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MOVING MASSASAUGAS: INSIGHT INTO RATTLESNAKE RELOCATION USING *SISTRURUS C. CATENATUS*

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***Abstract*.—Relocating snakes is used to reduce potential snake-human conflict and to re-establish or augment populations. Relocation may be unsuccessful if snakes attempt to home back to their capture locations or otherwise alter their behavior in ways that reduce fitness. To better understand the conditions under which the technique is likely to be successful, we conducted two types of relocation (repatriation and short-distance translocation) using Eastern Massasaugas (*Sistrurus c. catenatus*) in Ontario. For the repatriation experiment, 27 snakes were captive-born, raised for four years, and released into a nature reserve previously known to host massasaugas. Other than being relatively sedentary, snakes behaved normally upon release in that they engaged in reproductive behavior. Survival (70%) was relatively high until hibernation (19 weeks). However, none of the snakes that did hibernate (n = 19) survived into the following active season. In a preliminary assessment of the effects of short-distance translocation, snakes that we moved 200 m from capture locations (n = 4) did not return, nor did they exhibit abnormal movement or basking behavior relative to non-translocated controls (n = 7). The different outcomes of our two relocations could indicate that the success of relocation depends on the extent of displacement and the source of relocated individuals, although corroborating evidence is needed before these results can be used to support management strategies.**

Key Words.—Eastern Massasauga; head-starting; Ontario; reintroduction; repatriation; short-distance translocation; wildlife management

INTRODUCTION

Relocating animals (i.e., the deliberate movement of animals from one location to another) is a common conservation technique (Fischer and Lindenmayer 2000). In the case of venomous snakes, relocation is often prompted by the potential for negative human-snake interactions (Shine and Koenig 2001; Nowak et al. 2002; Kingsbury and Attum 2009). Other reasons to relocate snakes include the re-establishment of extirpated populations, establishment of new populations of imperiled species in more suitable locations, and augmentation of imperiled populations (Burke 1991; Dodd and Seigel 1991; Kingsbury and Attum 2009). Given growing threats to snake populations (Gibbons et al. 2000; Böhm et al. 2013), these latter reasons for moving snakes are likely to become increasingly important. Because relocations are premised on a benefit to individual snakes or populations, it is imperative that we understand how snakes respond to being moved and how this affects their longer term fitness (King et al. 2004).

Despite a growing number of studies documenting the outcome of relocating snakes, the varied outcomes of these studies mean that relocation remains an experimental rather than an established conservation method for snakes (Kingsbury and Attum 2009). The diverse outcomes reflect the fact that relocation is not a single technique, but a collection of techniques that vary according to the extent of displacement and the source of relocated individuals (wild or captive-born). When snakes are moved short distances, such as might occur when a “nuisance” snake is moved away from the point of conflict, homing behavior (e.g., Fraker 1970; Weatherhead and Robertson 1990) can result in the snakes simply returning to the area from which they were moved (Hardy et al. 2001; Brown et al. 2009). Short-distance translocation (i.e., relocation of wild animals within their home range) may also cause snakes to alter their behavior in ways that increase mortality in some cases (Hare and McNally 1997), but not in others (Brown et al. 2009). When snakes are translocated greater distances, the potential for negative outcomes appears to be higher, producing increased movement and other changes in behavior that result in higher mortality (Reinert and Rupert 1999; Plummer and Mills 2000; Nowak et al. 2002; Butler et al. 2005; Roe et al. 2010). The release of captive animals into areas of past or present species occurrence (i.e., repatriation) resembles long-distance translocation in that snakes are unfamiliar with the landscape, but the outcome in terms of snake behavior and survival may be different (Roe et al. 2010). While patterns are emerging across species, few studies have examined the response of a single species to multiple types of relocation (but see Sealy 1997, Reinert and Rupert 1999).

