SUZANNE L. COLLINS, CNAH

Increasing development in northeastern Kansas poses a distinct threat to Timber Rattlesnakes (*Crotalus horridus*) along much of the western limits of the species' distribution.

Successful Relocation of a Threatened Suburban Population of Timber Rattlesnakes (*Crotalus horridus*): Combining Snake Ecology, Politics, and Education

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Crotalus horridus has a geographic range covering somewhat more than the eastern third of the continental United States (Brown 1992, 1993; Martin 1992; Pisani et al. 1972), within which its distribution is patchy (Clark et al. 2007). This extensive area includes diverse climatic extremes to which the species has adapted successfully (Brown 1993; Martin 1992, 2002; Fitch and Pisani 2004, 2006a, 2006b). Of the several U.S. species in the genus *Crotalus*, *C. horridus* has among the most, if not the most, interactions with humans, primarily because it occurs near population centers in some of the most densely-populated areas of the country. Thus, in addition to depredation by humans hunting the snakes for bounty or commercial collection (Brown 1993, LeClere 2005), increasing development of rural areas has an impact on aggregation (den and birthing) sites as well as summer feeding-breeding ranges. This situation is not, of course, limited to *C. horridus* (Reinert and Rupert 1999, Ernst 2004; see also the introduction in Nowak et al. 2002) or, in fact, even to crotalids (Butler et al. 2005a, 2005b).

In the last two decades, increasing public education efforts by scientists conducting research on *C. horridus* and other members of the genus (Ernst 2004), along with an increasing ecological awareness by the general public, has resulted in an attitude shift (however slight) toward increasing tolerance of the species' frequent occurrence alongside human activities (Brown 1993). Nonetheless, increasing development (especially in northeastern Kansas, which generally lacks the physiographic barriers to development found


ROD WITTENBERG

A large adult male Timber Rattlesnake (*Crotalus horridus*). The red paint on the basal rattle allows for individual recognition without handling the animal.


ROD WITTENBERG

Like other species of snakes inhabiting areas experiencing human encroachment, Timber Rattlesnakes crossing roads or thermoregulating on warm pavement are vulnerable to vehicular traffic.

Although Timber Rattlensnakes usually are considered to be terrestrial species, arboreal behavior is not uncommon.

in many eastern states) poses a distinct threat to this species along much of the western limits of its distribution (Fitch 1999, Pisani and Fitch 2005, Edwards and Spiering 2005), which remains little-known in this part of its range despite 56 years of earlier snake research in the area (Fitch 1999). The species is classed as SINC (Species in Need of Conservation) by the Kansas Department of Wildlife and Parks; however, that listing, used in other states as well (e.g., Adams 2005), carries no legal protections for the species or its habitat.

Timber Rattlesnakes are highly secretive, which, along with their well-known generally inoffensive disposition (Ditmars 1936, Sealy 2002) and the relative infrequency of envenomations from snakes encountered in the wild (e.g., Keyler 2005), perhaps has contributed to their suburban survival. Where the snakes occur in proximity to human development, sightings often cause alarm for residents who are concerned for the safety of humans and pets. Often, snakes discovered close to human habitation either are killed or are removed by local animal control personnel. In most instances, sightings close to human habitation involve mature male Timber Rattlesnakes, which have larger home ranges than females or juveniles (Sealy 2002). In part, this wider ranging reflects mate searching (Clark et al. 2007).

Unfortunately but inevitably, the politics of educated, peaceful coexistence between encroaching humans and native pit vipers involve a very fragile balance. Municipalities facing the very real prospect of expensive litigation due to an envenomation (irrespective of whether the human or its pet was fundamentally to blame) occurring in a public park, golf course, or residential neighborhood most likely will strongly consider eradication of the snakes. Unlike, for example, northern New York, with large tracts of state-owned land and snake dens in sites with a geology that would prohibit development for human use, this scenario is especially likely in areas such as Johnson County, Kansas, where heavy population

A Timber Rattlesnake in a residential area near the original den site.

Table 1. Public land ownership by state (from NRCM 1999).

State	% of State's Total Area	State Rank
New York	36.97	10
Pennsylvania	14.74	20
Arkansas	11.85	22
West Virginia	9.92	24
Missouri	6.02	33
Massachusetts	5.54	35
Iowa	1.04	49
Kansas	0.92	50

growth has extended city limits into the easily developed Timber Rattlesnake habitats.

