Central Texas Spring Salamanders of the Genus *Eurycea*: Natural History and Policy

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Introduction

In the peaceful, rolling hills of central Texas, a hidden world lies beneath the ground: wet, dark, and poorly understood to science. Some of its inhabitants periodically emerge in surface waters, and their health provides insight into the quality of the groundwater that this region's rapidly growing human population relies on. These inhabitants are salamanders of the genus *Eurycea*, and the central Texas region has a high diversity of this genus (Bendik 2017). Several of these species are well known in the Austin area, as every Texan who has visited chilly Barton Springs in the summer is aware of the tiny Barton Springs salamander (*Eurycea sosorum*) that shares the pool with visitors. Salamanders that inhabit the Edwards Plateau to the north of the Austin metropolis, however, receive little attention other than that of devoted naturalists in this region. Their rarity and partially subterranean lifestyle make them exceedingly difficult to study, and scientific knowledge of these species remains limited. It is imperative that we not only increase scientific knowledge of these species, but also raise public awareness and push for better management policies so that these unique animals are not lost to the slow creep of suburban sprawl.

The Edwards Plateau encompasses a large area of the western portion of central Texas (**Figure 1**). Thirteen species of salamanders are found here, seven of which are endangered or threatened (Bendik 2017). The species discussed in this paper all rely on habitat in the northern segment of the Edwards Aquifer and live within ground water and surface water (Smith 2011). These waters are connected in a vast underground network that is affected not only by local changes, but also by conditions in the distant contributing and recharge zones of the aquifer (**Figure 2**) (Kirkland 2018).

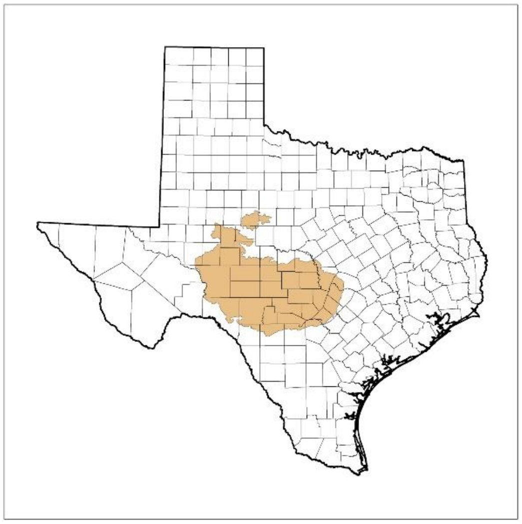


Figure 1: Map of the Edwards Plateau from "Target Species: Edwards Plateau Ecoregion." Texas Parks and Wildlife

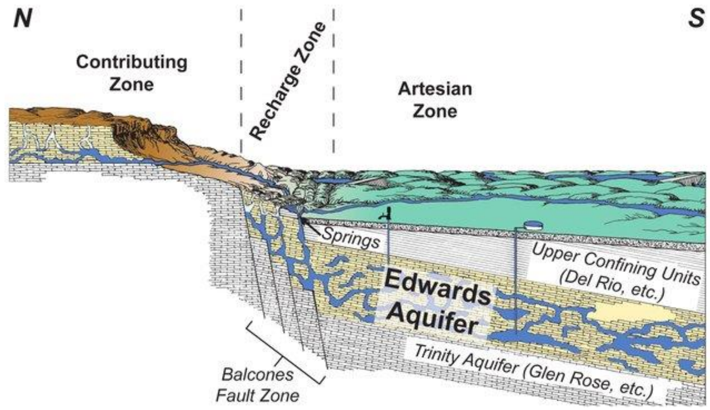


Figure 2: Illustration of the three zones of an aquifer. From Kirkland 2018.

The three salamander species found in the northern Edwards aquifer were first outlined in Chippindale *et al* 2000: the Jollyville Plateau salamander (*Eurycea tonkawae*), the Georgetown salamander *(Eurycea naufragia*), and the Salado salamander (*Eurycea chisholmensis*) (**Figure 3**). All three are neotenic spring salamanders (Smith 2011). Each species has a very limited range because they rely on temporal and thermal flow stability, minimal substrate disturbance, and move through refuges and corridors below the surface (Bowles *et al* 2006) (Tupa and Davis 1976)

