

Growth Rates and Post-Release Survival of Captive Neonate Timber Rattlesnakes, *Crotalus horridus*

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The need for conservation and management of rare species is becoming increasingly important as wildlife species and their habitat continue to decline. Translocation of wild captured adults to augment and reintroduce populations has been successfully used for some endangered avian species (see Carrie et al. 1999; Rudolph et al. 1992). In general, success rates for mammals and birds are higher than those for amphibians and reptiles (Dodd and Seigel 1991; Griffith et al. 1989).

The Timber Rattlesnake (*Crotalus horridus*) is listed as a State of Texas threatened species and translocation of captive raised snakes might benefit small populations. Controversy exists on the benefits versus problems associated with translocation of amphibians and reptiles (Burke 1991; Dodd and Seigel 1991; Reinert 1991). A recent evaluation of the impacts of translocation on behavior and survival of mature *C. horridus* suggests that translocation of adult snakes not be recommended as a standard management technique because of immediate aberrant movement behavior patterns and long-term elevated rates of overwinter mortality, predation, and disease (Reinert and Rupert 1999).

Because of the problems associated with translocation of adult *C. horridus*, the ability to successfully raise neonate rattlesnakes and successfully introduce them into forest habitat may be an essential conservation technique if viable populations of this rare species are to be maintained in the wild. If captive-raised neonates can be grown to sufficient size, predation-related and overwinter mortality events suffered by neonates and first-year juveniles might be minimized, increasing the net survival rates of cohorts released to the wild.

We captive raised one neonate *C. horridus* in 1993–1994 and eight in 1994–1995, recording detailed growth data on the eight snakes over an 11-month period. The nine snakes were released with surgically implanted transmitters in eastern Texas and we monitored their movements for six years. We determined their survival rates in the wild to evaluate the possible merit of using captive-raised neonates to augment small, isolated populations.

Materials and Methods.—Locations of released *Crotalus horridus* with transmitters were monitored in the Stephen F. Austin Experimental Forest, southern Nacogdoches County (31°29'N,

94°47'W), in eastern Texas. Bottomland hardwood forest comprises 728 ha of this 103%ha experimental forest and pine uplands the remaining 310 ha. Approximately 670 ha of the bottomland hardwood forest are in the Angelina River flood plain. Minimal timber harvesting has occurred on this forest and canopy trees in both the bottoms and uplands are 70+ years old.

On 30 August 1994 eight neonate *C. horridus* (6 females and 2 males) were obtained from the brood of a telemetered adult female from the Loco Bayou Hunt Club 8 km west of the experimental forest. The neonates were obtained prior to their first ecdysis as they crawled around the entrance to a nine-banded armadillo (*Dasypus novemcinctus*) burrow. The eight neonate rattlesnakes were individually housed in 27 x 29 x 56 cm herpetological cages with clear Lucite sliding fronts, an electric heating pad under the cage, and a rock to assist shedding. Water in a petri dish was always present. Between 31 August 1994 and 17 July 1995 live mice (*Mus musculus*) were offered weekly to the rattlesnakes in an attempt to maximize their growth. From a management perspective, our objective was to get the neonates to a near-adult size as quickly as possible to enhance their probability of survival when released in the wild. During the first two months mice < 18 g were offered to the neonates; thereafter, a range of mice between 10 and 35 g were offered and taken by the snakes. Mice and rattlesnakes were weighed prior to feeding and the weight of each mouse killed and consumed by each snake was recorded. Snake mass, snout-vent length (SVL), and total length were measured initially and then monthly over the next 10 months (last measurement 17 July 1995).

