra-Olea, García-París, Papenfuss, and Wake, 2005). The Southern Giant Salamander has an EVS of 17 and is occurs in "far western and southern Oaxaca, as far south as 15 km north of San Gabriel Mixtepec, in elevation[s] as low as 730 m but generally about 2000 m elevation, west to Ejido Tres Marias, municipality of Malinaltepec" (Frost 2019). This individual was encountered in Cerro Tigre, in the municipality of Tututepec, Oaxaca, México. Photo by Vicente Mata-Silva.

Ambystoma taylori Brandon, Maruska, and Rumph, 1982. Taylor's Salamander is a species known only from Laguna Alchichica, a saline crater lake in eastern Puebla (Frost, 2019). Wilson et al. (2013) determined the Environmental Vulnerability Score (EVS) of this salamander as 15, placing it in the lower portion of the high vulnerability category. This individual was photographed at the type locality in Laguna Alchichica, Puebla. Photo by Valeria Mas.

Aquiloeurycea scandens Walker, 1955. The Tamaulipan False Brook Salamander is endemic to Mexico. Originally described from caves in the Reserva de la Biósfera El Cielo in southwestern Tamaulipas, this species later was reported from a locality in San Luis Potosí (Johnson et al., 1978) and another in Coahuila (Lemos-Espinal and Smith, 2007). Frost (2019) noted, however, that specimens from areas remote from the type locality might be unnamed species. This individual was found in an ecotone of cloud forest and pine-oak forest near Ejido La Gloria, in the municipality of Gómez Farías. Wilson et al. (2013) determined its EVS as 17. This individual was found in the "El Cielo" (Biosphere Reserve) in the vicinity of La Joya de Salas, Miquihuana, Tamaulipas, México. Photo by Elí García Padilla.

Bolitoglossa celaque McCranie and Wilson 1993. The Celaque Mushroomtongue Salamander has an EVS of 17 (Mata-Silva et al. 2019) and is restricted the the Sierra de Celaque in the Southern Cordillera of the Chortís Highlands in western Honduras (Itgen et al. in press). This individual was photographed on the eastern slope of Cerro Celaque, Departamento de Lempira, Honduras. Photo by Louis W. Porras.

Bolitoglossa chinanteca Rovito, Parra-Olea, Lee, and Wake 2012. The Chinanteca Salamander has an EVS of 18 (Johnson et al. 2017) and a distribution within the Sierra Juárez of Oaxaca, Mexico (Frost, 2019). This individual was encountered in the Municipality of San Felipe Usila, Oaxaca, Mexico. Photo by Vicente Mata-Silva

Bolitoglossa colonnea (Dunn, 1924). The La Loma Salamander has an EVS of 16 (Mata-Silva et al. 2019) and is distributed "from Bocas del Toro and Comarca Ngöbe-Buglé Provinces, far western Panamá and Alajuela, Heredia, Limón, and Cartago provinces, Costa Rica; also in the Golfo Dulce and Las Cruces areas of Pacific slope Costa Rica (Puntarenas Province)" (Frost, 2019). This individual was found in Bocas del Toro, Panama. Photo by Javier Sunyer

Bolitoglossa cuchumatana (Stuart, 1943). The Oak Forest Salamander has an EVS of 14 and is found in the "departments of El Quiché and Huehuetenango in the Sierra de Cuchumatanes, Guatemala" (Frost, 2019). This individual was photographed in the Sierra de los Cuchumatanes, Guatemala. Photo by Todd Pierson.

Bolitoglossa dofleini (Werner, 1903). Doflein's Salamander has an EVS of 15 and occupies "the Caribbean versant from extreme northern Alta Verapaz, Guatemala, and Cayo District, Belize, to north-central Honduras" (Frost, 2019). This individual was encountered in Copán, Honduras. Photo by Javier Sunyer.

Bolitoglossa gomezi Wake, Savage, and Hanken 2007. Gomez's Web-footed Salamander has an EVS of 16 and occurs on "either side of the Costa Rica-Panama border" (Frost, 2019). This individual was found in Jurutungo, Panama. Photo by Javier Sunyer

Bolitoglossa helmrichi (Schmidt 1936). The Coban Mushroomtongue Salamander has an EVS of 16 and is distributed in cloud forest of mountainous regions of southwestern Alta Verapaz and Baja Verapaz, Guatemala, at elevations of 1,000 to 2,000 m (Frost, 2019). This individual was found in Purulha, Departamento de Baja Verapaz, Guatemala. Photo by Andrés Novales.