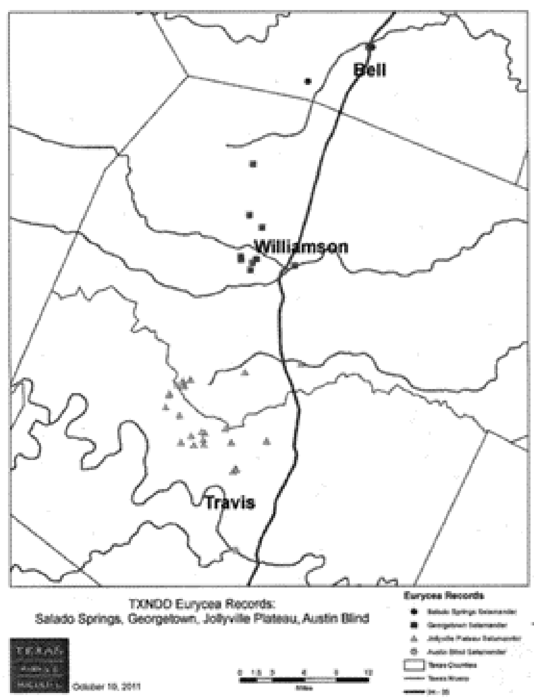


Figure 1: Distribution of central Texas Spring salamanders. E. chisholmensis designated by black circles, E. naufragia by black squares, and E. tonkawae by gray triangles. From Smith 2011.

(Rudolph, 1978) (Chippindale et al., 1993) (Tumlison and Cline, 1997).

Species Descriptions

<u>Jollyville Plateau Salamander: *Eurycea tonkawae*</u>

Figure 2: The Jollyville Plateau Salamander. Source: Ueda K (2020) <u>https://www.inaturalist.org/photos/2872823</u>

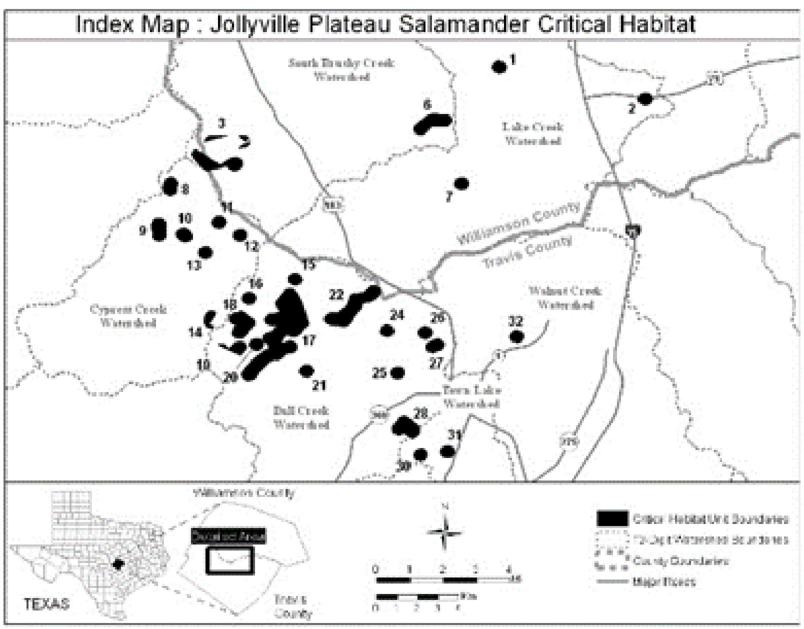


Figure 3: Map of distribution of the Jollyville Plateau salamander. From U.S. Fish and Wildlife Service "Texas Salamanders".

Out of all the species discussed, the Jollyville Plateau salamander is the most studied. This salamander is found on the border between Williamson and Travis County and is most frequently observed in surface waters during the spring and summer (**Figure 5**) (Bendik 2017). Within springs, this species is found most frequently under large rocks, which are used as shelter from predators, in areas with high amounts of rubble and cobble (Bowles 2006). These salamanders are primarily found close to the spring or stream source, as downstream areas show increased variability in temperature and flow and therefore have lower salamander densities (Bowles 2006). Deceased salamanders that were predated upon have been found, but the species that feeds on them remains unknown, as do the species which the salamanders prey upon for food (Bowles et al 2006). *E. tonkawae* is sexually mature within one year and reaches its adult size of a length of 31.73 mm after two years (Bendik 2017). This species appears to have a seasonal reproductive cycle, as gravid females are observed most frequently during two peaks in the fall and winter (Bowles 2006). The presence of multiple egg clutches per year implies that this species is able to respond quickly to environmental change (Bendik 2017). Egg clutches are most likely laid beneath the surface, so it is difficult to draw further conclusions about their reproduction from existing life history studies (Bendik 2017). Despite prolonged, periodic drought in this region, salamander populations did not decrease significantly after dry periods, suggesting adaptations to an environment with a periodically dry surface habitat (Bendik 2017).