Massasaugas (*Sistrurus* sp.) are rattlesnakes of conservation concern throughout their range (Symanski, unpubl. report). Because these snakes are venomous, short-distance translocation is commonly used to remove snakes from potential conflict with people (e.g., in campgrounds and in parks; Parent and Weatherhead 2000). In addition, repatriation is likely to be used to re-establish extirpated populations when formerly occupied sites are restored (King et al. 2004). Despite continuing use of relocation in managing massasauga populations, we currently know little about how these snakes respond to being moved. Two studies have investigated the efficacy of repatriation with captive-born massasaugas (King et al. 2004; Bieser 2008). In the Bieser (2008) study, 23 massasaugas were raised for one or two years and released concurrently in the spring at a location with resident massasaugas. Repatriated massasaugas experienced high mortality (91%) through the first winter relative to resident snakes (0%, n = 6), with most deaths occurring overwinter. In the King et al. (2004) study, massasaugas born in captivity were held for up to three years prior to release at locations formerly occupied by massasaugas. Habitat at those locations had been restored and the sites had been closed to the public. One cohort of snakes released in the autumn experienced high mortality through the first winter (87%, n = 15), whereas a second cohort released in the summer survived well into hibernation (100%, n = 15) before experiencing relatively high overwinter mortality (47%; Jones et al. 2012). The mixed outcomes of these experiments provide insight into the conditions more likely to result in repatriation success (e.g., spring or summer release versus autumn release), and evidence that relocated massasaugas are capable of essential life history functions in the wild, although low winter survival even when snakes were released in the summer is a serious concern.

We conducted two types of relocation on Eastern Massasaugas (*Sistrurus c. catenatus*). In the repatriation experiment, we assessed how snakes born in captivity responded to being reintroduced to a site formerly occupied by massasaugas. Given some similarities between this latter experiment and those of Bieser (2008) and King et al. (2004), our goal was to determine whether outcomes were similar between studies. We provide a preliminary assessment of the effects of short-distance translocation using wild-born snakes implanted with radio transmitters as part of a broader study (Harvey and Weatherhead 2006). For the translocation, our goal was to assess how massasaugas respond to being moved, as would occur when a snake is removed from a location where it is unwanted or in danger of harm, followed by immediate release a short distance away. In particular, we wanted to determine whether snakes returned to their capture location, and, if so, how quickly, and whether there was any evidence of negative effects on the snakes.

MATERIALS AND METHODS

Repatriation.–This experiment began in 2003, when four adult massasaugas were rescued from an isolated population in Windsor, Ontario that was faced with imminent demise due to land development. These snakes were placed in quarantine at the Toronto Zoo. Two of the rescued snakes were gravid females that underwent parturition soon after being captured. The goal was to raise the juvenile snakes for a year and release them in the Ojibway Prairie Provincial Nature Reserve, also in Windsor, Ontario. This 92-ha site had supported a massasauga population until the mid-1970s and the factors leading to their extirpation (human persecution, roads, and development) had subsequently been mitigated to the point that the site was judged to again be suitable for massasaugas.

The politics of releasing venomous snakes into a nature reserve in an urban setting (albeit one in which these snakes had previously occurred naturally) delayed the release until 2006, when the captive-born snakes were three years old. We surgically implanted 27 individuals with transmitters (model SI-2, Holohil Systems Ltd., Carp, Ontario, Canada) approximately five weeks before the release. The snakes were in excellent condition at this time. Males (n = 14) weighed an average 347.0 ± 35.8 g with a snout-vent length of 64.4 ± 3.0 cm. Females (n = 13) weighed an average 372.3 ± 52.5 g with a snout-vent length of 69.2 ± 2.4 cm. On 7 June we released snakes into two 10-m diameter pens constructed of 1.2 m wide landscaping fabric that were 27 m apart (i.e., a soft release). We placed males and females from the same litters in different pens. After 24 h, we removed the pens, at which point the snakes were free to move away.

We tracked snakes daily for the first two weeks after release and biweekly thereafter, with more frequent monitoring if snakes were moving. The goal of tracking was to confirm that the snakes were still within the nature reserve rather than to document movement patterns. Any snakes we found dead were necropsied.

Short-distance translocation.—We conducted the preliminary translocation study in Bruce Peninsula National Park in Ontario, Canada. The Park contains several well-travelled hiking trails, a beach, and a campground that collectively host over 220,000 visitors a year (Parks Canada Agency. 2012. Parks Canada attendance 2007–2008 to 2011–2012. Available from http://www.pc.gc.ca/docs/pc/attend/table3.aspx [Accessed 10 January 2013]). The peak season for tourism is July and August. Short-distance translocation of massasaugas that are encountered in campgrounds or on roads by park personnel has been a standard operating procedure for some time.