Bolitoglossa hermosa (Papenfuss, Wake and Adler, 1984).The Guerreran Mushroomtongue Salamander has an EVS of 16 and occur in Río Atoyac drainage on the Pacific slope of the Sierra Madre del Sur of Guerrero, Mexico, 765–2465 m elev. (Frost, 2019). This individual was found inside the "Corredor Comunitario del Jaguar" in the vicinity of Las Humedades in the municipality of Tecpan de Galeana, Guerrero. Photo by Enrique Vázquez Arroyo-Guerrero Jaguar.

Bolitoglossa huehuetenanguensis Campbell, Smith, Streicher, Acevedo, and Brodie 2010. The Huehuetenango Salamander has an EVS of 18 and is "known only from the vicinity of the type locality in the Sierra Cuchumatanes, Huehuetenango, Guatemala," at elevations of 2,450 to 2,835 m (Frost, 2019). This individual was photographed in the Departamento of Huehuetenango, Guatemala. Photo by Todd Pierson.

Bolitoglossa indio Sunyer, Lotzkat, Hertz, Wake, Aléman, Robleto, and Köhler 2008. The Río Indio Salamander has an EVS of 17 and is "known only from the type locality [of] Dos Bocas del Río Indio, Departamento de Río San Juan, northeastern Nicaragua" (Frost, 2019). This individual was found at Río Indio, Nicaragua. Photo by Javier Sunyer.

Bolitoglossa insularis Sunyer, Lotzkat, Hertz, Wake, Aléman, Robleto, and Köhler 2008. The Isla de Ometepe Salamander has an EVS of 18 and is known only from the type locality [of] the Isla de Ometepe, in Lago Nicaragua, Departamento de Rivas, Nicaragua" (Frost, 2019). This individual was located on Volcán Maderas, Isla de Ometepe, Departamento de Rivas, Nicaragua. Photo by Javier Sunyer.

Bolitoglossa lignicolor (Peters, 1873). The Camron Mushroomtongue Salamander has an EVS of 16 and is distributed "in southwestern Costa Rica and adjacent western Panama and the Peninsula de Azuero as well as Isla Coiba, west-central Panama" (Frost, 2019). This individual was found at Meseta Chorcha, Panama. Photo by Javier Sunyer.

Bolitoglossa lincolni (Stuart, 1943). Lincoln's Mushroomtongue Salamander has an EVS of 13 and occurs "from the Meseta Central of Chiapas, Mexico to the Pacific slopes in western Guatemala, including the Sierra de Cuilco, the western portion of the Guatemalan Plateau, and the Cuchumatanes" (Frost, 2019). This individual was found in Cerro Huitepec, Altos de Chiapas, México. Photo by Elí García Padilla

Bolitoglossa mexicana Duméril, Bibron, and Duméril, 1854. The Mexican Mushroomtongue Salamander has an EVS of 8 and is found "from southern Veracruz (Mexico) across the base of the Yucatan Peninsula, with an isolated population in northern part of Yucatan Peninsula, to Honduras (extending to the Pacific versant in Ocotepeque) and El Salvador (Departamento de Chalatenango, municipio de La Palma, Cerro La Palma) (Frost, 2019). This individual was found at Santa María Chimalapas, Oaxaca, México. Photo by Elí García Padilla.

Bolitoglossa minutula Wake, Brame, and Duellman, 1973. The Minute Mushroomtongue Salamander has an EVS of 17 and is distributed "on both slopes of the southern Cordillera de Talamanca of Costa Rica...and its extension into western Panama" (Frost, 2019). This individual was encountered at Jurutungo, Panama. Photo by Javier Sunyer

Bolitoglossa morio (Cope, 1869). Cope's Mushroomtongue Salamander has an EVS of 13 and occurs on the Guatemalan Plateau (Frost, 2019). This individual was located at Chichicastenango, Guatemala. Photo by Javier Sunyer.

Bolitoglossa mulleri (Brocchi, 1883) The Müller's Mushroomtongue Salamander has an EVS of 15 and occur in the Atlantic slopes of the mountains of Alta Verapaz, Quiché, and Huehuetenango, Guatemala, and adjacent Chiapas, Mexico, in the Municipio de Ocosingo, 140–1550 m elevation. This individual was found in the Departamento of Huehuetenango, Guatemala. Photo by Todd Pierson.

Bolitoglossa oaxacensis Parra-Olea, García-Paris, and Wake 2002. The Atoyac Salamander has an EVS of 17 and is distributed in "humid oak-pine and pine forest in the Sierra Madre del Sur, specifically from the mountains south of Sola de Vega, to immediately south of the Atoyac River Basin, in the vicinity of Puerto Portillo, Oaxaca, Mexico" (Frost, 2019). This individual was found in the Sierra Madre del Sur in Oaxaca, Mexico. Photo by Vicente Mata-Silva.