Georgetown Salamander: *Eurycea naufragia*

Figure 4: The Georgetown Salamander. Source: Ueda K (2020) https://www.inaturalist.org/photos/2872927

The Georgetown salamander is found only in thirteen springs and two caves within the San Gabriel River watershed in Williamson County (**Figure 7**) (Pierce 2014). Like the Jollyville Plateau Salamander, this species uses rocks as hiding places, but there is no correlation between the amount of rock cover and population density in the Georgetown Salamander (Pierce 2010). Still, large rocks may be an important component of pristine habitat for this species (Pierce 2010). *E. naufragia* is found primarily within 5 m of the spring source, and there is and no directional movement of the salamanders (Pierce 2010) (Pierce 2014). The number of gravid females observed peaks in the winter and early spring, suggesting a seasonal reproduction pattern much like the Jollyville Plateau salamander (Pierce 2014). There is currently no information on the location where eggs are laid and embryos develop (Pierce 2014).

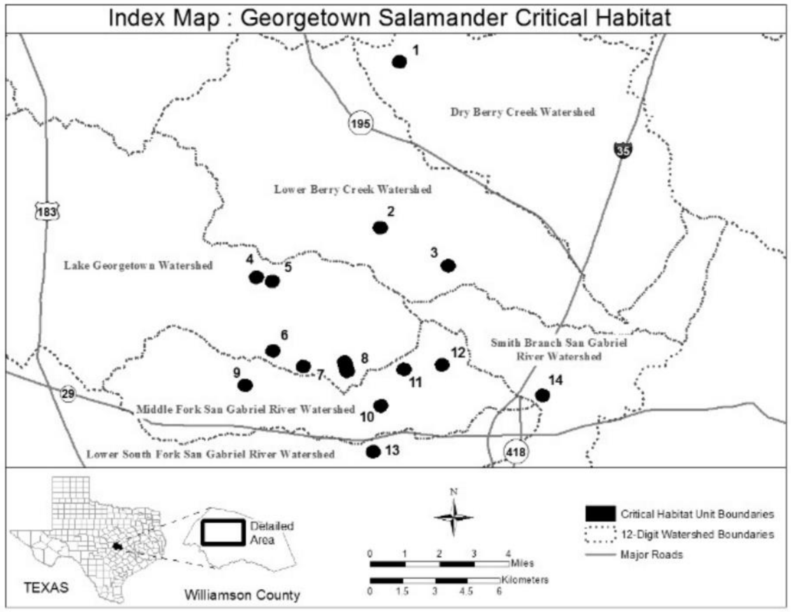
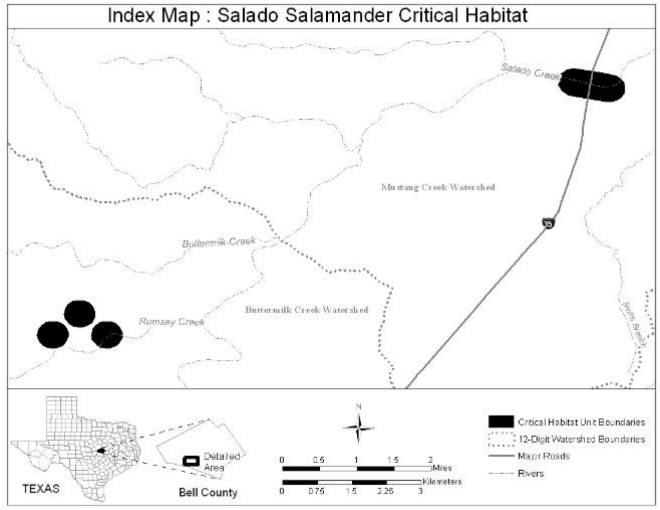


Figure 5: Map of distribution of the Georgetown Salamander. From U.S. Fish and Wildlife Service "Texas Salamanders".

<u>Salado Salamander: *Eurycea chisholmensis*</u>


Figure 6: The Salado Salamander. Source: Ueda K (2020) <u>https://www.inaturalist.org/observations/121829</u>

The Salado salamander is the least researched species out of the three discussed in this paper. It is found in limestone springs on the southern side of the Salado Creek watershed and in springs in the northern Edwards Aquifer (**Figure 9**) (Smith 2011). Habitat for this species is isolated and populations in each location are small (Smith 2011). This species is rarely found more than 20 m outside of the spring source, suggesting that they may move farther than the Georgetown salamander but primarily remain close to the source (Smith 2011). To date, nothing is known about their life history below ground, and their life history on the surface is little studied.



