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A chance encounter in central Texas yields insights on the ecology of aestivating *Siren nettingi* (Caudata: Sirenidae)

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Abstract

A chance encounter in central Texas yields insights on the ecology of aestivating *Siren nettingi* (Caudata: Sirenidae). *Siren* spp. are often dominant vertebrates in the wetlands they occupy and are known to estivate when such wetlands dry up. Practical considerations limit *in-situ* observations of estivating individuals. On 12 October 2021, we incidentally discovered an estivating aggregate of *Siren nettingi* in Bastrop County, Texas, USA. These salamanders were excavated from compact, rocky soil adjacent to a caliche road, at depths that ranged between ~0.2 to 1.5 m. The dominant vegetation at this site included *Ulmus crassifolia, Persicaria* sp., and various grass species. We recovered 140 individuals of which seven were salvaged and 133 were captured live. We measured 115 of these for snout–vent length (SVL) and observed the aggregate was predominated by juveniles. We estimated an estivation density of 2.33 sirens/m^2 that is comparable to densities estimated for non-estivating populations. However, in-lieu of monitoring that was in place for this study, we expect a mass mortality event would have likely occurred. We therefore suggest that roadway construction in preferred habitat be considered as a threat to siren populations.

Keywords: Amphibian, Conservation, Dormancy, Dynamic habitat, Roadways, Wetland.

Resumo

Encontro casual na região central do Texas fornece informações sobre a ecologia da estivação de *Siren nettingi* (Caudata: Sirenidae). *Siren* spp. costumam ser vertebrados dominantes nas áreas úmidas que ocupam e são conhecidas por estivar quando essas áreas úmidas secam. Considerações práticas limitam as observações *in situ* de indivíduos em estivação. Em 12 de outubro de 2021, descobrimos por acaso um agregado em estivação de *Siren nettingi* no condado de Bastrop, Texas, Estados Unidos. Essas salamandras foram escavadas em solo compacto e rochoso adjacente a uma estrada de caliche, em profundidades que variavam entre ~0,2 e 1,5 m. A vegetação dominante nesse local incluía *Ulmus crassifolia*, *Persicaria* sp. e várias espécies de gramíneas. Recuperamos 140

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indivíduos, dos quais sete foram resgatados e 133 foram capturados vivos. Medimos 115 deles quanto ao comprimento rostro-cloacal (SVL) e observamos que o agregado era dominado por jovens. Estimamos uma densidade de estivação de 2,33 indivíduos/m^2 que é comparável às densidades estimadas para populações sem estivação. No entanto, como não houve monitoramento para esse estudo, provavelmente tenha ocorrido um evento de mortalidade em massa. Portanto, sugerimos que a construção de estradas no habitat preferido seja considerada uma ameaça às populações dessas salamandras.

Palavras-chave: Anfíbios, Conservação, Dinâmica de habitat, Dormência, Estradas, Pântano.

Introduction

Amphibians inhabiting environments that experience seasonal episodes of drought often burrow into the soil and enter into a state of dormancy when faced with the dual challenge of no food and no standing water in such habitats. This adaptive tactic includes formation of a cocoon around the body to mitigate desiccation and a reduced metabolic rate to increase the duration of survival on endogenous body stores (Secor and Lignot 2009).

Sirens serve as a useful example of amphibians that inhabit dynamic wetlands. These aquatic salamanders possess gills, have lidless eyes, and compressed tails with fin blades. Additionally, pelvic girdles and associated hindlimbs are absent (Martof 1974). Body measurements and proportions, coloration and patterns of the body, and the number of costal grooves, each corresponding to single vertebrae and associated trunk muscles, are used to distinguish among species (Powell *et al.* 2016, 2019, Fedler *et al.* 2023). Given that sirens possess few physical attributes for diagnosis among species and that body coloration and patterns can vary among individuals within a species and from the same locality, questions regarding *Siren* phylogeny largely remain unresolved. Greater Sirens (*Siren lacertina* Österdam, 1766) and Lesser Sirens (*Siren intermedia* Barnes, 1826) are among species reported within this taxonomic group. *Siren lacertina* are known to range from Virginia south to Florida and west to Southwestern Alabama (Petranka 2010), while *S. intermedia* occurs in the Coastal Plain from southeastern North Carolina to southern Florida and westward in the Gulf states to the lower Rio Grande Valley and adjacent Mexico as well as northward in the Mississippi River drainage through Illinois, Indiana, and southwestern Michigan (Martof 1973, Fedler *et al.* 2023). More recently, morphological and genetic data have been used to describe the Leopard or Reticulated Siren (*Siren reticulata* Graham, Kline, Steen, and Kelehear, 2018) from southern Alabama and the Florida panhandle (Graham *et al.* 2018) and the Seepage Siren (*Siren sphagnicola* Fedler, Enge, and Moler, 2023) from the Florida parishes of Louisiana to the western Florida panhandle (Fedler *et al.* 2023). Further, Goin (1942) characterized the Western Lesser Siren (*Siren intermedia nettingi* Goin, 1942) as distinct from *S. intermedia intermedia* and *S. lacertina* based on the presence of light spots on the sides and venter and the number of costal grooves (Fedler *et al.* 2023). We follow Fedler *et al.* (2023) in our usage of *Siren nettingi* for the study species.