From 2–4 July 2003, we caught five massasaugas (four males, one female), which we translocated 200 m in a random direction (selected using a random number generator), and released on the same day. The translocation distance was within the normal limits for two-day movement in the population (Harvey and Weatherhead 2006) and well within the mean range length (1.2 km, Daniel Harvey, unpubl. data). As a control, we caught and released nine massasaugas (six males, three females) at the point of capture over the same time period. Snakes in the translocation group weighed an average of 293.9 ± 91.2 g with a snout-vent length of 62.0 ± 4.8 cm, and in the control group, 350.2 ± 173.3 g with a snout-vent length of 63.8 ± 5.6 cm. We implanted all snakes with radio transmitters (model SI-2, Holohil Systems Ltd., Carp, Ontario, Canada) as part of a broader study (see Harvey and Weatherhead 2006 for details), which allowed us to compare movement and behavior of the two groups post-release. Three of the five snakes in the translocation group were implanted in 2002, as were three of the nine control snakes. We implanted two snakes each from the translocation and control groups in mid-May 2003, and the remaining four snakes in the control group in mid-June 2003, 17–20 days prior to the translocation study. All females were non-gravid during the year of the study, as evidenced by a lack of significant weight gain or basking behavior typical of gravid females (Harvey and Weatherhead 2010). We located snakes once every two days and recorded locations in Universal Transverse Mercator (UTM) coordinates on a handheld global positioning system unit (GPS 12XL, Garmin Ltd., Olathe, Kansas, USA). Each time we located a snake, we estimated the extent of basking as the percentage of the snake visible to the naked eye from above, to the nearest 25%.

The focus of the short-distance translocation was on the movement and behavior of snakes immediately following release (from early to mid-July). Given that the handling of experimental and control snakes occurred over the course of only three days, we analyzed results by the number of days post-release. Capture dates from both control and experimental groups encompass all three days.

We used a repeated-measures ANCOVA to investigate how the distance moved by snakes varied as a function of days since release, group (experimental vs. control), and day by group interaction. We included the number of days post-translocation (2–18 d) as a covariate, assuming that the distance from initial or capture locations would increase over time (as it did). Individual snakes were treated as a random (repeated) effect and the main effect was translocation versus controls. We square-root transformed distance data to improve normality of residuals. Visual inspection of residuals confirmed that they approximated a normal distribution. Mean distances from release or capture sites at the end of the study were compared using *t*-tests. To determine whether translocated snakes moved closer to their initial capture points than expected by chance (i.e., exhibited homing behavior), we simulated a random walk from their release points using the *movement.simplecrw* command in Geospatial Modelling Environment (Beyer, H.L. 2012. Geospatial Modelling Environment Version 0.6.0.0. Available from http://www.spatialecology.com/gme [Accessed 10 October 2012]). Movement distances for the simulation were based on a lognormal distribution of observed snake movements.

RESULTS

Repatriation.—With a few exceptions, the snakes were fairly sedentary following release. After a month, 24 of the 27 snakes were within 100 m of their release site and after 73 days the mean distance of the 23 snakes still alive was 102 m. One female moved 400 m from her release site before returning close to the site. Another female moved 500 m away and a day later was seen with a male that had been with her before she moved. One male moved 875 m and was captured and returned to the release site because he was at the boundary of the Nature Reserve. He then moved 375 m to a bike path and was again returned to the release site.

While tracking the snakes, we observed several instances of close association suggestive of courtship and mating. We found three different pairs coiled together. Two of the pairs were composed of unrelated males and females, and the other pair was a male and female from the same litter. We found five other pairs of males and females in close association (i.e., within 0.5 m of each other). In two of these pairs, the male and female were unrelated and three of the pairs of snakes were from the same litter. Included in these pairings was one female found with two males, one related and the other unrelated.