On 17 July 1995 four *Crotalus horridus* (three females and one male) were selected for subcutaneous implantation of a 10.3 g Holohil® SI-2T radiotelemetry transmitter using the technique of Weatherhead and Anderka (1984) and, following at least a one week recovery period, were released together in bottomland hardwood forest on the Stephen F. Austin Experimental Forest on 4 August 1995. The remaining male and three females received a subcutaneous transmitter on 27 February 1996 and were released together at the same location as the initial four snakes on the experimental forest on 13 March 1996. Earlier, an additional female neonate (which weighed 35 g upon capture on 16 September 1993 near Bingham Lake, Tyler County, Texas, on the Forest Lake Experimental Forest and was captive-raised to a weight of 246.7 g) received a transmitter on 5 March 1994 and was released in the experimental forest on 21 March 1994 at a point 100 m ENE of the location where the other eight neonates were released. During periods when snakes were not in hibernacula they were radio-tracked and relocated approximately weekly using a Telonics receiver (TR-2, ISO-152 MHz) with a two-element Yagi directional antenna.

Locations of all released snakes were determined weekly until they settled in hibernacula in late November. Weekly relocation commenced again in March when rattlesnakes emerged from hibernacula. Thus, post-release movements of nine captive-raised rattlesnakes were monitored from mid-March to late November over a period between four and six years. Mortality of released rattlesnakes was assumed if bones and a transmitter were found together. Dead snakes with transmitters recovered on or immediately next to a road with obvious injuries were assumed to be road mortalities.

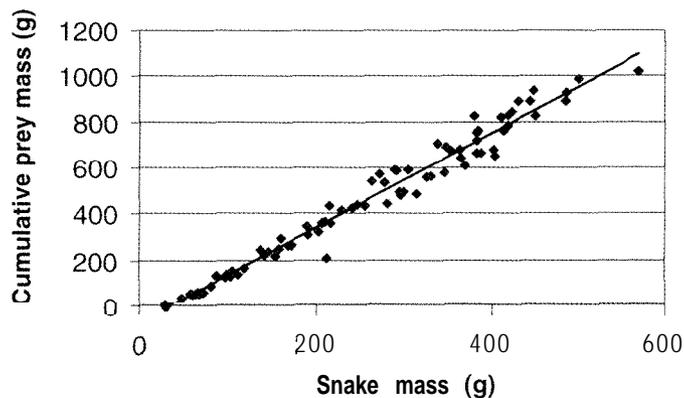


FIG. 1. Cumulative prey mass consumed by eight captive-raised neonate *Crotalus horridus* from eastern Texas versus snake mass as neonates grew (monthly measurements) over a 10-month period. The line within plotted points reflects a regression trend line ($Y = 2.0416X - 66.515$, $R^2 = 0.98$).

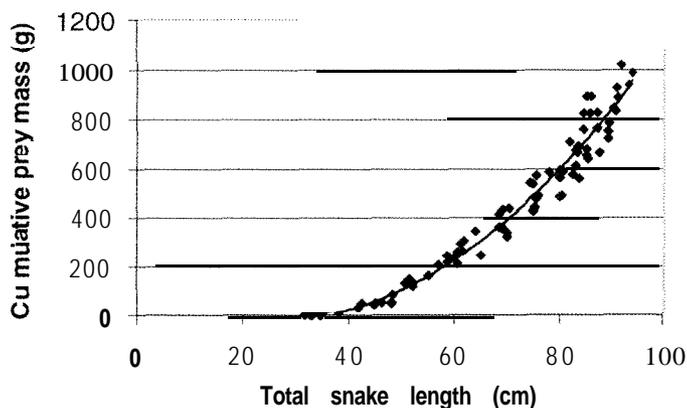


FIG. 2. Cumulative prey mass consumed by eight captive-raised neonate *Crotalus horridus* from eastern Texas versus total snake length as neonates grew (monthly measurements) over a 10-month period. The line within plotted points reflects a second-order polynomial trend line ($Y = 0.0021X^2 + 1.1265X + 142.04$, $R^2 = 0.97$).

