NATIONAL BIOLOGICAL SERVICE
U.S. DEPARTMENT OF THE INTERIOR

NBS INFORMATION BULLETIN

No. 46 1995

The Critical Thermal Maximum of San Marcos Salamanders

The San Marcos salamander (*Eurycea nana*) is an aquatic, neotenic species endemic to the upper reaches of the San Marcos River, Hays County, Texas. The salamander occurs only in Spring Lake (the headwaters of the San Marcos River) and the portion of the river to a point 150 m below the Spring Lake dam. Spring Lake receives its water from numerous springs emerging from the Edwards Aquifer. The water near the springs is thermally constant (21°–22°C). Population estimates for the salamander range from approximately 21,000 to 54,000. Due to its limited distribution and dependence on spring flow, the San Marcos salamander has been listed as threatened.

Substantial reduction or complete cessation of spring flow would allow water temperature in the habitat of the San Marcos salamander to fluctuate daily and seasonally. This could affect individual salamanders and the population. Temperature tolerances of this species are not known. The upper limit of temperature tolerance for the salamander, at a specific acclimation temperature, can be determined by calculating its critical thermal maximum (CTM). The CTM is defined as the mean of the collective thermal points at which movement becomes disorganized and the animals lose their ability to escape from conditions that will lead to their death. The purpose of our study was to determine the CTM for juvenile and adult San Marcos salamanders at the temperature of their stenothermal environment.

Collecting Salamanders and Determining Critical Thermal Maximum

San Marcos salamanders reach sexual maturity (based on gonadal development) at a snout-vent length (SVL, the distance from the snout tip to the posterior end of the vent) of 19 mm (males) and 21 mm (females). Based on this, we assumed that salamanders with a SVL < 19 mm were juveniles and a SVL > 21 mm were adults (i.e., were sexually mature). Salamanders were collected on 15 July 1994 (adults) and 1 September 1994 (juveniles) from the northern end of Spring Lake. The salamanders were transported to the laboratory and held in an ice chest containing water from the collection site. The water temperature in the ice chest was maintained (using ice in plastic bags) within ± 0.3°C of the water temperature at the collection site (21.7°C for adults and 21.9°C for juveniles).

An oil bath heating unit was modified and used as a water bath for the tests. A motor speed control was used to regulate the heating rate at 1°C/min and a small pump was used to ensure thorough mixing within the bath. A clear PVC test cell was built to hold the salamanders during the tests. The CTM tests were run on individual salamanders (n = 10 for juveniles and for adults) on the day of collection. For each test, the water bath was filled with chilled (19°C) Edwards Aquifer well water. After raising the temperature of the water to that at the collection site, a single salamander was placed into the test cell. Salamander behavior, water temperature, and time were monitored during the tests. The temperatures at loss of righting response and at the onset of spasms were recorded. Each salamander then was quickly removed from the test cell, placed inside a numbered recovery chamber (one salamander per container), and returned to the ice chest. After all CTM tests were run, the salamanders were anesthetized with 160 mg/L tricane methanesulfonate (MS-222) and SVL and total length (TL, the distance from snout tip to the tip of the tail) were measured for each. Weight (WT) also was measured for the adults (we were unable to accurately measure WT for the juveniles). They then were returned to their recovery chambers and held in aquaria at approximately 21°C. After 3 days, the salamanders were removed from their recovery chambers and deaths were recorded.

Adults Had a Higher Critical Thermal Maximum Than Juveniles

We used the onset of spasms as the CTM endpoint in this study. Based on observations during testing, we felt that it was a less ambiguous endpoint than the loss of righting response for this species and more accurately fits the definition of CTM. The adults had a significantly higher CTM (37.2°C) than the juveniles (35.8°C; Table). Three adults and one juvenile were found dead 3 days after testing. Stress from anesthetizing and handling may have been factors contributing to these deaths. We found no correlation between CTM and salamander size (TL, SVL, or WT) for either the adults or the juveniles. There was, however, significant correlation between CTM and TL and between CTM and SVL when the data were pooled.

Understanding Protected Organisms and Their Unique Habitat

Spring Lake is listed as critical habitat for the San Marcos salamander and two endangered species, the fountain darter (*Etheostoma fonticola*) and Texas wild rice (*Zizania texana*). The San Marcos pool of the Edwards Aquifer is the only known location for another endangered species, the Texas blind salamander (*Typhlomolge rathbuni*). These species all depend on the high quality water of the aquifer for their existence. How these species would react to possible changes in the quality of their water is not known. The information from this report and continued research on the species of this unique ecosystem will aid researchers in developing plans to ensure their continued existence.

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Table. Mean total length (TL), mean snout-vent length (SVL), mean weight (WT), and the critical thermal maximum (CTM) of San Marcos salamanders (*Eurycea nana*; $n = 10$ for both juveniles and adults).

	TL (mm) (range)	SVL (mm) (range)	WT (g) (range)	CTM (°C) (± 95% C.I.)
Juveniles	18.2[a]	10.7[a]	—	35.8[a]
	(14–25)	(8–14)	—	(± 0.5)
Adults	45.0[a]	25.8[a]	0.239	37.2[a]
	(36–54)	(22–30)	(0.18–0.32)	(± 0.4)

[a] Mean is significantly different ($P \leq 0.05$).