Notwithstanding the taxonomic uncertainty surrounding these salamanders, prior studies have yielded insights on *Siren* ecology. Sirens are known to occupy both stationary and moving bodies of water often being the dominant vertebrate in wetland communities (Frese *et al.* 2003, Secor and Lignot 2010). The latter is particularly true for *S. intermedia* that is reportedly quick to colonize and become a dominant secondary consumer in newly formed ponds (Gehlbach and Kennedy 1978). These salamanders can attain a high standing crop biomass of up to 72 g/m^2, with such productivity attributed to high fecundity and rapid growth rates to sexual maturity (Gehlbach and Kennedy 1978, Frese *et al.* 2003). Further, like other sirens, *S. intermedia* also estivates in temporarily dry ponds to facilitate its dominance (Gehlbach and Kennedy 1978, Luhring and Holdo 2015). The estivation strategy consists of burrowing in mud or existing crayfish burrows, forming a cocoon of dried mucus to mitigate desiccation, and reducing metabolic rate to rely on fat stores during the duration of estivation (Gehlbach *et al.* 1973).

Although the propensity to estivate under adverse conditions is known for *S. intermedia,* there are practical limitations for *in-situ* observations with current knowledge on estivation behavior known from laboratory studies (Gehlbach *et al.* 1973). Here, we provide details on a chance discovery of estivating *S. nettingi* in Bastrop County, Texas, USA that yielded insights on habitat use, size distribution, and estivation density.

Materials and Methods

On 12 October 2021, the installation of a roadway culvert was begun in Bastrop County (30°07'51.5" N, 97°07'56.1" W; Figure 1). The construction site occurred within occupied habitat for the federally endangered Houston Toad [*Bufo* (= *Anaxyrus*) *houstonensis*], requiring that the culvert installation using heavy machinery be monitored to prevent toad mortality and minimize potential disturbance to the habitat adjacent to the roadway. During this time, we encountered an aestivating population of *S. nettingi,* which was initially discovered after lifting a cedar elm (*Ulmus crassifolia* Nutt.) tree that had fallen along the roadside. We diagnosed these as *S. nettingii* by counting the number of costal grooves that were not touching the limbs (Fedler *et al.* 2023). We observed several estivating individuals within the associated matrix of roots and soil. Other dominant vegetation within the construction area included *Persicaria* sp., and various grass species. The roadway and adjacent roadsides were dry, with only limited vegetation that would have indicated its prior impoundment. Continued excavation revealed additional estivating individuals. We searched the substrate manually to minimize harm and enable capture of all *S. nettingi* that were excavated. Monitoring continued until adequate substrate had been excavated to allow for culvert installation.

At the time of excavation, dry conditions precluded a release site. Thus, all extracted individuals were kept indoors at an ambient temperature of 24°C within tubs filled with purified drinking water. Individuals were restrained within snake restraining tubes of an appropriate size and measured for snout–vent length (SVL) and total length (TL). Following a rain event on 14 October 2021, release of individuals was enabled on 15 October 2021 into an adjacent ephemeral creek within the same drainage system as the ongoing construction project. That creek flowed downstream into the wetland complex proximal to where the sirens were discovered (Figure 1). Salvaged individuals were fixed in 10% buffered formalin, stored in 70% ethanol, and deposited at the Amphibian and Reptile Diversity Research Center at the University of Texas at Arlington (UTA A-66394–66397) and the Texas State University Herpetofauna Teaching Collection. We generated histograms of SVL measurements to provide a size distribution of the estivating population.

Results

We found *S. nettingi* in soils directly adjacent to and touching the caliche road at depths ranging between ~0.2 to 1.5 m. These *S. nettingi* were ~20 m from an ephemeral creek that contained some water and ~100 m from a proximal wetland. We did not find any *S. nettingi* while digging in the extremely compacted soils

Figure 1. Map inset shows the state of Texas, USA with Bastrop County highlighted (in green). Base map shows the excavation site (orange polygon) for culvert installation where an estivating aggregate of *Siren nettingi* was discovered on 12 October 2021. *Siren nettingi* were only found in an area of approximately 60 m^2 on the northeast side of the road. Captured sirens were released on 15 October 2021 into an ephemeral stream (release site) leading downslope toward the same wetland complex from which the siren originated.

that made up the roadbed itself. We captured 133 live *S. nettingi* and salvaged an additional seven that had been killed during the roadway construction and culvert installation process. We searched a total area of approximately 300 m^2 (Figure 1) but only found *S. nettingi* in an area of approximately 60 m^2 on the northeast side of the road. Given the total number of *S. nettingi* captured and salvaged, as well as the area searched, we estimate aestivation density to be 2.33 sirens/m^2.