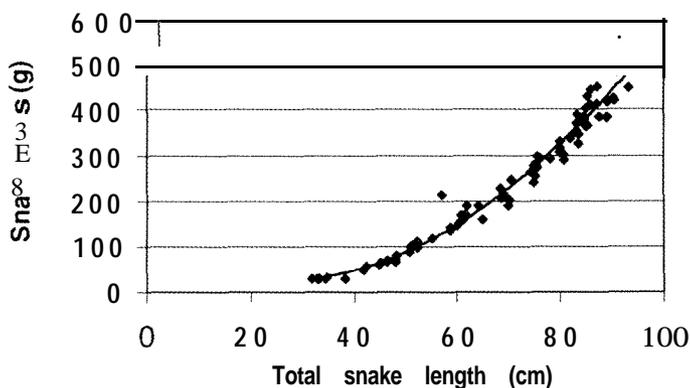


FIG. 3. Mass versus total length of eight captive-raised neonate *Crotalus horridus* from eastern Texas as neonates grew (monthly measurements) over a 10-month period. The line within plotted points reflects a second-order polynomial trend line ($Y = 0.0957X^2 + 4.5229X + 75.063$, $R^2 = 0.97$).

TABLE 1. Post-release survival of ad-lib fed neonate *Crotalus horridus* in eastern Texas. Minimum surviving rattlesnakes were those remaining in the experimental forest study area with functional transmitters. Maximum surviving includes minimum surviving plus those rattlesnakes of unknown status that dispersed from the study area or experienced transmitter failure. M = male, F = female.

Post release survival (y)	Minimum surviving		Maximum surviving	
	No. (M/F)	%	No. (M/F)	%
0	9 (7/2)	100.0	9 (7/2)	100.0
1	8 (6/2)	88.9	8 (6/2)	88.9
2	4 (3/1)	44.4	7 (5/1)	77.7
3	4 (3/1)	44.4	7 (5/1)	77.7
4	3 (2/1)	33.3	7 (5/1)	77.7
5	3 (2/1)	33.3	6 (5/1)	66.6
6	2 (1/1)	22.2	5 (4/1)	55.6

We used the program CALHOME (Kie 1994) to calculate annual minimum convex polygon (Mohr 1947) activity ranges and annual maximum distance between relocation points for nine released rattlesnakes during the first full tracking year after release, the second full tracking year after release, and all tracking years after the first full year of release.

Results and Discussion.—Captive, neonate *Crotalus horridus* initially averaged (mean \pm SD) 28.7 \pm 0.74 g, SVL 30.9 \pm 0.97 cm, and total length 33.2 \pm 0.98 cm. During the year of captivity the neonates consumed an average of 873.5 \pm 113.5 g of prey mass (mice) per snake and attained an average mass of 461.8 \pm 54.8 g, SVL of 81.7 \pm 3.1 cm, and total length of 88.3 \pm 3.4 cm (Figs. 1, 2). On average, for every 1 .0 g of prey mass consumed the snakes increased their body mass by 0.48 g and their total length by 0.063 cm (Fig. 3). Following their first post parturition shed, the captive-raised neonates shed four times prior to release. Ecdysis occurred approximately every time the snakes doubled their body mass.

Eight of the nine captive-raised neonates released in the wild with surgically implanted radio transmitters survived at least one full year after their release (Table 1). A female released March 1996 survived 4 months and a male released August 1995 survived 12 months in the wild, but both were killed in road-related mortality. A female released March 1996 died or lost her transmitter (unknown cause-transmitter found in hibernaculum) two years post-release. The status of three snakes is unknown because of dispersal from our study area or transmitter failure at one, two, and three years post-release, respectively. We strongly suspect that these snakes moved out of our study area because the weekly movement of these three snakes suggested that they were shifting the center of their activity toward the west on private lands. Three of nine captive-raised neonates were known to be alive and had entered the breeding population five years post-release (Table 1). These three snakes (a female released March 1994, a female released August 1995, and a male released March 1996) were observed copulating or participating in precopulatory behavior with wild conspecifics. Although sample size is too small to detect a statistical relationship, neither month of release (March versus August) nor sex appeared to be related to death, dispersal, or survival.

During the first full tracking year after release our captive-raised rattlesnakes averaged (mean \pm SD) an annual minimum convex polygon activity range of 12.10 \pm 9.61 ha and a maximum distance between relocation points of 0.97 \pm 0.69 km. During the second full tracking year after release the activity range was 22.01 \pm 29.95 ha and maximum distance between relocation points 0.82 \pm 0.06 km suggesting that activity area increased but maximum movement distance decreased slightly. For rattlesnakes that remained alive after the second full tracking year, activity area averaged 7.26 \pm 4.96 ha and maximum distance between points 0.51 \pm 0.16 km for all subsequent years.

