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NATURAL HISTORY OF THE MASSASAUGA, *SISTRURUS CATENATUS EDWARDSII,* IN SOUTHEASTERN COLORADO

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ABSTRACT—Studies of natural history are important for determining baseline information, particularly for species that might be threatened or endangered. We collected 254 (141M:94F:19UNK) massasauga, *Sistrurus catenatus edwardsii,* from May 1995 through October 1996. The average snout-vent length (SVL ± *SD*) for adult males (355 ± 45 mm) was not significantly different than the SVL of adult females (364 ± 24 mm). Habitat descriptions indicate that the massasauga in Colorado is a semi-arid grassland species that utilizes areas of relatively open shortgrass prairie. Massasaugas were active between 14 and 30°C, with an average ambient temperature during activity of 22.1 ± 2.5°C. The time of observed activity shifted through the season, with primarily diurnal activity during the cooler months (April and late September to October) and primarily early evening activity during the hotter months (May through August). Massasaugas in Colorado gave birth to litters of 5 to 7 young between late August and late September, and reproduction appeared to be biennial. Populations of *S. c. edwardsii* in Colorado are scattered but population size appeared to be relatively large based on number of captures and low recapture rates, particularly in Lincoln County. However, due to habitat loss and fragmentation resulting from agricultural expansion, these populations might become increasingly threatened in the future.

RESUMEN—Estudios de historia natural son importantes para determinar información básica, particularmente para especies que pueden estar amenazadas o en peligro de extinción. Colectamos 254 (141 machos:94 hembras:19 desconocidos) de massasauga del desierto, *Sistrurus catenatus edwardsii,* entre mayo de 1995 y octubre de 1996. El promedio de longitud hocico-cloaca (LHC) para machos adultos (355 ± 45 mm) no fue significativamente diferente al de las hembras (364 ± 24 mm). Las descripciones del hábitat indican que la massasauga en Colorado es una especie de pastizales semiáridos que habita áreas de praderas de pasto corto relativamente abiertas. Massasaugas estuvieron activas entre 14 y 30°C, con un promedio de temperatura ambiente durante la actividad de 22.1 ± 2.5°C. La época de la actividad observada cambió con la estación del año, con actividad diurna durante los meses más frescos (abril y finales de septiembre a octubre) y con actividad crepuscular durante los meses más calientes (mayo a agosto). Massasaugas en Colorado dieron a luz a camadas de 5 a 7 crías entre fines de agosto y fines de septiembre, y la reproducción pareció ser bianual. Las poblaciones de *S. c. edwardsii* en Colorado están dispersas pero el tamaño poblacional pareció ser relativamente grande basado en el número de capturas y las tasas bajas de recaptura, especialmente en el condado de Lincoln. Sin embargo, debido a la fragmentación y la pérdida de hábitat resultado de la expansión agrícola, estas poblaciones pueden ser amenazadas en el futuro.

The massasauga, *Sistrurus catenatus,* is a small rattlesnake broadly distributed across North American prairies from Ontario, Canada and New York to extreme southeastern Arizona, with an apparently disjunct population in northern Chihuahua, Mexico (Stebbins, 1985). It is listed as endangered or threatened across much of its range by several state and provincial agencies based largely on distribution and natural history reports and numerous surveys of historic populations funded by state agencies (Reinert, 1978; Seigel, 1986; Allen, 1988; Weatherhead and Prior, 1992). Distribution and life history studies conducted in eastern and central portions of the range of the massasauaga supplied critical information about

population status and viability. The Colorado Division of Wildlife (CDOW) currently lists the massasauga as a species of special concern, which indicates that the status of *S. catenatus* in Colorado is uncertain, but populations are likely declining due to habitat loss and human encroachment.

In Colorado, there is a paucity of data pertaining to the biology and ecology of *S. catenatus* (Hammerson, 1999). Data concerning massasauga in Colorado are limited to diet (Smith et al., 1965; Holycross and Mackessy, 2002), distribution (Hammerson et al., 1991; Pegler et al., 1995; Mackessy et al., 1996; Hobert et al., 1997; Montgomery et al., 1998), taxonomy (Maslin, 1965; Hobert, 1997), and reproduction (Goldberg and Holycross, 1999). Many of these studies originated from or included specimens from the survey summarized here. Recent morphological analysis indicated that *S. catenatus* in Colorado is the desert subspecies, *S. c. edwardsii* (Hobert, 1997), rather than an intergrade between the western and desert subspecies, *S. c. tergeminus* and *S. c. edwardsii,* respectively, as reported by Maslin (1965). Geographically, Colorado populations of massasauga apparently are disjunct from neighboring races but are west of an area in Kansas inhabited by an assumed intergrade form of the western and desert subspecies (Maslin, 1965; Conant and Collins, 1991).

