POPULATION SIZE, MOVEMENT, AND REPRODUCTION OF THE GEORGETOWN SALAMANDER, *EURYCEA NAUFRAGIA*

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Abstract.—Salamanders are important components of many headwater stream and spring habitats and may be important indicators of ecosystem health. At least 15 recognized species of endemic salamanders of the genus *Eurycea* occur on the Edwards Plateau of central Texas, US A. The Georg etown Salamander (*Eurycea naufragia*) is a neotenic, spring- and cave-dwelling species found only in the San Gabriel River watershed of Williamson County, Texas, an area undergoing rapid urbanization. In spite of conservation concern, lit tle research has been conducted o n the species and informatio n critical for conservation planning is unavailable. In this study, we used visual implant elastomers and mark-recapture methods to provide the first population estimates for the species, revealing small populations at two springs. Based on 24 months of recapture survey s, we found limit ed movement o f *E. naufragia* within individual sp r ings. Ove r a pe riod of three years, we checked salamanders for the presence of eggs and observed seasonal reproduction with bimodal peaks in winter and early spring. Measurements of gravid individuals suggest female reproductive maturity occurs around 26 to 28 mm head-trunk length. This information about the life history of *E. naufragia* can enhance conservation planning and management of the species.

Key Words.—Conservation; *Eurycea naufragia*; Georgetown Salamander; movement; population size; reproduction; salamander

INTRODUCTION

Salamanders play important ecological roles in many headwater streams, springs, and caves, where they comprise a significant proportion of consumer biomass and frequently serve as important predators and prey (Burton and Likens 1975; Peterman et al. 2008). These animals frequently act as indicators of ecosystem health because they typically require pristine conditions and are sensitive to anthropogenic influences, such as urbanization (Miller et al. 2007), road construction (Welsh and Ollivier 1998), and timber harvest (Lowe and Bolger 2002).

In central Texas, a number of endemic, spring- and cave-dwelling salamanders of the genus *Eurycea* reside on the Edwards Plateau, an extensive uplifted region of karst limestone. Chippindale et al. (2000) recognized 15 species within this group and pointed out that a number of undescribed species probably also occur. Bendik et al. (2013) provided additional information on species boundaries in the group. Almost all populations of Texas *Eurycea* are neotenic and critically dependent on water supplied by aquifers. Most species have restricted distributions, often limited to a few springs or caves. Some of the central Texas *Eurycea* occur exclusively in areas undergoing rapid urbanization, placing these populations at high risk of extirpation because of habitat loss, reduced aquifer recharge, groundwater pumping, and pollution (Chippindale and Price 2005).

One species of conservation concern is the Georgetown Salamander, *Eurycea naufragia*, known from 13 surface springs and two caves located within the San Gabriel River watershed in Williamson County, Texas. The entire distribution of the species occurs within an area undergoing rapid population growth and urbanization. Williamson County is the tenth fastest growing county in the United States; from 2010 to 2012, Williamson County increased in population size from 422,679 to 456,232, an increase of 7.9% (U.S. Department of Commerce: United States Census Bureau. 2013. Quick Facts: Williamson County, Texas. Available from http://quickfacts.census.gov/qfd/states/48/48491.html [Accessed 27 June 2013]). Shortly after species delineation on the basis of morphological and molecular characteristics (Chippindale et al. 2000), the United States Fish and Wildlife Service (USFWS) included the Georgetown Salamander as a candidate for listing as an endangered species (USFWS 2001). In 2014, the USFWS announced the listing of the species as threatened under the Endangered Species Act (USFWS 2014).

In spite of its conservation status and the need to develop a long-term management plan for the species, little information exists on biology of the Georgetown Salamander. Field observations of salamanders and limited habitat at each site (often consisting of less than 100 m^2), suggest that surface population sizes are small,

but no previous estimates of population size have been made.

Only three papers have been published on the species. Chippindale et al. (2000) described the species, provided information on morphological and molecular characteristics, and gave limited information on habitat. Pierce et al. (2010) provided results of visual encounter surveys at two sites, reported seasonal changes in abundance at one site, and documented microhabitat preferences. Biagas et al. (2012) focused on whether the time of day when visual encounter surveys were conducted affected the results of surveys of the species. Thus, natural history information that would be useful in conservation planning and management, such as population size, age structure, movement, and reproduction, is lacking. The objective of this study was to provide basic information on the ecology of *E. naufragia*, including estimates of population size, information on movement of salamanders within surface spring habitats, and information about the timing of reproduction.

