populations (Petranka, 1998), direct links between habitat loss and population declines have not been demonstrated.

*Eurycea junaluska* Sever, Dundee, and Sullivan, 1976

JUNALUSKA SALAMANDER

Travis J. Ryan, David M. Sever

1. Historical versus Current Distribution.

When described in 1976, Junaluska salamanders (*Eurycea junaluska*) were known "officially" from only three creeks, all located within Graham County, North Carolina. However, Junaluska salamanders had been collected in the Great Smoky Mountains National Park (GSMNP) as early as 1937. At that time, King (1939) recognized a unique form as *E. bislineata x cirrigera*, an intermediate between the northern (*bislineata*) and southern (*cirrigera*) subspecies of the widely distributed two-lined salamander. King was certain that the form he found in the GSMNP was distinct from the common Blue Ridge two-lined salamander (*E. bislineata wildana*); the three subspecies of *E. bislineata* later were all elevated to species level by Jacobs, 1987.

After describing *E. junaluska*, Sever (1976) examined a portion of King’s collection and determined that they were in fact the earliest collected forms of the new species. This post hoc discovery expanded the range of Junaluska salamanders to two additional counties in Tennessee—Blount and Sever. Subsequent surveys resulted in new records from Monroe County, Tennessee (Sever, 1983a). An additional site in Graham County was later reported, but extensive surveys in the three North Carolina counties surrounding Graham County proved fruitless (Ryan, 1997). More recent fieldwork in Tennessee has resulted in new records from within the GSMNP and in Polk County (W. H. M. Gutzke, personal communication).

2. Historical versus Current Abundance.

Most of the other members of the *E. bislineata* complex (*E. bislineata, E. cirrigera*, and *E. wildana*) are locally abundant throughout their ranges (Sever, 1989); but in our experience, Junaluska salamanders are an exception to this rule. Sever (1984) gives a particularly lucid and entertaining account of the difficulties that can be associated with studying this species. In the earliest account, King (1939) speculated that Junaluska salamanders were “a relic of a much older population” but did not mention their abundance. The type series of 23 individuals had to be assembled from collections made over a 3-yr period (Sever, 1984). A decade after the first members of the type series had been collected, Sever (1983a) commented on having “collected fewer than 50 metamorphosed individuals.” Ryan (1998a) suggested that larvae are preferred indicators of population size because larvae are locally concentrated (i.e., confined to streams) whereas the more uncommon metamorphosed individuals may be spread out over a substantially larger area. Bruce (1982b) and Ryan (1997, 1998a) studied larval populations of Junaluska salamanders and Blue Ridge two-lined salamanders; in both cases, larvae of the latter were far more abundant than that of the former. Ryan (1998a) determined that in North Carolina, Junaluska salamanders accounted for fewer than 20% of the larval *Eurycea* assemblage at Santeetlah Creek (perhaps the most stable and best studied population). Junaluska salamanders represented ≤30% of the assemblage at Snowbird Creek in August 1994, but have not been collected at that site since later that year (Ryan, 1998a; T. J. R., unpublished data). Essentially, Junaluska salamanders were rare to begin with (perhaps contributing to their relatively late discovery), and remain so in North Carolina.

Recent collecting efforts at the type locality on the Cheoah River have been in vain (T. J. R., unpublished data; W. H. N. Gutzke, personal communication), and this population is feared to be extirpated, due to anthropogenic activities upstream. Tennessee populations appear stable and quite possibly larger than those in North Carolina.

3. Life History Features.

The life history of Junaluska salamanders is perhaps the best-known aspect of this otherwise enigmatic species. While many of Sever’s Junaluska salamander papers (e.g., Sever et al., 1976; Sever, 1979, 1983a) contain valuable life history data, studies by Bruce (1982b) and Ryan (1998a) of the Santeetlah Creek population have resulted in the clearest picture of this species’ life history. The life histories of Junaluska salamanders, as well as all other *Eurycea*, are summarized in Ryan and Bruce (2000).