Background: The Lenexa, Kansas Population.—Proposed and actual development of land within the City of Lenexa used as habitat by Timber Rattlesnakes provided an opportunity to test the effect of relocating an entire population (or at least most of one) to other suitable habitat remote from development. Lenexa Animal Control (LPD-AC) occasionally received complaints about Timber Rattlesnakes previous to 2005. However, during June 2005, one Lenexa resident contacted LPD-AC seven times to report a rattlesnake in his yard, which was part of a new development bordering a golf course. In each instance, either LPD-AC or a Lenexa Police Officer responded and removed the snake; snakes were relocated to a less residential area within 2 km of where they originated. This resident was very tolerant of the snakes, but did not want them interacting with his small dogs. His yard was well groomed — free of debris or mature landscaping. Some residents of the adjacent suburban area seemed not overly afraid of the snakes, which were not at all shy about traversing mowed grass yards in residential areas.

Construction workers on sites bordering this residence admitted to LPD-AC that they were killing additional Timber Rattlesnakes found under scrap materials on their job sites. Several rattlesnakes also were found in additional yards and dead on newly paved roads in the area. LPD-AC contacted several local resources to learn more about the occurrence of these rattlesnakes in such a high concentration; the conclusion was that the snakes most likely were moving to what was once their summer foraging habitat (meadow). LPD-AC initiated a public education campaign about coexisting with rattlesnakes, and hosted a workshop with area authorities (Joseph Collins, Dana Savorelli, and Rod Wittenberg) speaking about rattlesnake behavior, habitat, and the need for tolerance and conservation. Wittenberg and Savorelli both assisted LPD-AC in searching for local dens, but did not locate any likely sites.

DYLAN LEHRBAUM

A large male found beneath a downed road sign at the original den site.

Male and female Timber Rattlesnakes courting in a suburban backyard in Lenexa, Kansas in July 2009. Note the landscaping fabric, which in some instances can have adverse effects on entangled snakes. These photographs were taken by the homeowner.

In late fall 2006, Dorr was informed by a Lenexa City employee of a den with "hundreds of rattlesnakes." When asked for further information, Dorr was referred to another employee, Mike Shipman, who had located the den. Shipman, a city inspector, advised that he frequently observed several rattlesnakes (a more realistic number) in a specific area in early fall 2006. In February 2007, Dorr and Rod Wittenberg (University of Arkansas) evaluated the area Shipman identified as a snake den. Although the area was frozen, they determined that it seemed to be a likely location for a potentially large population of Timber Rattlesnakes. Dorr was advised of pending development of the area for a large retail center and was asked whether "it would be better to bulldoze the snakes while they were sleeping or try to destroy them after they came out of their den." Neither was a particularly tasteful or ethical option for

GEORGE PISANI

A large male Timber Rattlesnake coiled at the original den site.

Dorr or Wittenberg, who were told that work was to begin on the site in March 2007.

Dorr contacted the Kansas Department of Wildlife and Parks (KDWP) to inform them of the planned development in an attempt to stop or delay the construction. KDWP responded in late February 2007 and brought Pisani in to assess the situation. Pisani independently had investigated rattlesnake reports from a resident north of the newly impounded Lake Lenexa and an adjacent recreation area that seemed to Pisani not to have a geology that would provide suitable hibernation sites. With the new information from Dorr and Wittenberg, a decision was made to capture as many snakes as possible at emergence and to move them to a new location to test a new model for conservation relocation. Emergence of this population was expected in April and May (Wittenberg, Pisani, unpublished data). Pisani drafted a funding proposal; Dorr and Wittenberg met with the private landowner to ask for permission to remove the snakes. The landowner was tolerant of the snakes and expressed interest in the study. He granted permission for snakes to be removed from his land and agreed to delay construction on this portion of the site for as long as possible.