MATERIALS AND METHODS

Study sites.—We studied salamanders at two relatively large, permanent springs located in the watershed of the San Gabriel River in Williamson County, Texas. Swinbank Spring (30°39′43.92″N, 97°42′37.80″W) occurs in an urban area within the city of Georgetown, Texas. The spring emerges from the base of a spring house and runs approximately 50 m downstream to the North San Gabriel River. We conducted our study along a transect extending from the base of the spring house to 24 m downstream, where initial surveys indicated that most of the salamanders occur. This section of the spring run consists of a series of small pools and riffles, with water depth ranging from a few centimeters to 0.5 m. The substrates of the spring run vary, consisting largely of silt, gravel, cobble, and large rocks. Pierce et al. (2010) described results from initial surveys and studies of habitat preferences of *E. naufragia* at this site.

Twin Springs occurs within a managed nature preserve (30°41′52.32″N, 97°46′53.15″W) and is adjacent to low-density residential areas in the North San Gabriel River watershed. We studied salamanders along a transect extending from the spring origin to 28 m downstream. The spring at this site originates within a well-shaded ravine and runs downstream approximately 2 km to Lake Georgetown. The spring run consists of pools and riffles with water depth ranging from a few centimeters to 0.5 m. The substrates vary, consisting largely of silt, gravel, cobble, large rocks, and leaf litter.

Mark-recapture.—We conducted three-day mark-recapture studies at Twin Springs between 1−3 June 2010 and at Swinbank Spring between 29 June–1 July 2010. At the beginning of the mark-recapture study, we placed fine-mesh (1.6 × 1.6 mm) nets across the beginning and end of the transect to prevent immigration and emigration of the salamanders. These nets remained in place throughout the three-day study. We divided the transect at each site into five sections, each approximately 5 m long.

On day one, we captured all salamanders observed with aquarium dip nets, uniquely marked all salamanders, and returned them to their 5-m section of capture. On day two, we captured all observed salamanders and marked any unmarked salamanders. At the end of the survey, we returned all salamanders to their 5-m section of original capture. On day three, we repeated the procedure from day two.

Following capture, we individually placed unmarked salamanders in single-use plastic bags filled with 10–20 mL of 0.25 g/L solution of MS-222 (tricaine) dissolved in spring water. Previously marked salamanders were placed in plastic bags with 10–20 mL of spring water. The bags containing salamanders from each section were placed in a mesh box (30 × 30 × 55.5 cm) within the spring run, allowing the salamanders to remain at ambient temperature.

To uniquely mark salamanders, we injected each anesthetized, unmarked salamander subcutaneously with visual implant elastomers (VIE; Northwest Marine Technology, Inc., Shaw Island, Washington, USA). Visual implant elastomer marks appear to have no negative effects on survival or growth of *Eurycea* salamanders (Phillips and Fries 2009). Prior to injection, the elastomers were mixed according to the manufacturer's instructions and placed on ice. We used a combination of five colors (white, red, orange, blue, and yellow) placed in three of four locations on each salamander: dorsal trunk posterior of the left and right front legs and the dorsal trunk anterior of the left and right hind legs. We did not attempt to mark salamanders less than 2.5 cm total length.

Following marking, we photographed each salamander in spring water against a 0.635 × 0.635 cm grid for future measurement and for identification based on melanophore patterns if the VIE marks were lost. After photography, we allowed the salamanders to recover from the anesthesia and then returned them to the spring in the original 5-m section of capture.

Population estimates.—We estimated population size using Peterson's estimate with Chapman's modification for small sample size (Donnelly and Guyer 1994) based on day-three recaptures. This estimate assumes that the population is closed during the sampling period. We addressed this assumption by placing fine-mesh nets at the beginning and end of the transect, which limited immigration or emigration of these completely aquatic salamanders, and by using a short sampling period (3

days), which minimized any births or deaths during the recapture study. Because the number of recaptured salamanders was small, we pooled all animals marked on days one and two, and based population estimates on the total number of marked animals recaptured on day three. The probability of detection during the mark-recapture experiment was calculated as the average daily probability of recapturing marked salamanders during the two days of recapture.