Of the 27 snakes released, 19 (70%) survived until hibernation (weekly survival rate of 0.981 for approximately 19 weeks). A male and female found together seem likely to have been preyed upon. We found the female's transmitter in a coyote scat and simultaneously we could no longer locate the male. We found two snakes dead late in the season near hibernacula (see below), one obviously depredated and the other apparently killed by blunt force. Of the remaining four mortalities, we recovered one carcass (cause of death unknown) and three were not found because we lost their signals.

We found snakes at hibernation sites beginning in mid to late October. We determined snakes to have entered

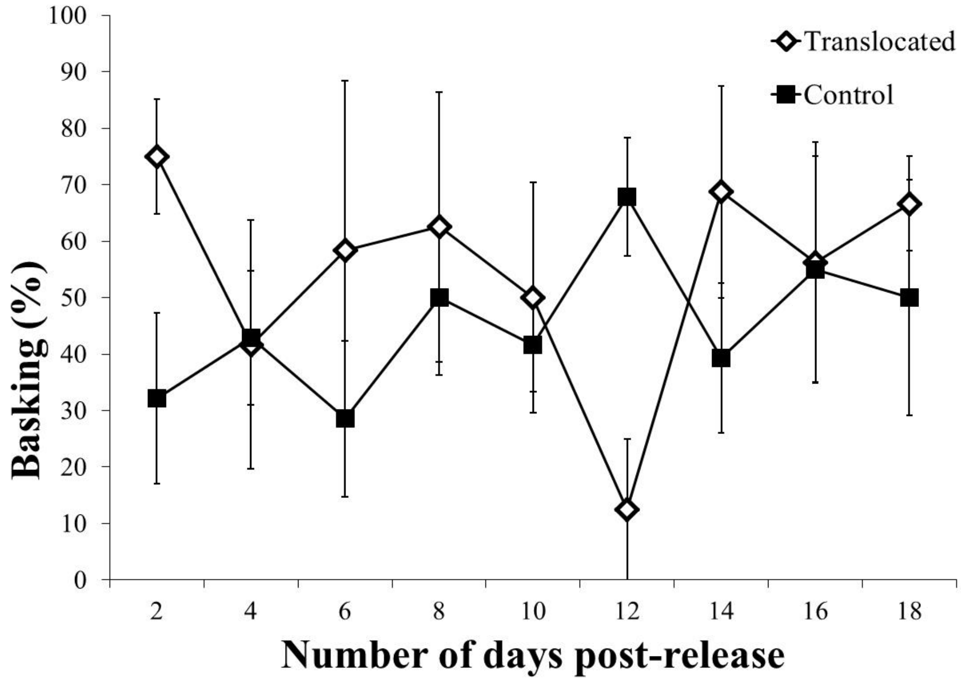

FIGURE 1. Basking behavior (% ± SE) of Eastern Massasaugas (*Sistrurus c. catenatus*) translocated 200 m (n = 4) and control snakes (n = 7) on the Bruce Peninsula, Ontario, Canada, by the number of days post-release in July 2003.

hibernacula once they were seen in a burrow and had stopped daily forays. Hibernacula were primarily crayfish and small mammal burrows. All but four of the 19 massasaugas that hibernated shared a burrow with at least one other rattlesnake. We also observed Eastern Gartersnakes (*Thamnophis sirtalis sirtalis*) in two burrows used by massasaugas. All hibernacula were within 140 m of the release sites, with no evidence of sex differences in dispersal (mean distance for males and females = 52 m and 58 m, respectively). Four snakes perished during the winter. We found one dead that had been killed by blunt force, one may have been predated as we found only its transmitter, and the final two we found on the surface and appeared to have died from exposure. We recovered only one carcass soon enough for necropsy to be informative. This female appeared to be in excellent condition and had approximately 10 mature follicles in each ovary. Flushing of the oviduct indicated that sperm were present. We found eight snakes dead on the surface after emerging from their hibernacula in March. Three more emerged in early April and we recovered their transmitters from mink dens. We excavated the burrows from which the other snakes failed to emerge. We found all snakes at least 94 cm below the surface. We also found seven dead gartersnakes in these burrows. None of the released massasaugas were alive following the winter.