A. Breeding. Reproduction is aquatic.

i. Breeding migrations. We are unaware of anything approaching a true breeding migration in Junaluska salamanders. However, the majority of adults that we have collected have come either in the fall, prior to when courtship and breeding occur in members of the *E. bislineata* complex, or in the spring, near the time of oviposition (e.g., Sever, 1983a; Ryan, 1998a; D. M. S. and T. J. R., unpublished data).

ii. Breeding habitat. Courtship of Junaluska salamanders has not been observed, but we believe that it likely occurs along streams where adults are found during the putative breeding season and also where eggs are deposited.

B. Eggs.

i. Egg deposition sites. Salamanders attend clutches of eggs around mid-May. Eggs typically are found attached to the underside of a large rock in water <0.5 m deep, with moderate stream flow, and between 1–12 m from the streambank. The location of the nests does not differ appreciably from where larvae have most frequently been collected.

ii. Clutch size. Clutch sizes observed in the field range from 30–49 (mean = 38, n = 5). Sever (1983a) reported gravid females contained between 41–68 (mean = 51, n = 10) mature ovarian follicles. About 1.1 mo is required for embryonic development, and hatchlings are about 7–8 mm TL (Bruce, 1982b). As a point of interest, each time we believe that it looks like

C. Larvae/Metamorphosis. The larvae of Junaluska salamanders are superficially similar to those of Blue Ridge two-lined salamanders with regard to morphology, ecology, and life history. A photograph of

Junaluska Salamander (*Eurycea junaluska*)
a larva appears in Sever (1983a), and Ryan (1998a) offers a description of the larvae and illustrations of larval Junaluska salamanders and Blue Ridge two-lined salamanders.

i. **Length of larval stage.** In North Carolina, the larval period appears to be 2 yr, possibly 3 (Bruce, 1982b; Ryan, 1998a); Ryan (1998a) estimated the age at metamorphosis to be 25.5 mo at Santeetlah Creek. Larvae grow at a faster rate in the first year of larval development than they do in the subsequent year(s) (Ryan, 1998a). Metamorphic individuals may be as small as 34 mm SVL, but most are closer to 40 mm SVL (Bruce, 1982b; Ryan, 1998a) making them the largest naturally metamorphosing larvae in the *E. bislineata* complex (Ryan and Bruce, 2000).

**k. Larval requirements.**

a. **Food.** No data on the diet of larval Junaluska salamanders have been reported. The most commonly encountered macroinvertebrates in the streams where larvae are abundant are stonefly and caddisfly larvae. In the laboratory, we have observed that larvae feed readily on white water worms (*Enchytraeus sp.*).

b. **Cover.** The ideal cover objects for Junaluska salamander larvae are large flat-bottomed rocks that come in close contact with the stream substrate. Most frequently these rocks are located in regions of relatively large (i.e., higher-order) streams where there is moderate water flow and low sedimentation. We also often find larvae in quiet pools on the margins of streams. Larvae are located by carefully displacing rocks. Less frequently, we have collected larvae in riffle areas of streams. In November, when the bulk of a stream's allochthonous input has been received, we have collected larvae using dipnets and searching through the leaf mats.

ii. **Larval polymorphisms.** Unknown.

iv. **Features of metamorphosis.** Based on the few field studies, it appears that metamorphosis is more or less synchronous within a population, occurring mostly in May–August, corresponding roughly to the time of hatching of a new cohort (Bruce, 1982b; Ryan, 1998a). The length of time to complete metamorphosis once it has been initiated (e.g., once gill resorption has begun) has not been studied rigorously, but Bruce (1982b) showed that while metamorphic individuals were common (approximately 1 in 4) during a July collection, none were found in the preceding (May) or following (September) collections.

v. **Post-metamorphic migrations.** Just as there appears to be no marked breeding migration, neither is there a record of recently metamorphosed juvenile migrations.

vi. **Neoteny.** Paedomorphosis is not known in Junaluska salamanders.

**d. Juvenile Habitat.** Ryan (1998b) reported that juvenile Junaluska salamanders are poorly recorded in the literature. The minimum size of adult Junaluska salamanders is not appreciably different from the size of metamorphic larvae; thus, the transition from juvenile to adult is likely minor, with the two classes overlapping to a wide degree. Unfortunately, little is known regarding the habitat characteristics of adults, as well see below.