Siren nettingi showed activity (i.e., were moving) on excavation and subsequent handling. Mean (± 1SE) SVL was 101.85 ± 81.96 mm (*N* =115; Figure 2). Of the 115 individuals measured, 93 (81%) were < 100 mm in SVL. All sirens observed at the time of excavation showed a nub like gill ramus and no filaments (Figure 3), however we observed the reappearance of gill filaments following 40 hours of inundation in water.

Discussion

Despite the abundance with which *Siren* occur in the habitats they occupy; particular aspects of their biology remain poorly known. Most studies of these salamanders are limited by practical considerations to sampling non-estivating individuals using passive trapping

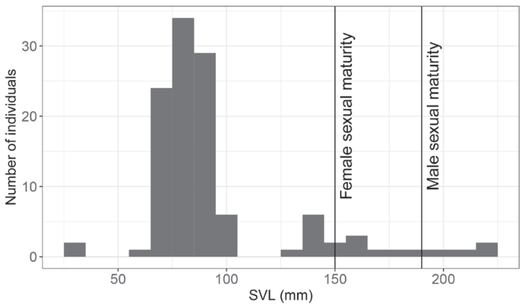

Figure 2. Size distribution (snout–vent length) of estivating *Siren nettingi* captured at a roadway construction site in Bastrop County, Texas, USA on 12 and 13 October 2021. We measured 115 individuals for SVL and observed our sample was comprised of predominantly juveniles. Thresholds lengths for sexual maturity are from Davis and Knapp (1953).

Figure 3. *Siren nettingi* restrained in a snake restraining tube for snout–vent length measurement. Following excavation, siren had atrophied gills with a nub like gill ramus and no gill filaments. We observed reappearance of gill filaments following 40 hours of inundation in water.

methods (Luhring *et al.* 2016). In particular, *in-situ* observations of estivating sirens are sparse since searching for estivating individuals poses the risk of physical harm from excavation (Aresco and Gunzburger 2004). Our chance encounter of an estivating aggregate enabled us to provide insights on estivation habitat characteristics, density, and size distribution.

Based on specimens collected in central Texas, male and female *S. nettingi* are estimated to attain sexual maturity at 190 and 150 mm SVL respectively (Davis and Knapp 1953). Similarly, in Arkansas, USA, the smallest female *S. intermedia* possessing yolked ovarian follicles measured 165 mm SVL (Trauth *et al.* 1990). Therefore, *S. nettingi* excavated during our study were predominantly juveniles. Frese *et al.* (2003) reported that 39% of the *S. intermedia* population sampled during their study comprised of juveniles. The proportion of juveniles in our sample was more than twice as large, although we are unsure of factors that explain the size/age distribution that we observed. Non-aestivating populations of *S. intermedia* occur at high densities, ranging from 1.1 to 2.17 sirens/m^2 (Gehlbach and Kennedy 1978, Frese *et al.* 2003). We report a comparable density for estivating *S. nettingi.* To our knowledge, this study represents the first report on such *in-situ* observations of estivating *S. nettingi.*

Given the high density at which we observed sirens estivating immediately adjacent to this roadway, roadway construction conducted proximal to wetland habitat may pose a serious risk to siren populations. In our instance, culvert installation in lieu of monitoring would have resulted in desiccation and physical injury and therein mortality of over 100 sirens. In examining organic sediment removed from lake beds in Florida, Aresco and Gunzburger (2004) reported that large aquatic salamanders (*Siren* spp., *Amphiuma means* Garden, 1821) were among the most abundant herpetofauna encountered. They reported that mortality from sediment removal operations in these wetlands was likely skewed to taxa with limited dispersal abilities and which relied on dried lake sediments for estivation (Aresco and Gunzburger 2004). Further, Cagle and Smith (1939) observed an aggregate of 100 *S. intermedia* in a cement culvert. This was considered a hibernating aggregate with the culvert offering ‘ready access to either pond' (Cagle and Smith 1939). Such temporarily occupied culverts could enable connectivity among wetland habitats. However, the process of culvert installation or replacement should consider means to mitigate mortality risks to the species. In regions where *Siren* spp. are imperiled, we recommend oversight of excavation activities in or proximal to wetland habitat. We emphasize here that the detection of these animals was also the first scientific documentation of the taxon in Bastrop County in Texas (Bohannon *et al.* 2022). We demonstrate that monitoring or oversight during construction minimized mortality, although with unavoidable losses still occurring.

Distribution assessments for herpetofauna in Texas continue to show gaps in such updated distributions (Dixon 2013, Bassett 2023). We suggest further surveys be conducted on the western edge of the currently known distribution to address such distributional gaps.

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