Short-distance translocation.—Of the five translocated snakes, one male died late in the season (14 September) of unknown causes and four survived to hibernation. Of the nine control snakes, one male died of predation on 11 August and eight survived to hibernation. We observed one of the translocated snakes (male) and two of the control snakes (both males) preparing to shed (i.e., with cloudy blue eyes) during the study. We excluded these snakes from analyses because shedding can affect both movement and thermal preferences (hence, the propensity to bask; Gregory et al. 1987).

Although the very small sample size means it is difficult to draw conclusions, we found no difference in the overall amount of basking by translocated and control snakes ($F_{1,9}$= 3.15, P = 0.110). Additionally, there was no apparent difference in the pattern of basking behavior over time (Fig. 1). The cumulative distances travelled by translocated and control snakes over the course of the study were similar ($F_{1,9}$ = 2.97, P = 0.120). Both groups of snakes moved away from release sites over time ($F_{1,10}$ = 73.61, P < 0.001) and were equidistant from release sites at the end of the study on day 18 (t = 0.51, df = 7, P = 0.630). However, the patterns of movement differed. Translocated snakes moved greater distances immediately upon release, before maintaining a relatively constant distance from

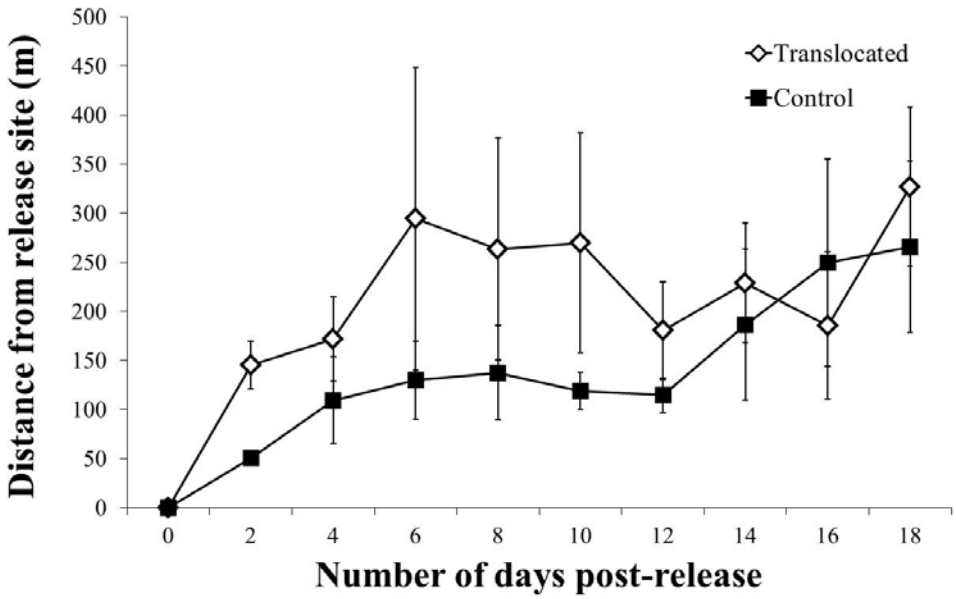

FIGURE 2. The distance from release site (m ± SE) of Eastern Massasaugas (*Sistrurus c. catenatus*) translocated 200 m (n = 4) and control snakes (n = 7) on the Bruce Peninsula, Ontario, Canada, by the number of days post-release in July 2003.

release sites, whereas control snakes moved steadily away from release sites over the course of the study (Fig. 2). Analysis of movement relative to capture locations indicated a day by group interaction ($F_{1,9}$ = 6.26, P = 0.020) such that translocated snakes maintained a relatively constant distance from their capture location, whereas control snakes steadily moved away from their capture location in a manner indistinguishable from random movement (Fig. 3). As a result of these differences in movement, after 18 days, both groups of snakes were similar distances from where they had been captured (t = 0.44, df = 7, P = 0.670; Fig. 3). This analysis provided no indication that translocated snakes moved back toward their capture locations (i.e., homing).

DISCUSSION

The results of our two relocations have different implications for using relocation as a conservation and management tool for snakes. For this reason, and because the two approaches are used in different circumstances and for different purposes, we discuss the two relocations separately.