Captive-raised neonate *Crotalus horridus* gained 0.48 \pm 0.04 g of body mass for every 1 .0 g of prey consumed. Jauch (1993) observed a higher (0.58 g) mass gain per 1.0 g prey in captive-born Puff Adders (*Bitis arietans*) that were offered mice every 2-3 weeks. However, our captive-raised *C. horridus* gained 0.063 \pm 0.012 cm in total length for every 1 .0 g of prey consumed, whereas Jacobsen (1986), who provided white mice and later white rats every 1-3 weeks, measured only 0.018 cm gain in total length per 1 .0 g prey consumed in captive *B. arietans*. Similar to our observations with *C. horridus*, ecdysis occurred in *B. arietans* approximately every time they doubled their body mass (Jauch 1993).

Our captive-raised neonate *C. horridus* attained an average total length of nearly 90 cm prior to release in the wild. Although inexperienced in the wild, the size of these snakes after one year of *ad libitum* food in captivity would likely offset some of the predation-related mortality incurred typically by neonates during their first year. Several years would be required for wild-raised neonates to attain this size, and during these years predation rates would probably be high.

The known survival and incorporation of three (33%) of nine captive-raised neonate *C. horridus* (Table 1) into the breeding population five years post-release indicates at least some potential value of the technique to augment small populations or possibly repopulate areas where extirpation has occurred, especially if neonates were obtained through a captive breeding program. The actual survival of the captive-raised neonates may exceed 33% because the status of three additional snakes was unknown either because of long distance dispersal or transmitter failure. Some of these snakes may have moved off the study site to neighboring properties where we could no longer monitor their movements. The road mortality (two cases in which individuals were killed on blacktop roads adjacent to the experimental forest) and death in hibernaculum (one case) likely reflect what would occur in wild snakes in similar habitat (Rudolph et al. 1998). However, it is likely that unfamiliarity with habitat accounted for some of the mortality and unknown losses of snakes that we observed because the relocated snakes spent more time than typical looking for acceptable habitat, which increased the probability of predation. Charland (1989) reported a 45% overwinter mortality rate of neonate Western Rattlesnakes (*Crotalus viridis*) during their first six to eight months. Timber Rattlesnakes in eastern Texas did not seem to overwinter in communal dens, but instead typically went down a stump hole or an armadillo burrow when temperatures approached freezing. Although winters in eastern Texas are shorter in duration and milder than winters in more northern latitudes, temperatures often reach -8°C and can go as low as -18°C (Chang et al. 1996). Our captive-raised neonates avoided possibly high first-winter mor-

tality and were artificially given a boost to body mass and length well beyond what would occur in wild snakes.

Reinert and Rupert (1999) reported that 6 of 11 (54.3%) wild-captured, mature *Crotalus horridus* experienced mortality over an approximate two-year period. Three of these snakes experienced overwinter mortality, predators killed two, and one died from disease. At least 44.4% and possibly 77.7% of our neonates survived two years post-release (Table I). The actual survival rate for our captive-raised neonates probably does not differ much from what Reinert and Rupert (1999) observed with mature rattlesnakes.

Translocated adults also exhibited higher activity and larger activity range areas than resident adult *C. horridus* (Reinert and Rupert 1999). Based on these results, they concluded that the translocation of wild-raised mature rattlesnakes to bolster diminished local populations should not be recommended as a standard conservation practice. The maximum activity ranges of our captive-raised neonates was less than 4% of the activity area observed by Reinert and Rupert (1999) for translocated adult snakes, and about 33% of the area observed for resident adults. Although our released rattlesnakes were not mature, their activity range areas did not seem to be excessive.

We do not disagree with the conclusions of Reinert and Rupert (1999) relative to the translocation of mature *Crotalus horridus*, but suggest that translocation of captive-raised neonates may be a feasible conservation technique to bolster diminished populations, particularly if captive breeding is the source of the translocated snakes.

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