**e. Adult Habitat.** Little is known regarding the habitats of adults. Most adults have been collected on roads near creeks during warm, rainy nights (Sever, 1984) or on streambanks and in streams during early spring (Bruce, 1982b; Sever, 1983a, 1984; Ryan, 1998a). Most likely, adult Junaluska salamanders have seasonal activity patterns similar to Blue Ridge two-lined salamanders. In colder months, adults are most commonly found within streams, as this habitat is more thermally stable than the surrounding terrestrial habitat; in warmer months, adults are found predominantly in the forests surrounding the streams. Within the streams, adults have been collected within the same habitat as larvae, that is, beneath large flat rocks in regions of shallow water and moderate stream flow.

**f. Home Range Size.** Unknown.

**g. Territories.** Unknown.

**h. Aestivation/Avoiding Desiccation.** Aestivating behavior is unknown.

**i. Seasonal Migrations.** See “Breeding migrations” above.

**j. Torpor (Hibernation).** Unknown.

**k. Interspecific Associations/Exclusions.** The range of Junaluska salamanders is sympatric with that of Blue Ridge two-lined salamanders, with the latter being far more common. Nonetheless, the two species are frequently syntopic, with larval Junaluska salamanders; thus, the transition appreciably different from the size of adult Junaluska salamanders is not. Unfortunately, little is known regarding the habitat characteristics of adults, as well see below.

**l. Age/Size at Reproductive Maturity.** The age at first reproduction is unknown (Ryan and Bruce, 2000). The smallest mature female recorded in the literature (37 mm SVL; Sever, 1983a) falls well within the size range of metamorphic larvae (34–44 mm SVL; Ryan and Bruce, 2000), leading us to speculate that reproduction likely shortly follows metamorphosis. Thus, if most individuals metamorphose in their third summer, they likely breed initially at the end of the third year. The average size of females is approximately 43 mm SVL (Sever, 1983a) with maximum sizes of 47 and 49 mm SVL for females and males, respectively (Sever, 1983b).

**m. Longevity.** We are unaware of any reliable information regarding the age of Junaluska salamanders.

**n. Feeding Behavior.** Both the diet and feeding behavior of metamorphosed larval Junaluska salamanders are unknown. We speculate that they feed on a wide variety of invertebrates, as with other members of the *E. bislineata* complex (e.g., Burton, 1976).

**o. Predators.** There are no reports of predation specifically on larval Junaluska salamanders. They likely face threats similar to those experienced by other members of the *E. bislineata* complex: fish, birds, small mammals, snakes, and other salamanders (Petranka, 1998).

**p. Anti-Predator Mechanisms.** Unknown.

**q. Diseases.** We are not aware of any reports of diseases of larval Junaluska salamanders. However, Ryan (1998b) described scoliosis (lateral spinal malformations) in two larvae from the Cheoah River. The cause of the condition is unknown and could be due to either exogenous (e.g., disease or parasites) or endogenous (e.g., genetic) causes.

**r. Parasites.** See “Diseases” above.

**4. Conservation.** Tennessee populations of Junaluska salamanders appear stable. In North Carolina, however, they were rare to begin with and remain so. For example, they have not been collected at Snowbird Creek since late in 1994, and recent collecting efforts at the type locality on the Cheoah River have been in vain. This population is feared to be extirpated, due to anthropogenic activities upstream. In North Carolina, Junaluska salamanders are listed as a Species of Special Concern and has been proposed for Threatened status.

**Eurycea latitans** Smith and Potter, 1946

**CASCADe CAVERNs SALAMANDER**

Paul T. Chippindale

1. **Historical versus Current Distribution.** Cascade Caverns salamanders (*Eurycea latitans*) were first described by Smith and Potter (1946) from Cascade Caverns, Kendall County, Texas. Brown (B.C., 1967a) provided a review of what was known about this species at that time. Sweet (1978a, 1978b) demonstrated that this population includes individuals with a