Movement.—Following initial marking in June 2010, we conducted monthly visual-encounter surveys for 24 months along the same transects used in the mark-recapture study. During these surveys, we overturned cover objects (e.g., rocks, mud, leaf litter, and sticks) and attempted to capture all observed salamanders with aquarium dip nets. We placed captured salamanders in mesh boxes, with one box per 5-m section. We checked the captured salamanders for elastomer marks using a hand-held ultraviolet light. We anesthetized and photographed all marked animals, as described for the mark-recapture study, and returned them to the same section of capture.

Occasionally, one or more elastomer marks of a recaptured salamander were missing, or the marking pattern was recorded incorrectly in the field. In these cases, patterns of melanophores on the heads of salamanders were compared between photographs; using these patterns, we identified every salamander recaptured. We ran a two-tailed Fisher's exact test to compare the proportion of salamanders that moved between 5-m sections at Swinbank Spring and Twin Springs during the 24 months of the study.

Reproduction.—Upon capture, we checked salamanders for the presence of eggs. To facilitate observation of eggs, each salamander was placed individually in a Petri dish filled with spring water and held up to sunlight or examined with a small flashlight. When present, eggs were visible through the ventral surface of the abdominal wall, appearing as distinctly white, opaque, and circular masses. We checked salamanders for eggs over a three-year period, from June 2010 to May 2013. We examined only marked salamanders for the presence of eggs from June 2010 to March 2011, except for November 2010 when we examined all captured salamanders. From April 2011 to May 2013 we checked all captured salamanders for the presence of eggs.

From October 2012 to May 2013, we photographed and measured all captured salamanders, allowing us to determine average and minimum size of gravid females. To compare sizes of gravid salamanders captured during spring and fall, we measured head-trunk length of individual salamanders from digital photographs using ImageJ software (vers. 1.43u, U.S. National Institutes of Health, Bethesda, Maryland, USA). We used head-trunk length, defined as the distance from the tip of the snout to the anterior insertion of the back legs, instead of snout vent length, because we were unable to determine the location of the vent from the photographs, which were of the dorsal surface.

We ran a two-tailed Fisher's exact test to compare the proportion of salamanders that were gravid observed for two time periods: (1) November through April and (2) May through October, for 35 months (from June 2010 to May 2013) of observations. We used an analysis of variance to compare the sizes of gravid salamanders in November 2012 and gravid salamanders captured in March 2013 from Swinbank Spring; a Kolmogorov-Smirnov test verified the assumption of normality. Small sample size at Twin Springs precluded a comparison of body size. An alpha level of 0.05 was used for all statistical calculations. We used QuickCalcs (GraphPad Software, Inc. 2013) and SPSS (SPSS 19 for Windows, Release 19.0.0, SPSS Inc., Chicago, Illinois, USA) for statistical analyses.

RESULTS

Population estimates.—At Swinbank Spring, we marked 43 salamanders on day one of the mark-recapture study, 25 on day two, and 22 on day three, resulting in 90 marked salamanders. At Twin Springs, we marked 49 salamanders on day one, 10 on day two, and three on day three, for a total of 63 salamanders. The probability of detection of marked salamanders was 0.357 ± 0.048 (mean $\pm$ SE) at Swinbank Spring and 0.046 ± 0.005 at Twin Springs. We estimated the population at Swinbank Spring to be 137 animals ($\pm$ 16.79 SE) and the population at Twin Springs to be 119 animals ($\pm$ 36.66 SE).