The threatened den site was located in ~2 ha of road rubble dumped into a northeast-facing creek valley during reconstruction of an adjacent Kansas state highway between 1980 and 1984. The rubble was capped with ~1 m of dirt fill. The periphery of the rubble dump consisted of largely exposed concrete slabs and culverts; the soil-covered surface also contained concrete culvert ends and assorted edges of concrete slabs. Depth of the rubble was ~1.5–3.0 m, and the flat surface of the dump was vegetated by grasses and forbs typical of highly disturbed roadside areas. Lacking any overstory, the surface received full insolation. While we do not know when the population of *C. horridus* initially colonized the site, the population age-size structure suggested a time period of at least 10–15 years, probably longer, based on a comparison of this population structure to that of a den being monitored by Henry Fitch and Pisani since 2003 (Pisani, unpublished data). Fitch (pers. comm.) noted that the den had been largely extirpated by construction activity in the early 1990s, but continuing studies indicated a recovered population of ~60 Timber Rattlesnakes.

BECKY COLIN

Original hibernaculum after some development in summer 2007.

Table 2. Size, mass, and survival of transmittered Timber Rattlesnakes in spring 2007. * = gravid. P = Predation, E = Exposure after successful hibernation and emergence.

Sex	Mass (g)	SVL (cm)	TL (cm)	Survival
F	519	92.0	6.4	Y
M	450	91.4	7.6	N (P)
F*	490	74.3	4.5	N (E)
M	1,248	116.0	9.0	Y
F*	409	75.3	4.4	Y
M	459	92.5	7.8	Y
F	327	74.0	5.8	Y

JENNIFER DORR

A portion of the original hibernaculum, an extensive system of road rubble, prior to development.

In addition to emerging *C. horridus*, collectors also encountered over 90 individuals of other reptiles (*Elaphe obsoleta, Terrapene ornata, Lampropeltis triangulum, Agkistrodon contortrix, Diadophis punctatus, Coluber constrictor*) using the den. This was further suggestive of a well-established community.

Background: The Arguments For and Against Moving "Nuisance" [venomous] Snakes.—The debate over the efficacy of moving "nuisance" snakes (almost uniformly venomous species), in addition to other herpetofauna, as a conservation measure has gone on over many years, and no doubt will continue. Opinions have ranged from decidedly negative (Dodd and Seigel 1991, Reinert 1991, Reinert and Rupert 1999) to guarded optimism (Burke 1991, Sealy 2002, Ernst 2004, Butler et al. 2005a). In some instances, relocation efforts somewhat magnified the initial problem (Butler et al. 2005b). Dodd and Seigel (1991) made the well-taken point that "... the burden of proof is on the investigator to show that a self-sustaining population [has been established] before declaring success." This can be difficult to evaluate if snakes are simply relocated into another population. Additionally, as more than a few threatened herpetofaunal populations are of species with lengthy life spans and prolonged reproductive cycles, well-planned relocation efforts often might be based upon less than unequivocal indications of success.

Over the timeline of the debate, much has been learned about the behavioral characteristics of snakes in general, including a considerable body of literature on crotalid social behavior (e.g., Cobb et al. 2005, Clark et al. 2007, Clark 2004, Aldridge and Duvall 2002, Weldon et al. 2002). Additionally, the various arguments against the practice of relocation (by any of its synonyms in the citations above) sometimes have been broad with respect to taxa, and have included taxa with widely disparate dispersal potentials (e.g., Burke 1991).

The concerns advanced in the references cited above, as well as others, have elucidated some basic concerns that conservationists interested in such efforts must consider. These are: (1) Relocations ideally should not be made into an extant population with an established social order; (2) As a corollary, relocations of individuals of a social species should be implemented in a way that does not force the relocated animals to survive the stresses that may be attendant to fitting into an established social structure; (3) Investigators should not relocate individuals or populations of vagile species (i.e., fish to a different drainage, birds, insects, etc.) in a way likely to contaminate the genetic makeup of other populations; (4) Investigators should ascertain the suitability of habitats to their species-of-question prior to the relocation.

In all instances we have found and cited variously in this introduction, several underlying similarities, which in light of the above-mentioned gains in knowledge of snake biology, seem to have contributed to the results reported by others. These are:

(1) Nuisance snakes were collected at varying times of the year (and published reports sometimes have encompassed snakes relocated at different times through several years of a study) based upon their occurrence in human habitats where they caused alarm;
(2) Snakes generally were collected/moved singly without regard to naturally occurring family groups;
(3) Snakes were sometimes transported many km from their sites of capture (8–172 km in Reinert and Rupert 1999);
(4) Snakes were relocated into established conspecific populations (and thus social structures);
(5) Release micro-sites at the new location were not chosen with regard to foraging or hibernation habitats the snakes would need for survival;
(6) Snakes were not necessarily handled in ways that minimized stress prior to relocation.