Repatriation.—Repatriations comprise two types of management actions. In both cases snakes are released in unfamiliar locations, but in some cases snakes are caught in the wild and released shortly after being captured (e.g., Reinert and Rupert 1999; Plummer and Mills 2000), whereas in others, snakes are born and maintained in captivity for extended periods prior to release (e.g., King et al. 2004; King and Stanford 2006; Bieser 2008; this study). A fundamental difference in outcomes appears to be that wild-caught snakes move extensively when released, as though attempting to relocate their home ranges (Reinert and Rupert 1999; Nowak et al. 2002), whereas captive-reared massasaugas do not display this behavior (King et al. 2004; Bieser 2008; this study). In fact, captive-raised snakes may be less vagile than non-translocated snakes (Bieser 2008; Roe et al. 2010), suggesting that captivity may have contributed to the sedentary behavior we observed. Although repatriated snakes were sedentary in comparison to many massasauga populations (mean range lengths 272–1,379 m; Durbian et al. 2008), we note that similarly sessile behavior has been observed in wild populations (mean range length 89 m; Reinert and Kodrich 1982) and no resident snakes were present for comparison. Therefore, we cannot state conclusively that movement patterns were abnormal.

Other than being relatively sedentary, the snakes in our study behaved normally after being released in that they engaged in reproductive behaviors and survived well up until hibernation. The weekly survival rate (0.981) was comparable to non-relocated massasaugas in nearby Michigan sites during the active season (range 0.970–0.990; Jones et al. 2012). Negatively, however, mortality was high immediately prior to hibernation in our study and none of the snakes that did hibernate survived into the following active season. The fact that native gartersnakes were using the same hibernacula and also did not survive the winter suggests that weather conditions contributed to mortality, although without baseline information on weather and mortality this conclusion is speculative. Disease may also have

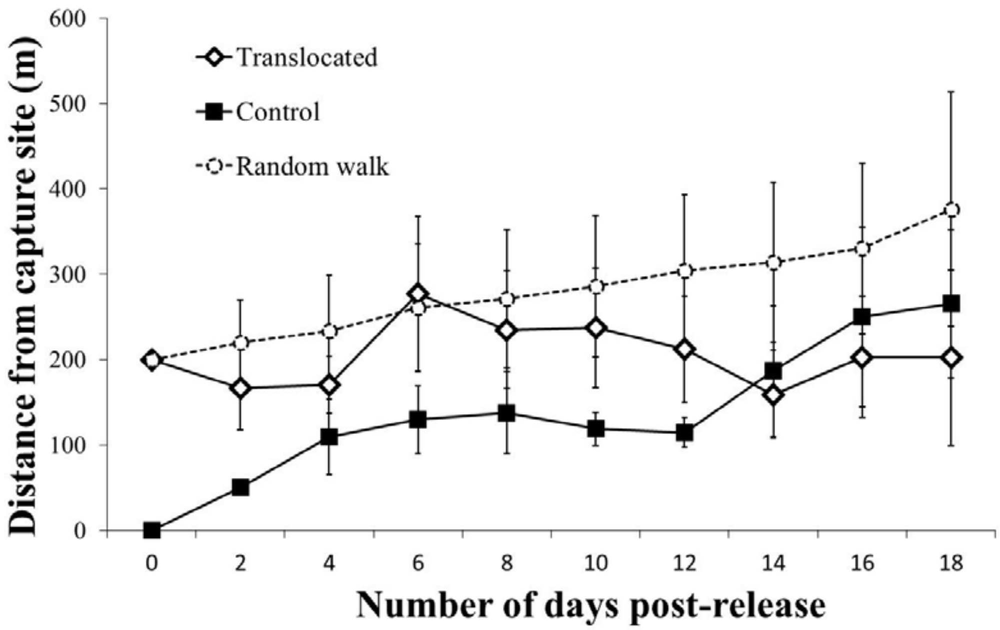

FIGURE 3. The distance from capture location (m ± SE) of Eastern Massasaugas (*Sistrurus c. catenatus*) translocated 200 m (n = 4) and control snakes (n = 7) on the Bruce Peninsula, Ontario, Canada, by the number of days post-release in July 2003. A simulated random walk is shown for reference.

contributed to mortality among co-hibernating snakes (*sensu* Allender et al. 2011). Our inability to distinguish between stochastic events (e.g., unusual weather, disease) and translocation as the cause of winter mortality in our study is a result of having released all the snakes at once. Future efforts should spread releases over more than one year if possible. All the snakes in our study were also the progeny of only two females, which themselves came from a small, isolated, and thus presumably inbred population. Thus, lack of genetic variation within and among the snakes we released may also have contributed to their poor performance (King 2009). Because these snakes were rescued from a population about to be extirpated, our study was constrained. It seems clear that when planning to translocate captive-bred snakes to re-establish a wild population, multiple releases of genetically diverse individuals is recommended.