Bolitoglossa odonnelli (Stuart, 1943). O'Donnell's Salamander has an EVS of 16 and ranges in the cloud forests of the Atlantic drainage of the mountains of eastern Alta Verapaz, east to the Montañas del Mico, Guatemala," at elevations of 100–1,200 m; "also in adjacent western Honduras" (Frost, 2019). This individual was located at Morales, Departamento de Izabal, Guatemala. Photo by Andrés Novales.

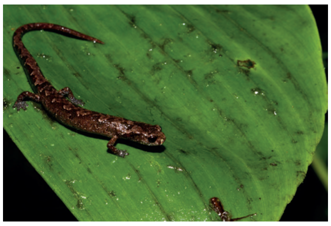
Bolitoglossa pesrubra (Taylor, 1952). The Red-footed Salamander has an EVS of 15 and is distributed in "the Cordillera de Talamanca, including the Fila Cedral" (Frost, 2019). This individual was found on Cerro de la Muerte. Photo by Javier Sunyer.

Bolitoglossa salvinii (Gray, 1868). Salvin's Mushroomtongue Salamander has an EVS of 16 and occurs on "the Pacific slopes of southern Guatemala and El Salvador" (Frost, 2019). This individual was located at Suchitepeques, Patulul, Guatemala. Photo by Javier Sunyer.

Bolitoglossa striatula (Noble, 1918). The Cukra Mushroomtongue Salamander has an EVS of 16 and occupies "the Atlantic versant from eastern Honduras through eastern Nicaragua to central Costa Rica" (Frost, 2019). This individual was photographed at Río San Juan, Nicaragua. Photo by Javier Sunyer.

Chiropterotriton magnipes Rabb, 1965. The Bigfoot Splayfoot Salamander has an EVS of 16 and is distributed in "pine-oak woodland or northeastern Queretaro, Mexico" (Frost, 2019). This individual was located inside a cave at La Trinidad, in the municipality of Xilitla, San Luis Potosí, México. Photo by Pablo Garrido Szegedi.

Chiropterotriton cieloensis Rovito and Parra-Olea, 2015. The El Cielo Salamander is one of the most recently described amphibians from Tamaulipas. This species is known only from the Reserva de la Biósfera El Cielo in the municipality of Gómez Farías, located in the extreme southwestern portion of the state. The salamander is known to occur at elevations from approximately 1,000 to 1,860 m in the Sierra de Guatemala, where it has been encountered in bromeliads and caves in broadleaf cloud forest. The EVS of this species is 17. Pictured here is an individual from the vicinity of the species' type locality at "El Cielo" (Biosphere Reserve), Tamaulipas, México. Photo by Elí García Padilla.



Cryptotriton veraepacis (Lynch and Wake 1978). The Baja Verapaz Salamander has an EVS of 17 and occurs in eastern Guatemala in the Sierra de las Minas and nearby mountains above 1610–2290 m elevation" (Frost, 2019). This individual was found at Reserva Natural Ranchitos del Quetzal, Guatemala. Photo by Andrés Novales.

Isthmura gigantea (Taylor, 1939). The Giant False Brook Salamander has an EVS of 16 and is "known from the pine-oak/cloud-forest interface in the La Joya-Jalapa region of Veracruz and into northeastern Hidalgo, Mexico" at elevations of 1,000 to 2,000 m (Frost, 2019). This individual was found on the road between Tequila and Zongolica, Veracruz. Photo by Matthieu Berroneau.

Ixalotriton niger Wake and Johnson 1989. The Jumping Salamander has an EVS of 18 and is "known from the montane rainforest in the immediate vicinity of the type locality, near Berriozábal in northwestern Chiapas, Mexico, 1200 m elevation, and in two small caves at Cerro Baul, on the southwestern border of Chiapas with Oaxaca, 1592 and 2000 m elevation" (Frost, 2019). This individual was encountered at La Pera, Berriozabal, Chiapas, México. Photo by Jesús Ernesto Pérez Sánchez.

Nototriton guanacaste Good and Wake 1993. This salamander has an EVS of 17 and is found "on the summits of Volcán Orosi and Cerro Cacao, in the Cordillera de Guanacaste, province of Guanacaste, northwestern Costa Rica" (Frost, 2019). This individual was found on Cerro Cacao, Guanacaste Province, Costa Rica. Photo by Javier Sunyer.