Several published reports among those we cited above indicated that distant relocation of individual snakes usually results in the death of the animal, either by failure to locate shelter from predators in the new area or a failure in fall to locate suitable hibernation sites. We do not find this surprising given the current knowledge of crotalid sociality. Snakes taken from varied family groups at times well after egress and deposited into a resident population that has its own established social order probably would be subject to considerable expenditures of energy devoted to resource-orientation, and also substantive exposure to predation through increased movement. Particularly instructive is the notation by Reinert and Rupert (1999), who indicated that by September 1991 (the second season of their study), some translocated snakes were observed to have formed associative relationships with each other and with residents.


PAIGE HOUGHTON

The senior author tracking rattlesnakes with implanted radio transmitters.

Predation losses alone may not always be a good indicator of relocation failure. So, while increased movement surely does factor into snake vulnerability, Fitch and Pisani (2004, 2005) experienced close to 50% predation loss of transmitter-bearing Timber Rattlesnakes in a resident population, most probably (Pisani, unpublished data) from avian predators (Red-tailed Hawks or unknown species of owls). Such high losses in areas with high populations of relatively large raptors (or particularly adept ones — Fitch and Pisani 2005; Ernst 2008, pers. comm.) may not be unusual. Because relocation efforts of less than 20 km may well mean that the relocation site still is very vulnerable to human incursion, we question the weighting of all anthropogenic mortality causes equally, or equal to losses from natural predation. So, for example, extensive daily movements of a disoriented relocated Timber Rattlesnake may result in its abandoning species-typical road-avoidance behavior (Andrews and Gibbons 2005), and its death as a roadkill can be attributed to that behavior. However, if humans aware of the chance of finding snakes at a relocation site do so and kill one or more of the snakes, we view that as unfortunate but not as mortality that necessarily detracts from the success of the relocation.

Telemetry is a time-intensive methodology. Consequently, most relocation studies, in addition to the variables discussed above, have used reasonably few specimens, and have not always had comparative samples available. An exception is Nowak et al. (2002). They conducted a limited but rigorous experimental test of the effects of translocation on *Crotalus atrox*. Even so, snakes were relocated to the new site at varying times of year and not necessarily from the same family group.

While single-specimen relocations are acknowledged to generally fare poorly, we hypothesized that capture of all available adults and young upon emergence from a single den in spring and relocating them to suitable other habitat would result in minimal population disorientation, stress, and concomitant losses. We further hypothesized that, as *C. horridus* largely orients by scent-trailing (especially young following adults — Weldon et al. 1992, Cobb et al. 2005), mass-reintroduction during the spring to a rock formation suited to future hibernation would allow dispersion of adults (to feeding and birthing grounds), effectively establishing scent trails that would lead back to the new den site in the fall. We felt that a relocation thus timed would give snakes the best opportunity to orient to new habitat during warmer weather.

Our model was developed using the knowledge that *C. horridus* is a long-lived (Brown 1993 and pers. comm., Pisani and Fitch 2002) and highly social (Cobb et al. 2005, Clark 2004, Aldridge and Duvall 2002, Weldon et al. 1992) species. Our underlying belief was that, if a considerable number of snakes from a den could be captured upon first emergence in spring, kept together, and then released together into a suitable denning/foraging/birthing habitat several km (but <20 km) distant from their original den, they would reorient and establish themselves as a group in the new site.

Methods

Several potential release sites were assessed by Pisani and Dorr during February and early March 2007 using the following criteria:

- Presence of a limestone stratum that weathered to produce deep fissures, with rock fractured by apparent mechanical weathering plus penetration of tree roots, and having several crevices with surface openings >6 cm in width;
- Southerly (SE–SW) exposure;
- Adjacent grassland and forb fields (natural and/or cultivated) that, combined with edge habitat, would support an abundant population of small mammals (potential prey species);
- Abundant edge habitat;
- Nearby sources of permanent water;
- Minimal nearby human development;
- Land owned by a county or municipal government (and thus protected from development) that would agree to host the project;
- No known extant population of *C. horridus*;
- Readily accessible to the research team for tracking.

