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New occurrence records for *Eurycea sosorum* Chippindale, Price & Hillis, 1993 (Caudata, Plethodontidae) in Travis and Hays counties, Texas, USA

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Abstract

We present 7 new occurrence records for the Barton Springs Salamander (*Eurycea sosorum* Chippindale, Price & Hillis, 1993) from Hays and Travis counties, Texas, USA, including the first for this species from the Trinity Aquifer. *Eurycea sosorum* is listed as endangered under the Endangered Species Act of 1973 due to ongoing threats from urbanization and aquifer overdraft throughout its narrow range. Although this species is more widely distributed than when it was first described in 1993, its range is still exceptionally small, restricted to portions of only two watersheds (Onion and Barton creeks) in one of the fastest-growing metropolitan areas in the United States (Austin, Texas). Under any ecologically-relevant criterion that is based on the best available scientific evidence, this species remains in danger of extinction throughout its range.

Key words

Amphibian; Edwards Aquifer; conservation; endangered species; groundwater; spring; Trinity Aquifer.

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Introduction

The Barton Springs Salamander (*Eurycea sosorum* Chippindale, Price & Hillis, 1993) is a permanently aquatic, groundwater-obligate plethodontid salamander described in 1993 from Barton Springs in Austin, Texas, USA (Chippindale et al. 1993). At the time of its description, this species was known only from 3 nearby springs (Parthenia, Eliza, and Old Mill springs) in the City of Austin's Zilker Park that had been impounded to create areas for swimming. Due to ongoing threats to water quality and quantity resulting from urbanization and groundwater development in the Barton Springs segment of the Edwards Aquifer (hereafter, Barton Springs segment), in 1997 the United States Fish and Wildlife Service listed *E. sosorum* as endangered under the Endangered Species Act of 1973, as amended (U.S. Fish and Wildlife Service 1997). This species' status is ranked as Critically Imperiled (G1) by NatureServe (2017) and considered to be at "high risk of extinction in the wild" (Vulnerable, D1 + 2) by the International Union for the Conservation of Nature (IUCN 2017).

In the 2 decades following the description of *E. sosorum*, *Eurycea* salamanders were discovered at 5 spring and cave sites in the recharge zone of the Barton Springs segment, up to 25 km southwest of the type locality at Barton Springs. These sites included Blowing Sink Cave