Nyctanolis pernix Elias and Wake 1983. The Nimble Long-limbed Salamander has an EVS of 15 and ranges in the Parque Nacional Lagunas de Montebello in southern Chiapas (Mexico) and northwest of there near Leyva Velázquez, Municipio de las Margaritas, Chiapas, Mexico, 835–2145 m elevation; in Guatemala on the northeastern slopes of the Sierra de los Cuchumatanes and in the Sierra de las Minas above Puruhlá, Baja Verapaz, Guatemala, 1200–1610 m elevation" (Frost, 2019). This individual was encountered at the Departamento of Huehuetenango, Guatemala. Photo by Todd Pierson.

Oedipina elongata (Schmidt, 1936). The Central American Worm Salamander has an EVS of 15 and occur in low and moderate elevations from north-central Chiapas (Mexico) and near the Caribbean coast of eastern Belize across the Atlantic foothills of Guatemala to the Montañas del Mico and into adjacent northwestern Honduras (Frost, 2019). This individual was encountered in Santo Tomás de Castilla, Departamento de Izabal, Guatemala Photo by Andres Novales.

Oedipina fortunensis Köhler, Ponce, and Batista 2007. The Fortuna Worm Salamander has an EVS of 18 and is known "only from the type locality (Reserva Forestal Fortuna, Chiriquí, Panama)" (Frost, 2019). This individual came from Fortuna, Panama. Photo by Javier Sunyer.

Oedipina grandis Brame and Duellman 1970. The Cerro Pando Worm Salamander has an EVS of 17 and is distributed in the Cordillera de Talamanca in extreme southern Costa Rica and immediately adjacent western Panama" (Frost, 2019). This individual was found at Jurutungo, Panama. Photo by Javier Sunyer.

Oedipina koehleri Sunyer, Townsend, Wake, Travers, Gonzalez, Obando, and Quintana 2011. Koehler's Worm Salamander has an EVS of 16 and is found in "three isolated highland areas in northern Nicaragua" (Frost, 2019). This individual came from Musun Matagalpa, Nicaragua. Photo by Javier Sunyer.

Oedipina nica Sunyer, Wake, Townsend, Travers, Rovito, Papenfuss, Obando, and Köhler 2010. The Nicaraguan Worm Salamander has and EVS of 17 and is distributed in north-central Nicaragua (Frost, 2019). This individual came from Finca Monimbo, Matagalpa, Nicaragua. Photo by Javier Sunyer.

Pseudoeurycea conanti Bogert 1967. Conant's Salamander has an EVS of 16 and is "known only from the type locality (Oaxaca, Mexico)" (Frost, 2019). This individual was found near Sola de Vega, Oaxaca, México. Photo by Vicente Mata-Silva.

Pseudoeurycea leprosa (Cope, 1869). The Leprous False Brook Salamander has an EVS of 16 and is found in the "high mountains of Puebla, Veracruz, Morelos, Distrito Federal (Ciudad de Mexico), and Mexico (Estado de Mexico), Mexico; also reported for Guerrero and Oaxaca" (Frost, 2019). This individual was encountered at Milpa Alta in the municipality of the same name, in the state of Ciudad de México. Photo by Claudio Contreras-Koob.

Pseudoeurycea mixteca Canseco-Márquez and Gutiérrez-Mayén 2005. The Mixteca False Brook Salamander has an EVS of 17 and is found in the "Mixteca Alta region of northwestern Oaxaca in pine-oak forest; isolated relict cave locality in the arid Tehuancan Valley, Puebla" (Frost, 2019). This individual was found at Teposcolula, Oaxaca, México. Photo by Bruno Enrique Téllez Baños.

Pseudoeurycea rex (Dunn, 1921) The Royal False Brook Salamander has an EVS of and occur in High elevations of western Guatemala; expected in adjacent Chiapas, Mexico (Frost, 2019). This individual was observed in the Departamento of Huehuetenango, Guatemala. Photo by Todd Pierson.

Thorius boreas Hanken and Wake 1994. The Boreal Thorius has an EVS of 18 and is "known only from the vicinity of the type locality in pine-oak forest both north and south of the crest of Cerro Pelón in the Sierra Juarez, 2800–3000 m elevation, Oaxaca, Mexico" (Frost, 2019). This individual was found in the vicinity of Llano de las Flores in the Sierra Madre de Oaxaca, Mexico. Photo by Vicente Mata-Silva.

Thorius narisovalis (Taylor, 1940) The Cerro San Felipe Pigmy Salamander has an EVS of and it is known only from Oaxaca, Mexico, in three areas: (1) the vicinity of the type locality (Cerro San Felipe), the (2) vicinity of Zaachila, in central Oaxaca, and (3) the vicinity of Tlaxiaco, in cloud forests in pine-oak woodland, 2600-3000 m elevation (Frost, 2019). This individual was photographed in Cerro San Felipe, San Felipe del Agua, Oaxaca, México. Photo by César Halla García Mayoral.