In general, the site sought was to reflect the characteristics of the habitats used by *C. horridus* studied by Fitch and Pisani (2004, 2005, 2006a, 2006b). All but one were rejected for failure to meet all of the criteria. The site selected for the release was not known to have a resident population of *C. horridus* (Thompson, pers. comm. to Pisani; Pisani, personal observation), and was a few kilometers from the original den location.

The forested portion of the site is dominated by mature Chinquapin (*Quercus muehlenbergii* and *Q. prinoides*) and Burr (*Q. macrocarpa*) oaks and Shagbark Hickory (*Carya ovata*), which is typical of Timber Rattlesnake habitat in Kansas (Fitch 1958). The prairies are characterized by Big Bluestem (*Andropogon gerardii*) as well as Prairie Pepper (*Lepidium densiflorum*), Cord (*Spartina pectinata*), Switch (*Panicum virgatum*), Indian (*Sorghastrum nutans*), and Kentucky Blue (*Poa pratensis*) grasses, and dotted with prairie forbs such as various sedges (*Carex* spp.), asters (*Aster* spp.), and milkweeds (*Asclepias* spp.). This oak-hickory forest interspersed with open areas provides extensive ecotonal zones, ideally flanked by shelter and basking habitats. In order to further characterize these microhabitats, we assessed the density and diversity of prey (small mammal) species by placing three parallel grids comprising 100 total Sherman traps. The area sampled was an approximately 230 x 110-m (25,500-m^2) tract of land encompassing three distinct types of habitat. One-third of the traps were situated in the forest, one-third in the edge zone, and the remainder in the prairie. Traps were set in the afternoons and checked for three consecutive mornings, and mammals were marked with temporary designations. The traps were then allowed to lie fallow for one night, followed by two additional days of trapping. The Bailey-modified Lincoln-Peterson (Bailey 1952) index was employed to approximate the population density of each species, and Margalef's *d* (Margalef 1958) and Shannon's diversity (Shannon and Weaver 1949) indices were used to assess small mammal community structure.

Following a protocol training session by LDP-AC, snakes were captured by investigators and trained volunteers at the Lenexa den site in April 2007, and were processed as follows: (1) Marked by unique scale-clips (scales saved for pending DNA analysis) and sub-

Rod Wittenberg, University of Arkansas, conducts a training session for persons involved with this study.

MINDY WALKER

Habitat at the relocation site. A large male was found beneath these logs soon after release.


GEORGE PISANI

Hibernaculum at the release site in the relocation area. Note the fractured, southwest-facing limestone outcrop in mature Oak-Hickory forest.

cutaneous implantation of a Passive Integrated Transponder (PIT) RFID tag (AVID Systems); (2) Collected population data on sex, body sizes, mass, etc; (3) Implanted transmitters into selected snakes so their movements and survival could be monitored; (4) Released in one or two groups PREFERABLY by heading them into the new den hole so they could re-emerge, scent-trail the first individuals to disperse, and disperse in a pattern that, for them, would be reasonably normal.

In order to minimize stress to animals whose natural movements we planned to monitor, captured snakes were placed as gently as possible using aluminum tongs into clean plastic buckets for transport to the holding and/or surgery facilities (cf. Nowak et al. 2002). This procedure minimized handling, was safer both for the snakes (keeping stress to a minimum) and investigators, and minimized the transfer of human scent to the skin of snakes. In subsequent handling during processing, and thereafter as required during the study to assess post-release feeding or reproductive status, snakes were "tubed" by using 36-inch aluminum tongs and inducing snakes to enter rigid-wall acrylic tubes chosen to limit their ability to turn. Once the head/neck were in the tube, animals were grasped at the tube/body juncture for safe handling, which also minimized animal stress and struggling.