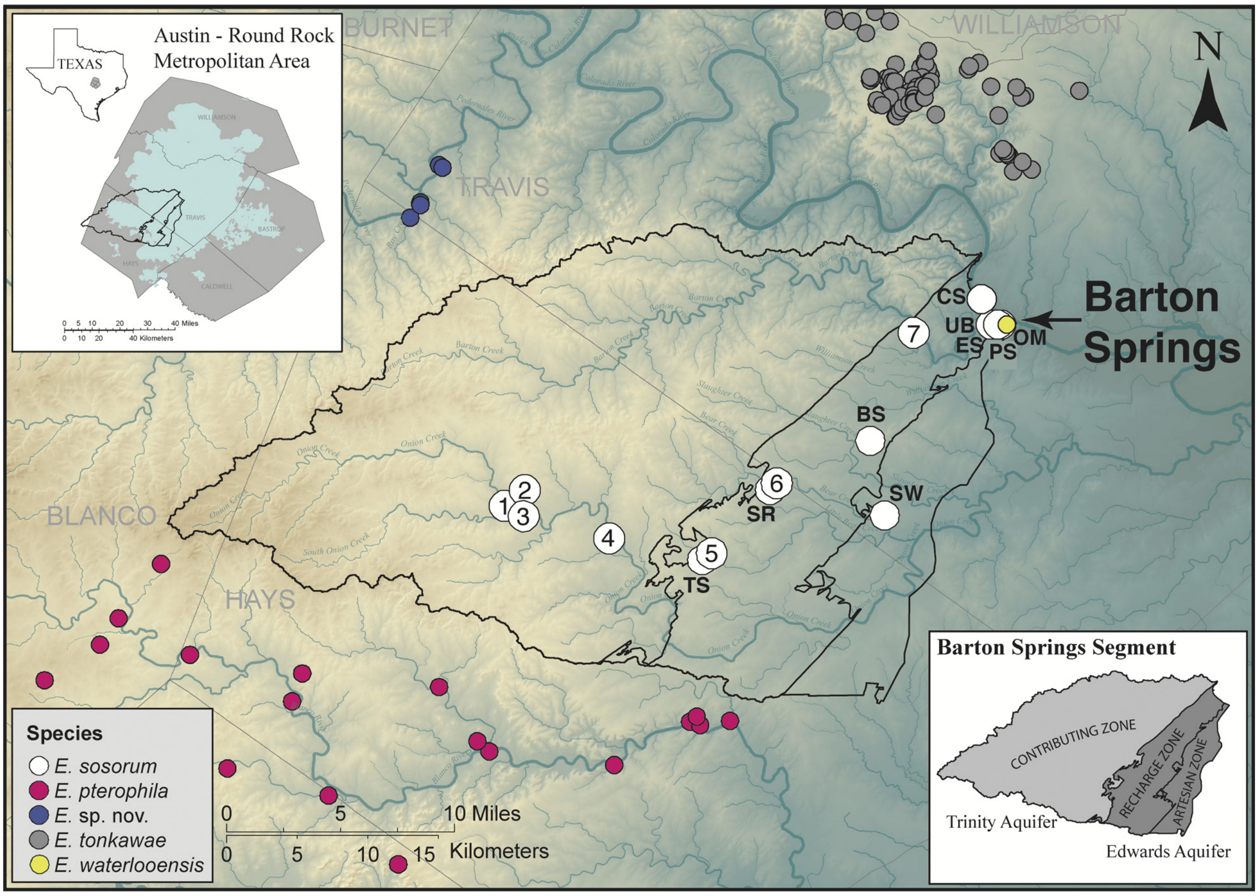

Figure 1. Map of the Barton Springs segment of the Edwards Aquifer, and its contributing zone in the Trinity Aquifer. White circles represent occurrence records for the Barton Springs Salamander (*Eurycea sosorum*); those with numbers represent new occurrence records reported here. Previously known *E. sosorum* localities are indicated by a white circle with a 2-letter abbreviation as follows (from north to south): CS, Cold Spring; UB, Upper Barton Spring; ES, Eliza Spring; PS, Parthenia Spring; OM, Old Mill Spring; BS, Blowing Sink Cave; SR, Spillar Ranch (spring 1); SW, State Well No. 58-50-705; and TS, Taylor Spring. Portions of the distributions of three parapatric *Eurycea* species found in adjacent watersheds are also shown (*E. pterophila* in the Blanco river basin, *E.* sp. nov. from the Pedernales river basin, and *E. tonkawae* from the Colorado (Austin-Travis Lakes) river basin. *Eurycea waterlooensis* is sympatric with *E. sosorum* at Barton Springs.

in 1996, Upper Barton Spring in 1997, Cold Spring and Taylor Spring in 2004, and Spillar Ranch in 2012 (Fig. 1). Of these newly discovered localities, only the Upper Barton Spring population was confidently assigned to *E. sosorum* at the time it was found, based on its proximity (ca 300 m) to the type locality. The species membership of the remaining populations remained uncertain until they were assigned to *E. sosorum* based on mitochondrial DNA sequence data (Bendik et al. 2013). In 2015, a salamander was collected from a monitoring well 58 m below ground in the confined portion (artesian zone) of the Barton Springs segment 15 km southwest of Barton Springs (Fig. 1) that was also assigned to *E. sosorum* based on similarity to animals from the type locality (McDermid et al. 2015).