Additional information on the biology and ecology of the massasauga was necessary to provide baseline information to ensure adequate protection of *S. catenatus* in Colorado. Specifically data on basic demographic parameters, such as habitat, life history characteristics, and distribution are lacking. Objectives of this study were to determine distribution and population parameters of *S. catenatus edwardsii* and to evaluate habitat characteristics in areas of known occurrence in southeastern Colorado.

METHODS—*Study Site*—A survey for massasauga was conducted in 12 southeastern Colorado counties, consisting broadly of the area south of Interstate Highway 70 and east of Interstate Highway 25. The most common natural vegetation type in southeastern Colorado is shortgrass prairie, interspersed with sandsage (*Artemesia filifolia*) prairie and piñon-juniper (*Pinus edulis-Juniperus*) woodland (Weber, 1976). We concentrated survey efforts within and immediately around the boundaries of the historic range of *S. catenatus* (Hammerson, 1986). All localities visited during this survey are summarized in Hammerson (1999).

Data Collection—Snakes were located by driving roads or by searching suitable habitat on foot. Surveys were conducted from 15 July 1994 through 18 October 1996 during the reported active season each year. Data collected at time of capture included location, time, temperature (30 cm above ground in the shade), and habitat type. National Oceanic and Atmospheric Administration reports from the nearest weather station were summarized to determine daily temperature ranges and precipitation levels. Additional data, including weight, snout-vent length (SVL), tail length (TL), sex, and age class (young of the year [YOY], juvenile, adult) were collected from live animals at the University of Northern Colorado animal facility. Weight was measured to the nearest 0.1 g. Length measurements (±0.5 cm) were made by extending the snake next to a meter-stick. Snakes were classified as adult based on minimum size of reproduction of 280 mm SVL in males and 329 mm SVL in females (Goldberg and Holycross, 1999). Snakes were classified as YOY if they were found in the fall with only the first rattle segment (button). Live snakes were individually marked using a PIT-tag (passive integrated transponder) (Avid Identification Systems, Inc., Norco, California) (Camper and Dixon, 1986).

Data collected on road-killed specimens (DOR) included location, habitat type, SVL, TL, and sex. All DOR specimens were preserved and entered in the University of Northern Colorado Museum of Natural History (UNC-MNH) herpetology collection.

Habitat Description—A modified version of the line intercept method (Cox, 1996) was used to sample areal vegetation at capture sites of *S. c. edwardsii*. The number of transects in each capture area was based on the relative number of encountered rattlesnakes. Transect lines were 30 m long and vegetation was recorded at 0.33-m intervals. Vegetation along the transect line was recorded as grass, forb, shrub, or cactus. If a living plant was not touching the line, the point was classified as rock, bare ground, or litter. For road encounters, line transects were conducted perpendicular to the road beginning at a distance of approximately 3 m from the edge of the road to avoid the highly disturbed roadside ditches. For visual encounters, the midpoint of the transect was placed at the exact location of the snake and the transect direction was randomized.

Data Analysis—To analyze sexual size dimorphism in body size, we used analysis of variance (ANOVA). To analyze sexual dimorphism in the relationship between TL and SVL, we log10 transformed both variables to linearize them and used ANOVA to test the assumption of homogeneous slopes. Because of heterogeneous slopes, we presented the regression

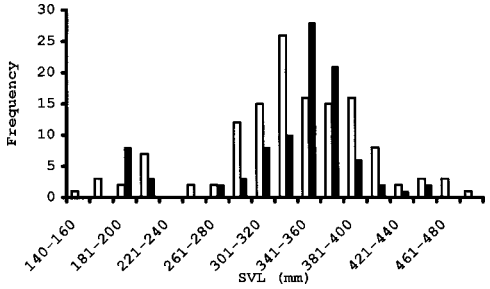

FIG. 1—Frequency distribution of snout-vent length (SVL) of male (open) and female (solid) *Sistrurus catenatus edwardsii* in southeastern Colorado.

equations of LogTL on LogSVL for both sexes. All statistics were performed using Jump 4.0 (SAS Institute, Cary, North Carolina).