Movement.—Following marking, at Swinbank Spring we recaptured 60 of the original 90 marked animals at least once (66.7%) over the next 24 months. At Twin Springs, we recaptured 29 of the original 63 marked salamanders at least once (46.0%). Movement was limited at both sites. At Swinbank Spring, only 7% of recaptured salamanders had moved outside their 5-m section of initial capture over the first six months; only 25% had moved after 24 months (Fig. 1). At Twin Springs, we observed higher rates of movement: 30% had moved in the first six months and 45% had moved over 24 months (Fig. 1). We did not detect a difference in movement between Swinbank Spring and Twin Springs (Fisher's exact test; $P = 0.0884$). The salamanders that moved exhibited no obvious directional pattern: at Swinbank Spring six moved upstream and nine moved downstream and at Twin Springs five moved upstream and eight moved downstream. A chi-square goodness-of-fit test demonstrated that the
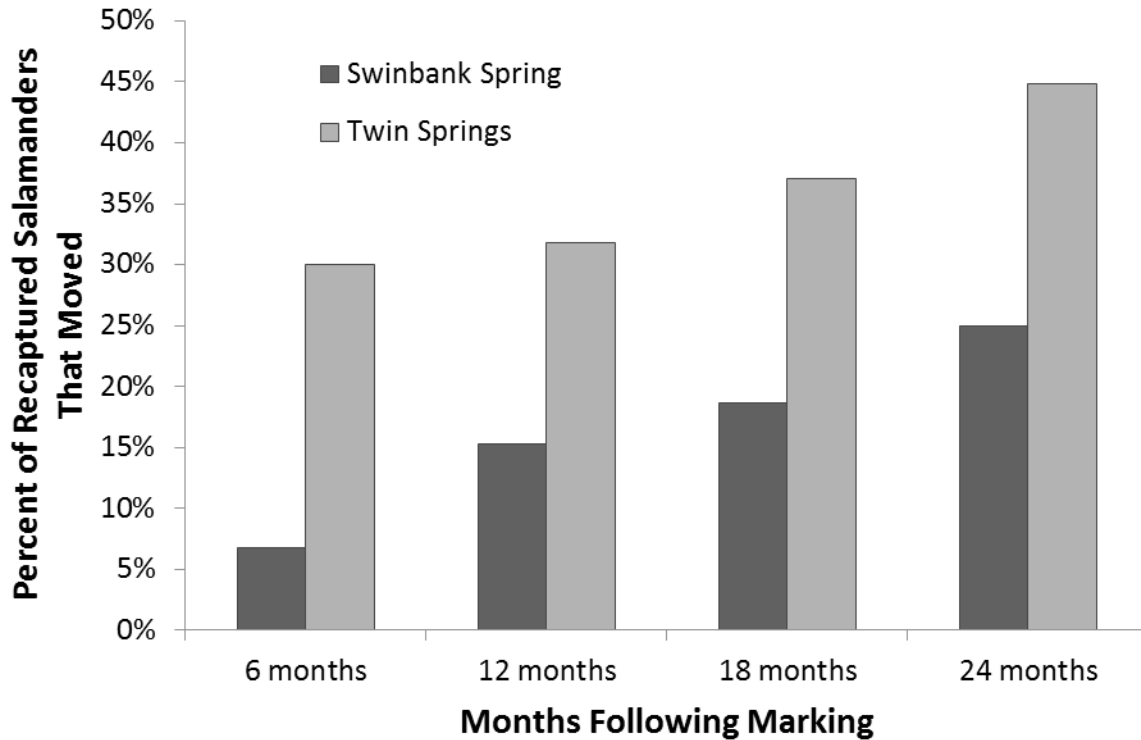
FIGURE 1. Cumulative percentage of recaptured Georgetown Salamanders (*Eurycea naufragia*) that moved between 5-m sections at Swinbank Spring and Twin Springs, Williamson County, Texas, over 24 months. The time points are cumulative following initial marking.

proportions of salamanders that moved upstream and downstream did not differ significantly from 1:1 (X^2 = 1.29, df = 1, P = 0.26, numbers from both sites combined). At Swinbank Spring, two salamanders moved both upstream and downstream in subsequent recaptures.

Reproduction.—We examined egg presence in 15.3 ± 2.08 (mean ± SE) salamanders per month at Twin Springs and in 30.8 ± 3.63 salamanders per month at Swinbank Spring over the three-year study period. The presence of eggs in salamanders was highly seasonal at both sites (Fig. 2). We observed a greater proportion of salamanders that were gravid from November through April than from May through October at both Swinbank Spring (Fisher's exact test; P < 0.001) and Twin Springs (P < 0.001). Within the November through April period, there were two peaks in the proportion of salamanders that were gravid, one peak in November or December and another in February or March (Fig. 2). We consistently observed seasonality and presence of two peaks at both sites for all three years of the study.

Head-trunk length of all salamanders captured at Swinbank spring from October 2012 to May 2013 ranged from 8.9 to 34.3 mm with an average of 27.6 ± 1.63 mm (SE). The head-trunk length of gravid females during this same period ranged from 25.9 to 34.0 mm

with an average of 30.7 ± 0.71 mm. At Twin Springs, head-trunk length of all salamanders captured during this period ranged from 11.2 to 35.4 mm with an average of 29.0 ± 1.27 mm. The head-trunk length of gravid females ranged from 28.2 to 32.0 mm with an average of 30.1 ± 0.46 mm. Thus, the minimum size of gravid females was 25.9 and 28.2 mm at Swinbank Spring and Twin Springs, respectively. We found no significant difference in the head-trunk length of gravid females captured in November and those captured March at Swinbank Spring (F = 0.05, df = 1,9, P = 0.824).