Here, we report 7 new occurrence records of salamanders that are assignable to *E. sosorum* based on morphology and coloration, and discuss the implications of this range extension for conservation.

Methods

During 2015−2017, we visited 18 spring sites along tributaries to Onion, South Onion, and Barton creeks where salamanders had not been documented. We searched for salamanders in suitable habitat in or near flowing spring outlets and spring runs. If salamanders were not detected during an initial visit, we deployed artificial cover consisting of strands of cotton mop (Holsinger and Minckley 1971, Gibson et al. 2008) and/or aquatic drift net traps to increase detection probability. Voucher specimens were collected under scientific permits from the Texas Parks and Wildlife Department (SPR-0113-006) and the United States Fish and Wildlife Service (TE833851-4). Specimens were photographed alive and preserved following standard protocols for amphibians (Jacobs and Heyer 1994, McDiarmid 1994). Tissue samples were taken from each specimen for genetic analysis. Voucher specimens have been deposited in the Biodiversity Collections (formerly Texas Natural History Collections) at The University of Texas at Austin, Austin, Texas, USA (Table 1).

Results

New records. Salamanders were found at 7 previously undocumented localities. We collected 1–3 voucher specimens from each new site (Table 1). Three of the

Table 1. New occurrence records and voucher specimens of *Eurycea sosorum* deposited in the Biodiversity Collections (formerly Texas Natural History Collections) at The University of Texas at Austin, Austin, Texas, USA. Locality numbers correspond to numbers in Figure 1.

Catalog num.	County	Locality	Latitude	Longitude
TNHC 101244, 102948	Hays	1. Emerald Spring, South Onion Creek	30.1477	–98.0787
TNHC 102949	Hays	2. Bello Spring, Onion Creek	30.1454	–98.0760
TNHC 101241-3	Hays	3. Pearly's Spring, Onion Creek	30.1460	–98.0719
TNHC 100830, 103342	Hays	4. Ben McCulloch Spring, Onion Creek	30.1273	–98.0171
TNHC 95433-4	Hays	5. Stuart Spring, Little Bear Creek	30.1138	–97.9530
TNHC 96995-6	Hays	6. Spillar Ranch Spring 2, Bear Creek	30.1625	–97.9108
TNHC 102716, 103015	Travis	7. Backdoor Spring, Barton Creek	30.2595	–97.8237

sites are springs in watersheds over the recharge zone of the Barton Springs segment (Backdoor, Spillar Ranch 2, and Stuart springs; Fig. 1). The remaining 4 springs discharge from the contributing zone (catchment area) of the Barton Springs segment, located upgradient and west of the recharge zone, in the Hill Country portion of the Trinity Aquifer system (Fig. 1).

Identification. These specimens are assignable to *E. sosorum* based on the characteristics that distinguish this species from other west-central Texas *Eurycea* salamanders, including a narrow, flattened head with a truncate snout, reduced eye size, and a slender body with elongate limbs (Sweet 1978, Chippindale et al. 1993). The dorsal color pattern is within the range of variation described for *E. sosorum* (Sweet 1978, Chippindale et al. 1993), consisting of irregularly shaped, pale pinkish-orange patches on a purplish-brown background (Fig. 2). All specimens exhibit the clusters of reflective white iridophores that are characteristic of this species (Sweet 1978, Chippindale et al. 1993). In most individuals, the iridophores are arranged in 1–3 rows along the lateral region of the trunk. Some individuals also possess smaller iridophore aggregates elsewhere on the body and head. In 1 specimen from Backdoor Spring, the iridophore clusters are scattered across the entire dorsum, giving an overall appearance of fine white flecking (Fig. 2, number 7). The ventral surface is unpigmented in all specimens.