RESULTS AND DISCUSSION—*Body Size and Stage Class*—We captured or recovered 254 *S. c. edwardsii* (141M:94F:19UNK) over the course of this study. Of the 141 males found, 80 were alive and 61 were dead; for females, 75 were alive and 19 were dead. We were unable to determine sex for 19 dead snakes. Of the 254 snakes recovered, 199 were adults (126M:69F:4UNK) and 55 were juveniles and YOY (15M:25F:15UNK). The average SVL ($\pm$ *SD*) of adult males (355 $\pm$ 45 mm) was not significantly different than the average SVL of adult females (364 $\pm$ 24 mm) (ANOVA, F ratio = 2.5480, $df = 1$, $P = 0.1122$) (Fig. 1). However, this is not a direct test of sexual size dimorphism because specific age structure of the population was unknown. Average adult total body length for the massasauga in Colorado was smaller than reported for *S. c. tergeminus* (457 to 660 mm) and *S. c. catenatus* (472 to 760 mm) (Ernst, 1992) but was consistent with reports for male (368 $\pm$ 60.1 mm) and female (380 $\pm$ 36.5 mm) *S. c. edwardsii* in Arizona (Goldberg and Holycross, 1999). There was no difference in average SVL between adult male and adult female in a Missouri population of *S. c. tergeminus* (Seigel, 1986) or in *S. miliarus barbouri* in northern Florida (Bishop et al., 1996). However, sexual dimorphism in body size has been reported in other crotaline snakes (Shine, 1994).

Because of a significant interaction effect (Sex*LogSVL; ANOVA, F ratio = 11.7092, $df = 1$, $P < 0.001$), the relationship between LogTL and LogSVL was dependent on sex, with males having increasingly longer tails with increasing size than females. The regression line for males was LogTL = $-1.080954 + 1.0669459$LogSVL (ANOVA, F ratio = 434.67, $n = 117$, $P < 0.0001$) and for females was LogTL = $-0.388615 + 0.743036$LogSVL (ANOVA, F ratio = 95.2216, $n = 83$, $P < 0.0001$). The same pattern of sexual dimorphism in tail length was reported for *S. c. edwardsii* in Arizona (Holycross and Douglas, 1996).

Habitat Description—Most snakes were found in Lincoln County (208), followed by Kiowa (24), Cheyenne (10), and Crowley (8) counties, with only 1 snake each found in Bent, El Paso, Prowers, and Otero counties. Areas with greatest perceived abundance were public and private lands with intact native habitat and limited grazing by cattle. Results of 49 transects performed on 9 and 10 July 1996 at snake capture sites indicated grass (57.0% $\pm$ 12.5 *SD*), litter (21.6% $\pm$ 11.9 *SD*), and bare ground (16.6% $\pm$ 9.9 *SD*) were the 3 most common types of areal cover. Forb, shrub, and rock constituted less than 4% of areal coverage at snake capture sites.

Massasaugas seemed to be locally abundant at several localities within the range based on total captures, with smaller populations occurring in the 6 most southeastern counties. Massasauga in Colorado is a semi-arid grassland species, with greater numbers of individuals captured in areas of relatively open shortgrass prairie with grasses and sand sagebrush. According to Hammerson (1986, 1999), massasaugas in Colorado inhabit a variety of habitats in the Arkansas River drainage, ranging from arid, open sagebrush prairie to shortgrass prairie below 5,500 feet. Open shortgrass prairie habitat utilized by *S. c. edwardsii* in Colorado was structurally similar to the clumped tobosa (*Hilaria mutica*) grasslands utilized by *S. c. edwardsii* in southeastern Arizona (Holycross and Douglas, 1996). Native habitats are becoming increasingly fragmented, which might result in isolation of small populations of *S. c. edwardsii*. Satellite data suggest significant habitat destruction (agriculture) has occurred along the eastern edge of the distributional limit of massasauga in Colorado (Hammerson, 1999). It remains unknown if the apparent range disjunction between the Colorado populations and those in Kansas and Oklahoma is due to more recent human disturbance or to long-term

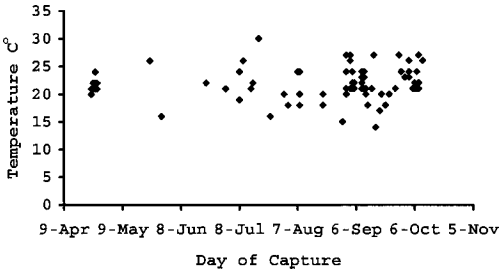

FIG. 2—Relationship of ambient temperature at time of capture and capture date of *Sistrurus catenatus edwardsii* in southeastern Colorado. Ambient temperature of activity remained relatively constant (22.1 ± 2.5°C) across the activity season.