Effects of urbanization

The habitat and morphology of these three species are similar, and the little information available on their natural history points to similarities as well. Therefore, they are likely prone to many of the same dangers from urbanization. Salamanders living in undeveloped areas with pristine springs display stable populations and are robust to natural environmental cycles in the region (Bendik 2014). However, aquatic salamanders are sensitive to variation from a narrow set of environmental parameters, and there is a strong negative effect of urbanization on salamander density due to the resulting increase in variation from these parameters (Bendik 2014) (Miller *et al* 2007). This relationship is a result of the addition of impervious ground covers, causing more frequent flooding which washes pollutants from these surfaces into springs and streams (Walsh *et al* 2005). These pollutants can include heavy metals, pesticides, herbicides, and organic compounds, and their effect on ecosystems in which salamanders dwell remains unclear (Bendik 2014). Impervious ground cover also leads to increased flooding after storms, which has the potential to increase salamander mortality by flushing adults and larvae from their refuges under rocks (Barrett *et al* 2010). Additionally, increased flooding causes greater variation in stream flow rate and temperature, therefore, species less tolerant to fluctuation in environmental parameters are likely to be displaced by more tolerant species (Bendik 2014). This could potentially affect the distribution of salamander prey and predator species, but more research is needed to determine which species the salamanders are involved in trophic interactions with before the effects of changes in their distribution can be extrapolated. Additionally, human use of watersheds and groundwater poses various concerns for salamander populations. Increased pumping from aquifers to sustain human populations means that the risk of saline water encroaching into freshwater springs is higher, an event which would spell disaster for species dependent on groundwater (Smith 2011). Because small, isolated salamander populations are vulnerable to population crashes as a result of genetic and environmental stochasticity, the negative effects of urbanization on one population can have significant ramifications on species level diversity and distribution (Bowles 2006).

Amphibians are widely known as indicators of ecosystem health; therefore, it is vital to collect more natural history information on these species so that we know to what extent ecosystems are affected by urbanization (Bowles *et al* 2006). Currently, the greatest amount of knowledge is available on *E. tonkawae*, which also lives in the closest proximity to the metropolis of Austin (U.S. Fish and Wildlife Service, “Texas Salamanders”). The extent of threats faced by poorly understood, geographically remote species such as *E. chisholmensis* may be underestimated due to a lack of information (Smith 2011). Once more information is available on these species, it is possible to design and implement management programs and focus conservation efforts where they are needed.

Policy and Protections

All three salamander species are endemic to an area that is experiencing the highest rates of human population growth in the nation, therefore, swift action towards management and conservation are crucial if these species are going to survive for posterity (Keemahill and Huber 28 April 2019). Key steps to take to conserve these species include protecting spring openings, recharge zones, and the groundwater itself in salamander habitat (Smith 2011). The recommended course of action is to protect watersheds that have not been developed yet, however, this is often difficult for several reasons (Bendik 2014). Watershed boundaries often do not align with the political borders of counties which makes conservation and management difficult for species such as the Salado salamander, found in two different aquifers with separate recharge and contributing zones (Smith 2011). Additionally, the localized distribution of these species means that a spring in which a population is found may be contained entirely on private property, further complicating management (Smith 2011). Protecting watersheds often requires the involvement of entities directly responsible for managing the watershed, however, there is currently no groundwater conservation district for Williamson or north Travis county, so pumping from the northern Edwards Aquifer is unregulated (Smith 2011). Creating a groundwater management and conservation entity in this region would provide a path to regulate of pumping and development in this region. Regulation to encourage sustainable development would preserve water quality not only for endemic species but also for the people of central Texas, to ensure that access to clean drinking water is guaranteed for years to come.

According to the U.S. Fish and Wildlife Service, the Jollyville Plateau salamander is listed as endangered, while the Georgetown and Salado salamander are listed as threatened (U.S. Fish and Wildlife Service, “Texas Salamanders”). This listing decision was done in 2013 with extensive input from central Texas communities, many of which are opposed to listing these species under the Endangered Species act, as doing so would place stricter regulations on development in this fast-growing region (Buchele 2012 “Why the Fight Over Salamanders in Texas is Only Just the Beginning”). To ensure that protections are enacted for these species into the future, it is vital to increase public education efforts to ensure that regulation to protect these species is viewed favorably and enjoys the support of the public.

Much remains unknown about the *Eurycea* of central Texas. Science has yet to discover much of the information about natural history and abundance of these elusive animals, and their recent description to science means that species boundaries are still contested (Devitt 2018). Greater research and public education will lead to management practices and conservation that will allow these unique species to survive and protect the natural resources of this region for all its residents.

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