Twenty-nine Timber Rattlesnakes were collected and processed in 2007, and 22 were relocated to the new den site within 2–3 days of capture. The seven others were held for transmitter implantation and later release; delayed receipt of electronics and, in a few cases, waiting for ecdysis prior to surgery resulted in snakes being released at the new site anywhere between 2 days and 5 weeks after initial capture. Snakes emerging together were housed together during holding periods. In mid-summer 2007, LPD-AC was called to remove a large male Timber Rattlesnake courting a mature female in the yard of a residence. This male bore a distinctive series of dorsal scars and was recognized (Shipman, pers. comm.) as being from the den threatened with development. The female's den of origin is unknown. Site of capture was ~6 km east of the threatened den (straight line measure), and even a circuitous route for that male would have taken him through several densely populated neighborhoods. These two snakes were fitted with transmitters and released at the new site to compare their subsequent behavior with that of the group-relocated snakes moved earlier in 2007.

Surgeries were performed per the established protocol for the species (Reinert and Cundall 1982, Reinert 1992, Hardy and Greene 2000) using isoflurane anesthetic. Telemetry transmitters and associated items were purchased from Wildlife Materials International, Inc. (Murphysboro, Illinois; transmitter weight 11–12 g). Transmitter mass as a percent of snake body mass ranged from <1% to 3.5%, with an average of 2.2%. Transmitters were positioned so that their


JENNIFER DORR

Ushering a Timber Rattlesnake into a containment tube prior to processing.


ERIC KADLEC

Anesthetizing an adult Timber Rattlesnake in preparation for radio-transmitter implantation.


JENNIFER DORR

George Pisani and Mindy Walker preparing a Timber Rattlesnake for radio-transmitter implantation surgery.

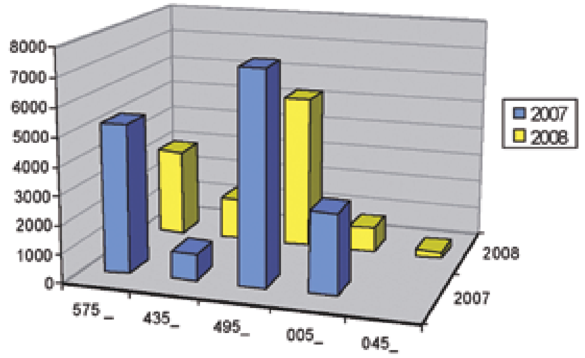
flattened surface was in contact with the snake's ventral musculature, with the flexible wire antenna extended through the primary incision, thence subcutaneously cephalad. A previously applied monofilament anchor suture around the base of the antenna wire was secured through the body musculature to prevent shifting of the transmitter and possible intestinal transfer with subsequent expulsion in feces (Pearson and Shine 2002). Snakes that were slow to recover from anesthesia were resuscitated by inserting an endotracheal tube, followed by evacuation of inhaled anesthetic by investigator exhalation into the tube according to the protocol. Snakes thereafter were kept in captivity for 24–48 hours at 21–24 °C to assure both complete recovery from anesthesia and wound closure. They then were released in groups at the new den site.

A Timber Rattlesnake report form modeled on one in use by the Natural History Division, Missouri Department of Conservation (Briggler 2001) was developed for distribution to the general public near the selected release site.

Results

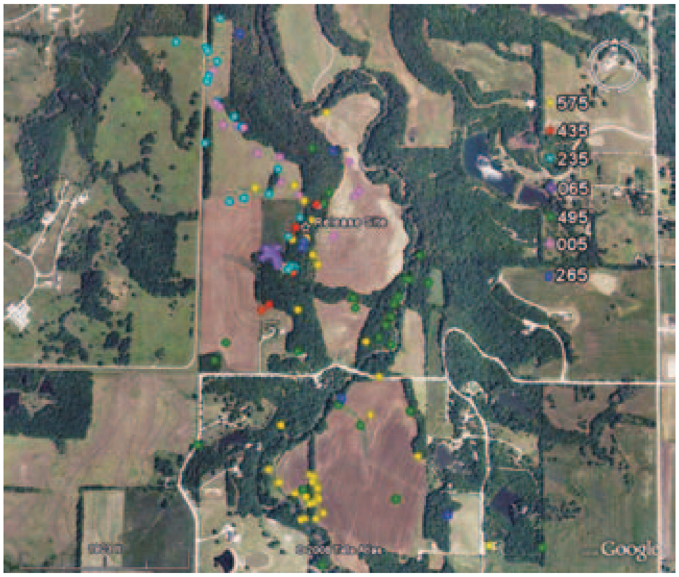
Behavior and Relative Movements.—The translocated snakes, in general, behaved as might be predicted from studies of nearby populations (Fitch 1999; Fitch and Pisani 2004, 2006a, 2006b). The aerial photographs illustrate each individual's movements throughout the first (2007) and second (2008) seasons, respectively. Snake #435 crossed into a prohibited area and could not be precisely located in 2008, but radio contact was not lost. For this reason, she was removed from statistical analyses. Circumferential foraging loop distances of the remaining five monitored snakes from both active seasons, in addition to that of a gravid snake introduced in 2008 (#045), are indicated in the graph. A paired *t*-test of foraging loop distances indicated that the 2008 foraging loops were significantly smaller ($P = 0.0007$) than those in 2007. During both seasons, snakes tended to utilize edge zone habitats more frequently than forested or prairie areas.