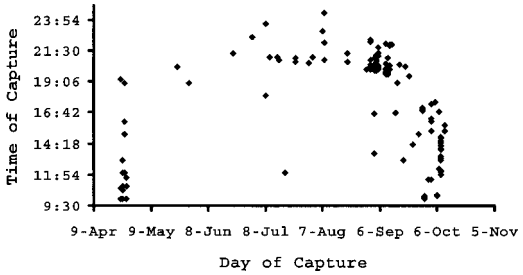

FIG. 3—Relationship of time of capture and capture date of *Sistrurus catenatus edwardsii* in southeastern Colorado. Snakes became increasingly nocturnal during warmer summer months.

range contraction. The Mesa de Maya and Raton Mesa regions in southeastern Colorado seem to represent a physical barrier between massasauga in Colorado and New Mexico.

Activity Patterns—We observed massasaugas as early as 13 April (1996) and as late as 15 October (1995). Because these snakes were observed on roads, it can be assumed that the active season was longer, because snakes need to move to and from suitable hibernacula. Snakes were found most commonly in April (38), September (106), and October (53) and were less commonly encountered from May through August. Increased capture success at the beginning and end of the active season probably was due to seasonal migrations to and from hibernation areas in several localities. Along a road at 1 site, all massasauga observed were moving from west to east in April (29 individuals) and from east to west in the September and October (85 individuals). In this area, habitat to the west was shortgrass prairie associated with loamy soil, while to the east the habitat was sandsage prairie associated with loose sandy soil. Radio-tagged massasauga spent the entire active season in sandsage prairie and hibernated in the shortgrass prairie habitat (Manzer and Mackessy, unpubl. data). Occurrence of an abundant prey base (harvest mice, *Reithrodontomys megalotis*) to the east and appropriate hibernacula to the west (Manzer and Mackessy, unpubl. data) might be a factor in this migration. A similar migration pattern from hibernacula to activity areas in the spring and back to hibernacula in fall has been shown for the western massasauga, *S. c. tergeminus* (Siegel, 1986), and the eastern massasauga, *S. c. catenatus* (Johnson, 2000).

Based on 157 records of temperature data at capture, massasaugas were active between 14 and 30°C, with an average ambient temperature of activity of 22.1°C (±2.5°C). Temperature when snakes were captured was relatively consistent throughout the season (Fig. 2). The time of observed activity shifted through the season (Fig. 3), with primarily diurnal activity during cooler periods (April and late September to October) and primarily evening and early night activity during warmer periods (May through mid September; National Oceanic and Atmospheric Administration, 1994, 1995, 1996, 1997). In Arizona, massasaugas were described as a nocturnal species (Lowe et al., 1986).

Growth—Eight of the 143 (5M:3F) PIT-tagged rattlesnakes were recaptured (5.6%). Recapture rates in our study were too low to analyze growth or population size. However, 1 adult male snake captured on 24 April and recaptured on 21 September grew 56.0 mm (from 320 to 376 mm) and 27 g (24.2 to 51.2 g), which represented an increase in SVL of 117% and in body mass of 112% in 149 days. Using drift fences and road cruising, the recapture rate for *S. c. edwardsii* in Arizona (Holycross and Douglas, 1996) was much higher (18%) than recapture rates in our study.

Reproduction—We collected 1 DOR adult female on 30 May 1996 that measured 380 mm SVL and contained 5 vascularized ova. A total of 23 YOY collected in the field averaged 191.4 mm (±16.0 *SD*) SVL. The earliest YOY was observed on 3 September (1994) and the latest YOY was observed on 15 October (1995). Ob-

servation of YOY during this period indicated massasaugas in Colorado probably birth between late August and late September, consistent with reports for Arizona and Colorado snakes (Goldberg and Holycross, 1999). One gravid female collected on 24 July and held in captivity until birth showed a weight loss of 26% (from 54.0 to 39.9 g) after parturition. The female gave birth on 24 August to 7 young that averaged 148 mm SVL and 3.46 g. Average SVL of YOY in Colorado from our study seem to be larger than the SVL for Arizona YOY (Goldberg and Holycross, 1999). Because birth date is unknown for all YOY in both studies, actual size at birth is unknown.

Information presented here on the massasauga represents the first examination of the natural history of the species in Colorado. Baseline data on all aspects of natural history of threatened species is a necessary step for future conservation. At the time of this survey, some populations of *S. c. edwardsii* in Colorado appeared to be relatively large, based on numbers of individuals captured. However, due to habitat fragmentation and loss from increasing agricultural use, these populations will become ever more threatened in the future. Additional information through continued monitoring is needed to understand the distribution, population sizes, and contiguousness of populations in southeastern Colorado to make sound conservation decisions. Currently state and federally owned land, as well as privately owned native grassland, offers habitat strongholds for the massasauga in Colorado.

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