Discussion

Unlike at the type locality for *Eurycea sosorum* (Barton Springs) where individual abundance on the surface is generally high during average conditions (Sweet 1978, Chippindale et al. 1993, Hillis et al. 2001), abundance was very low at all of the newly documented sites, except for Stuart Spring and Pearly's Spring. The spring runs issuing from Stuart and Pearly's springs have sufficient suitable cover (gravel, cobble, and rocks or vegetation free of fine sediment) to support a small number of individuals during periods of high springflow, as was the case during the latter half of 2016 and beginning of 2017. In contrast, drift net traps and mops were deployed at some sites (e.g., Emerald and Bello springs) for up to 4 months before salamanders were found there.

From a biogeographic perspective, the distribution limits of *E. sosorum* are coincident with surface and/or subsurface hydrologic divides, as is the case with other west-central Texas *Eurycea* species (Chippindale et al. 2000, Bendik et al. 2013). To the north, the deeply incised Colorado River separates *E. sosorum* from a divergent clade of 3 *Eurycea* species that are restricted to the northern segment of the Edwards Aquifer (Chippindale et al. 2000). To the south, a groundwater divide that shifts between the Blanco River and Onion Creek (Smith et al. 2012, Hauwert 2016) separates *E. sosorum* from parapatric *E. pterophila* Burger, Smith & Potter, 1950 populations in the Blanco River basin (Fig. 1; Chippindale et al. 2000, Bendik et al. 2013). An undescribed *Eurycea* species inhabits the Pedernales river basin to the northwest (Fig. 1; Chippindale et al. 2000). The only species that is sympatric with *E. sosorum* in any part of its range is *E.* (*Typhlomolge*) *waterlooensis* Hillis, Chamberlain, Wilcox & Chippindale, 2001, a primarily subterranean species that has only been found in the 4 Barton springs (Hillis et al. 2001).

The Onion Creek *E. sosorum* occurrence records reported here extend the distribution of this species into the contributing zone of the Barton Springs segment in the Hill Country portion of the Trinity Aquifer system (see Anaya 2004). Although the Edwards and Trinity aquifers have historically been treated as distinct hydrogeologic units from scientific and management perspectives, recent work provides evidence of lateral continuity between the two aquifers, with Onion Creek specifically acting as an important hydrologic link (Wong et al. 2013, Hunt et al. 2015). *Eurycea sosorum* has not been documented from the northern portion of the contributing zone in the upper Barton Creek watershed, but this species may eventually be found there considering its occurrence in this drainage downgradient over the recharge zone.

Like many other groundwater-obligate organisms, *E. sosorum* is highly specialized from an evolutionary perspective, with a small, naturally fragmented distribution, a narrow niche, and low dispersal ability, traits that make it especially vulnerable to population declines and extinction (see Kotiaho et al. 2005, Gallagher et al. 2015). Although this species is more broadly distributed than was originally believed when it was first described, its range remains exceptionally small, and the degree of population connectivity is unknown. Populations of this species in the contributing zone are at high risk of extinction given the rapid rate of urbanization (see for example U.S. Census Bureau 2017) and groundwater depletion

Figure 2. Specimens of *Eurycea sosorum* in life from the new localities reported here. Numbers correspond to localities in Figure 1. 1, Emerald Spring (TNHC 102948); 2, Bello Spring (TNHC 102949); 3, Pearly's Spring (TNHC 101241); 4, Ben McCulloch Spring (TNHC 100830); 6, Spillar Ranch Spring 2 (TNHC 96996); and 7, Backdoor Spring (TNHC 102716). Locality number 5 (Stuart Spring) is not pictured.

in the Hill Country portion of the Trinity Aquifer (Ashworth 1983, Bluntzer 1992, Chowdhury 2008, Jones et al. 2011). Because the Barton Springs segment receives a proportion of its recharge from the Trinity Aquifer—both via interformational, subsurface flow as well as surface streamflow originating from Trinity springs (Mace et al. 2000, Green et al. 2011)—any ecologically relevant policy for the conservation of *E. sosorum* and the regional aquifer ecosystem must include the contributing zone.

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