Table 2 indicates the measurements and survival or mortality of each of the original snakes captured during the 2007 season. One large, vagile male is thought to have joined a resident population of Timber Rattlesnakes with a hibernaculum ~2 km (1.26 mi) north of the relocation site. Despite some attrition (one snake to predation in year 1, one to exposure after successful hibernation and emergence in year 2), the two gravid females gave birth to an unknown number of young, perhaps as many as ten based on follicle counts at capture. Moreover, the gravid female that was added to the population in 2008 gave birth to six (observed) young.



	575_	435_	495_	005_	045_
▦ 2007	5215.27	938.63	7395.13	2805.71	
▦ 2008	3079.75	1436.53	5398.24	850.35	198.85

Comparisons of the total circumferential foraging loop distances (meters) traveled by each telemetered individual during the 2007 and 2008 active seasons.



Aerial view of the release site (✩) and new habitat (1903 ft = 580 m). Each snake's foraging loop for the first (2007) active season is indicated by a different color.

Aerial view of the release site (✩) and new habitat (1903 ft = 580 m). Each snake's foraging loop for the second active season (2008) is indicated by a different color. Note that #435 crossed into a prohibited area; dots represent sites of greatest signal strengths.

Small Mammal Community Structure.—A total of 30 small mammals was captured and marked in the study area, with *Peromyscus leucopus* (White-footed Mouse) and *P. maniculatus* (Deer Mouse) together comprising 76.7% (40 and 36.7%, respectively) of the total captures. *Microtus ochrogaster* (Prairie Vole) and *Blarina brevicauda* (Northern Short-tailed Shrew) represented 16.7 and 6.7% of the total individuals marked, respectively. Half of the animals were captured in the prairie, whereas 33.3% were trapped

JOEY BROWN

Two-day-old Timber Rattlesnake; one of six newborns observed outside the rookery of a relocated female in September 2008.

REBECCA BENJAMIN

Female Timber Rattlesnake in the rookery in September 2008.

in the woods and only 16.7% in the edge zone. This may explain why the rattlesnakes were most commonly found in the ecotonal areas, thereby strategically affording themselves access to both habitats with the highest concentrations of prey. Small mammal density in the sampled area was relatively low, at a value of 0.001 animal/m^2. Population size estimates in this area for each species were determined to be 15 individuals of *Peromyscus leucopus*, 11 *P. maniculatus*, 6 *Microtus ochrogaster*, and 2 *Blarina brevicauda*. Margalef's diversity index, which evaluates small mammal species richness in the area, was 0.882, indicating a very taxonomically rich small mammal fauna. Shannon's diversity index, which considers evenness of the inclusive populations, was determined to be 1.75. This diversity value is typical of empirical data (commonly ranging from 1.5 to 3.5; Magurran 2004) unless vast numbers of species are sampled. Prey density and diversity values may be underestimated due to small sample size and sample area, yet these data seem to indicate a healthy population of Timber Rattlesnake prey species at the relocation site, comparable to that found in other locations (Fitch et al. 1984).