DISCUSSION

Our mark-recapture studies at Swinbank Spring and Twin Springs suggest similar and relatively small population sizes of *Eurycea naufragia* at these two sites. The relatively small number of recaptures we obtained on day three of the study at Twin Springs resulted in a larger standard error. It is important to note that these are estimates for adult animals; at both sites, we observed few salamanders less than 2.5 cm total length and we did not mark salamanders smaller than 2.5 cm total length.

Few other studies have estimated population size for *Eurycea* salamanders. Using mark-recapture studies, Burton and Likens (1975) estimated adult population
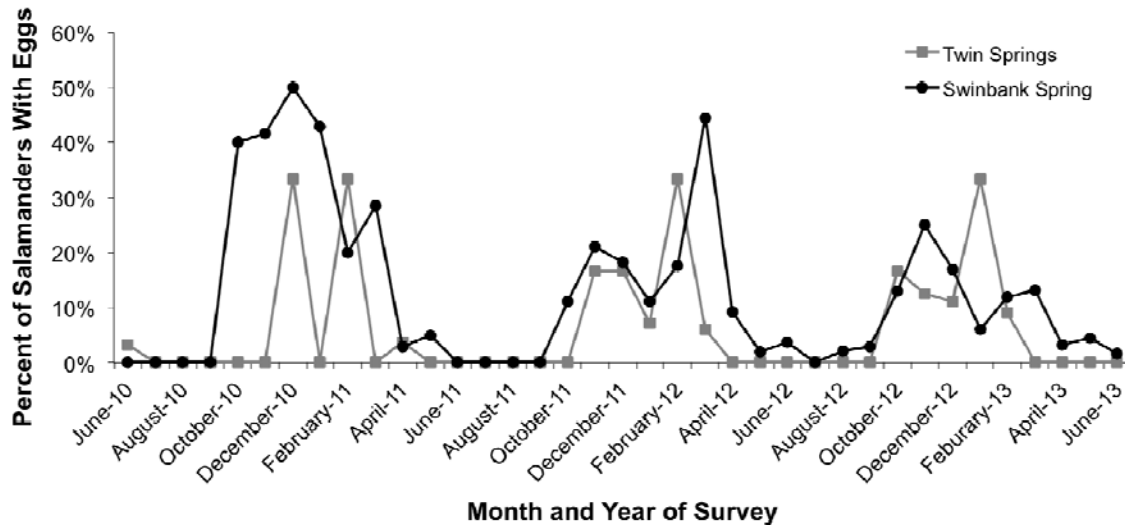
FIGURE 2. Monthly percentage of all Georgetown Salamanders (*Eurycea naufragia)* that were gravid at Swinbank Spring and Twin Springs, Williamson County, Texas, from July 2010 to May 2013.

sizes of *Eurycea bislineata* at one site in New Hampshire to be 626 ± 225 (salamanders ± 95% error limits) in 1970 and 365 ± 165 in 1971. However, *E. bislineata* is biphasic; Burton and Likens estimated population size for terrestrial populations, and we estimated population size for aquatic adults. Additionally the site used by Burton and Likens included a much larger area than the sites we surveyed. Johnson and Wallace (2005) estimated the population size of aquatic *Eurycea wilderae* larvae in one stream to be about 153 individuals (98–233, 95% CI), but they examined larvae, while we estimated population size for adults. Huntsman et al. (2011) estimated population size of *Gyrinophilus palleucus*, a neotenic cave-dwelling salamander, at two sites to be 215 (128−302; 95% CI) and 109 (77−141).

Population estimates have been conducted for only a few populations of neotenic, central Texas *Eurycea*. Estimates for three surface populations of *Eurycea tonkawae* ranged from 144 to 581 salamanders per site (Nathan Bendik, unpubl. report). A mark-recapture study of *Eurycea rathbuni*, a cave-dwelling species, estimated population size at one cave to be only 12 salamanders (10–93, 95% CI; Andrew Gluesenkamp, unpubl. report). Results from these studies suggest that our finding of small population size in *E. naufragia* is not unusual for *Eurycea* salamanders.