Discussion and Conclusions

Most relocation studies (including ours) have involved tracking a small number of snakes (<25) and have not included the experimental component in the design of Nowak, et al. (2002), making detailed statistical evaluation of parameters such as observed home range size tempting but basically invalid. Fitch and Pisani (2004, 2006a) found that home ranges of tracked Timber Rattlesnakes in a naturally resident population closely reflected the overall physiography of the available habitat (small tracts of open habitat transected by wooded ledges), making detailed description via various statistical constructs an unprofitable exercise for a small sample size. Additionally, the comparison of statistically described home range sizes of various authors' study populations, while having an attractive mathematical appeal, fails to integrate (and in fact deflects attention from) the question of resource availability. Thus, as any individual snake moves from a hibernaculum to an activity range each season, the annually changing resource availability it encounters (food abundance, necessary thermoregulation sites, changes in plant community growth or cover — in Kansas not infrequently altered by controlled burns, etc.) along with natural and/or anthropogenic barriers, will, we believe, determine its home range shape and size for that season. For an extensive review of the pitfalls inherent to the application of detailed statistical home-range models to small data sets see Aebischer et al. (1993).

We do not question the conclusion (Sealy 2000, 2002; Nowak et al. 2002) that short distance (<50 m) relocation of "nuisance" rattlesnakes is preferable to longer distance relocations. The authors and colleagues often have responded to rural and suburban calls regarding "nuisance" Timber Rattlesnakes, and have moved the snake 50–300 m from its point of human interaction. Usually, we tell the alarmed human we will "take the snake away." Although such snakes were not tracked, we acted in the belief that this SDT was preferable to the human killing the snake, and most incidents seem to have been resolved favorably as the encounter was purely by chance and usually does not recur.

Neither do we question the recommendations regarding the desirability of educating an encroaching human population about the probability of encountering venomous snakes in what have become shared habitats. Indeed, some outstanding successes relate to the latter (Ernst 2004, Sealy 2000) and we are developing a similar Lenexa plan with the support of the city government. We believe that, in such situations, good models for relatively short-distance relocation of populations to more secure areas (possibly supplemented by careful siting and construction of artificial dens — see Ernst 2004 re *C. viridis*) are additional valuable manage-

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Newborn Timber Rattlesnake in rookery in September 2008.

Female near her rookery (with newborns inside). The senior author is in the background.

ment tools that also can be integrated with public education. That the nature of the original Lenexa den was entirely anthropogenic is itself of considerable interest, with obvious implications for snake conservation. Augmentation or *de novo* establishment (Ernst 2004) of suitable den sites is a largely untested conservation method, but observations on the original den of our population, combined with preliminary results of Ernst (2004) and a very few others (Edwards, pers. comm.) suggest that snakes of several crotalid genera may readily accept suitable anthropogenic dens. For example, *Agkistrodon piscivorus* utilizes hibernacula in anthropogenic dam rubble and is active in anthropogenic ditches (Savitzky 2002 and pers. comm.). We here advance the suggestion that any planned new den sites be prepared in winter or spring, and then treated with whole corn and sunflower seed to more rapidly attract a small rodent (snake prey) population.

The documented high natal philopatry (Clark et al. 2007) of *C. horridus* (e.g., individuals recruit to same hibernaculum as their mother) also is valuable to conservation efforts because it suggests that successful relocation of gravid females that give birth at the new site and then den there will establish the new population. The model we employed, headstarting the majority of relocated snakes at the investigator-selected new den site early after emergence, makes use of the social characteristics of the species to reduce the stress of relocation and hopefully thereby to increase survival.

The relocated snakes ranged, survived, and behaved seasonally in a fashion that mirrors undisturbed populations within 50 km. Based upon behavior and survival of the tracked snakes through the second full activity season after relocation, during which time their foraging loops became less erratic and significantly smaller, we believe this effort has been successful, and that our results provide a more realistic definition of success than others have demanded. Our effort may have been unique in that the original den plainly was slated for destruction and suitable relocation habitat was found a reasonable (too far for the snakes to return; not so far as to cause population genetics alteration) distance away. We also hope that this relocation will provide a model for the future salvage of populations of this and related species that are threatened by habitat destruction via development. Evidence exists that much farther relocations of small colubrids can successfully establish a population (Clark 1970). Careful application of the model to crotalids deserves consideration.

The Timber Rattlesnake Report Form will be employed by personnel of the City of Lenexa and Kansas Department of Wildlife and Parks as desired to gain information on this species from the general public, as well as raise awareness of the public to the snakes as a valuable component of local ecosystems. We hope that such feedback will be useful in assessing the proximity of other populations of this species to human habitation. It also will be helpful in monitoring dispersal of released snakes.

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