Our observation of small population sizes for *E. naufragia* has implications for the conservation of the species. Small population size generally increases the risk of extinction and increases loss of genetic variation due to stochastic factors, placing these populations at greater risk (Lande and Barrowclough 1987). However, some studies suggest that amphibians with long-lived adults and high fecundity, including central Texas *Eurycea*, may be adapted to withstand years of small population size and low recruitment associated with unfavorable environmental conditions (Green 2003; Taylor et al. 2006; Gillespie 2011). One limitation of our study is that we only examined population size at two sites and at a single time point. At other sites where we have observed *E. naufragia*, we usually see fewer salamanders than at Swinbank Spring and Twin Springs, suggesting that population size at these other sites may be lower. However, we cannot rule out the possibility that we see fewer salamanders at these sites due to lower probabilities of detection. Another limitation is that we conducted our study over only the upper portion of the spring run at each site. However, we typically find few salamanders further downstream at these two sites, and *Eurycea* on the Edwards Plateau are usually found close to the spring origin (Sweet 1978; Pierce et al. 2010). Also, we only assessed the surface population of salamanders at each site; the extent to which salamanders may reside underground within the aquifer remains completely unknown. Additional mark-recapture studies at other sites would be helpful to determine if small populations are consistent across sites, and to elucidate subterranean population sizes.

We found limited movement of *E. naufragia* within the spring run. Movement at Twin Springs was not different from that at Swinbank Spring. The limited movement that we observed was remarkable in light of a 500-year flash flood associated with tropical storm Hermine that occurred in the third month of the study (Parzybok et al. 2011). The flood sent large volumes of surface water down the spring runs, altering the surface topography at each site. Nevertheless, after the flood the

salamanders tended to be recaptured within their original 5-m section of capture.

A pilot study of *E. tonkawae* (Nathan Bendik, pers. comm.) found higher movement than we observed in *E. naufragia*: 25% of marked *E. tonkawae* moved between 15-m sections of a spring-fed stream over a 3.5 month period. Bendik calculated that about 6–14% of marked *E. tonkawae* salamanders moved per month compared to only 1–2% of *E. naufragia* in our study. These differences may reflect habitat differences in the two species. The population of *E. tonkawae* studied by Bendik occurred in a spring-fed stream, where there exists a much larger area of available habitat than at the small spring runs where *E. naufragia* occurs.

Other studies of aquatic headwater stream salamanders have also found limited movement. Cosentino et al. (2009) found that only about 12% of *Gyrinophilus porphyriticus* moved more than one meter from their original capture location during eight mark-recapture studies conducted over about four weeks. Similarly, Lowe (2010) found that 25% of *Gyrinophilus porphyriticus* moved < 1 m from their original locations in 18 surveys over five years and the majority of movements were dispersal-and-settlement events. In our study, we observed no directional bias in movement: similar numbers of salamanders moved upstream and downstream. In contrast, Lowe (2003) observed a strong upstream bias in the movement of *G. porphyriticus*.

One limitation of our estimates of movement was that we only looked at movement between 5-m sections of the spring run. Undoubtedly, some movement occurred over shorter distances, which we were unable to detect. Nevertheless, the degree of movement we observed was quite low considering the short lengths of the transects. Although we have no data on movement between populations, the limited movement we observed within sites and the absence of suitable surface habitat between populations suggests that limited surface movement occurs among populations of *E. naufragia*. The extent of gene flow that might occur underground through the aquifer remains unknown.

No previous information exists on the timing of reproduction in *E. naufragia*. Our observations of individuals with eggs suggest that reproduction in *E. naufragia* occurs seasonally, with egg development and oviposition taking place during winter and early spring. We first observed gravid salamanders during October and November and we observed few gravid individuals after April. This finding was consistent at both sites and across all years, in spite of the fact that weather conditions and spring flow varied over the three-year study. For example, spring flows were high during the winter of 2010−2011, following the major flood that occurred in September 2010. This was followed by drought conditions and lower spring flows during the summer and fall of 2011. The study area then received

unusually high winter precipitation in January and February 2012, which again raised spring flows. In spite of these variations in precipitation and spring flow, females with eggs appeared at the same time each year. In the first year of the study, we only checked marked salamanders that we captured for the presence of eggs, and the number of salamanders observed in any one month was low that year. However, the trend observed in the first year remained consistent with that seen in subsequent years.

Most *Eurycea* species have a biphasic life cycle. The reproductive timing of these species generally exhibits a seasonal trend, though the season largely depends on location (Petranka 1998). Southern populations of *Eurycea cirrigera* typically oviposit in the winter and early spring (Petranka 1998). Peak egg laying time for *Eurycea multiplicata griseogaster* occurs from November through January in springs and spring-fed streams (Ireland 1976; Petranka 1998). Reproduction for *Eurycea quadridigitata,* the biphasic species most closely related to the central Texas *Eurycea* (Kozak et al. 2009), generally occurs from September through February (Petranka 1998). Reproduction has been studied in only a few of the neotenic species of *Eurycea* found in central Texas. Based on anecdotal observations of the presence of eggs, Bowles et al. (2006) suggested that the Jollyville Plateau Salamander (*E. tonkawae*) reproduces from November through February. Additional studies of this species reported increased numbers of small salamanders in April and May, supporting a winter and early spring reproductive period (O'Donell et al., unpubl. report). Sweet (1977) proposed that midwinter reproduction occurred in *Eurycea neotenes*, recognized at the time as a widespread species that occurred throughout central Texas, including populations now considered *E. naufragia*. In contrast, Najvar et al. (2007) concluded that *Eurycea nana* reproduces year round; however, this conclusion was based on captive-bred animals, and *E. nana* lives in a different type of habitat (a spring-fed lake) than *E. naufragia*. Gillespie (2011) proposed that reproduction in the Barton Springs Salamander (*Eurycea sosorum*) can occur at any time of year, triggered by increased spring flows associated with major precipitation events. However, this conclusion was based on analysis of salamander size class data, not on the presence of eggs. We did not have access to flow data for the springs to see if this pattern is consistent for *E. naufragia*. Our data suggests that reproduction in *E. naufragia* occurs seasonally, in winter and spring, but this does not exclude the possibility that the extent of reproduction might be affected by water flow or other environmental factors.

During the winter and spring breeding seasons, we observed a bimodal distribution of gravid individuals: there were two separate periods with high numbers of

gravid salamanders, one appearing in late fall (October–December) and another occurring in spring (March at Swinbank Spring and January to February at Twin Springs). The relative numbers of gravid salamanders observed in each peak varied from year to year, particularly at Swinbank Spring, but the two peaks were present at both populations in all three years.

The bimodal distribution could be an artifact of the small number of salamanders sampled each month, but this seems unlikely given its consistency at both sites across years. Another possible explanation for a bimodal distribution is that different sets of females become gravid at different times of year; for example, larger females might reproduce in the fall with smaller salamanders delaying egg development until spring. For *E. naufragia*, we saw no difference in average body size of gravid females in the fall compared with gravid females in the spring, but factors other than size might differ between females reproducing in fall and spring.

Females producing two egg clutches per year might also result in two peaks of reproductive activity. Marking salamanders provided the opportunity to determine if individual females become gravid more than once, but this requires catching the same individual during both periods of egg development and in between, meaning we would need to capture an individual salamander at least three times during one reproductive season. We captured few individuals this frequently. After we started photographing all captured salamanders (in October 2012), we observed one salamander that appeared to become gravid twice, with an observation of no eggs in between. This suggests that it is possible for females to produce more than one clutch a year, but we hesitate to generalize based on a single observation.

Ringia and Lips (2007) also observed bimodal peaks of reproductive activity in one population of *Eurycea lucifuga* with an extended breeding period (5−8 months), which they suggested resulted from females producing multiple clutches per year. Other researchers (Petranka 1998; Ringia and Lips 2007) have recorded multiple egg-laying events from single *Eurycea longicauda*, but whether this represents the production of multiple clutches is not clear.

In our populations, gravid females ranged in size from 25.9 to 34.0 mm head-trunk-length. Two other neotenic salamanders *E. neotenes* and *Eurycea tynerensis* become sexually mature at > 25 mm and 26–27 mm snout-vent-length, respectively (Petranka 1998), similar to the minimum size of gravid females we observed for *E. naufragia*.

We assessed only one aspect of salamander reproduction: the presence of eggs in the females. We have never observed eggs in the field, and no published records of eggs being laid exist for this species; thus, we have no information on precisely when eggs were laid, although we assume that eggs were laid between the dates of first and last appearance of gravid females. We also have no information about the length of embryonic development.

In summary, this study provides some of the first data on population size, movement, and the timing of reproduction of *E. naufragia*, information that will be useful for developing an effective conservation plan for the species. However, major gaps in our knowledge of the species remain and much additional research is needed.

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