When snakes are released in the spring or summer, a common finding among repatriation studies is relatively high active season survival and low overwinter survival (King et al. 2004; Bieser 2008; Roe et al. 2010; this study). Massasaugas released in the fall by King et al. (2004) moved less, put on less weight, and had lower overwinter survival than snakes released in the summer, suggesting that an early release facilitates the establishment of successful foraging patterns that are critical to overwinter survival. The low overwinter survival of repatriated snakes may be related to inadequate foraging prior to hibernation. Repatriated Northern Watersnakes (*Nerodia sipedon*) moved less, did not appear to engage in foraging behavior as often, gained less weight prior to hibernation, and were twice as likely to die overwinter than resident snakes (Roe et al. 2010). Also, repatriated watersnakes emerged from hibernation approximately one month prior to resident snakes (Roe et al. 2010), which may be a sign of a poor nutritional state (e.g., Shine et al. 2001). Whether the sedentary behavior observed in our study was associated with poor foraging success could not be determined because snakes were not weighed post-release, although a carcass recovered from the surface during the winter appeared to be in good body condition. An alternative explanation for the low overwinter survival of repatriated snakes could be that, with no prior hibernation experience, snakes are unable to locate suitable sites, or are otherwise unable to use suitable sites in an appropriate way. Repatriated snakes typically have small activity ranges (King et al. 2004; Bieber 2008; this study); thus, they may have a limited awareness of hibernation site options in comparison to resident snakes. Whether the small activity ranges reflect a lack of discernment about what constitutes a suitable hibernation site or a reluctance to search further afield for other reasons is unclear.

Repatriated massasaugas commonly co-hibernate with gartersnakes (King et al. 2004; Bieber 2008; this study), which, while not implying massasaugas are locating appropriate sites, suggests some common site selection cues between captive-born and wild snakes.

Interestingly, the small movements and selection of hibernation sites near the site of release by massasaugas in our study are reminiscent of neonatal massasauga behavior (Jellen and Kowalski 2007), more so than the behavior of sized-matched wild snakes (e.g., Bieser 2008). If these behaviors represent the process by which massasaugas locate their first hibernation sites, then repatriation will only be successful if snakes are released in close proximity to suitable sites. Research that explores how the behavior of captive-reared snakes differs from that of wild snakes (e.g., Almli and Burghardt 2006), and what steps help captive-reared snakes acquire natural behaviors like foraging and hibernation, would be valuable in helping us know how best to prepare snakes for release.

Short-distance translocation.—Our study provides preliminary insight into the response of massasaugas to short-distance translocation. Until additional studies are conducted with larger samples and more females, however, our results must be treated as tentative. In the national park where we conducted this study, rattlesnakes are regularly translocated short distances to remove them from potential conflicts with people using campgrounds and trails. The snakes we translocated did not show a tendency to return to their capture locations. Translocated snakes did behave differently from control snakes, but in a subtle way. Translocated snakes moved away from where we released them, but maintained a relatively constant distance from where we caught them initially, whereas control snakes gradually moved away from where we caught and released them. After 18 days, both groups of snakes were similar distances from their capture locations. Given mean activity ranges of 0.25 km^2 for Eastern Massasaugas in this population (Weatherhead and Prior 1992), the movement patterns suggest that translocated snakes moved in a way that kept them in their home ranges. If this lack of homing to the capture location and mild impact on behavior is supported by additional studies, it suggests that short-distance translocation may be an effective method of mitigating snake-human conflict for massasaugas, at least in the short term.

The few studies that have used telemetry to document the response of snakes to short-distance translocation have produced varied results. Sealy (1997) found that Timber Rattlesnakes (*Crotalus horridus*) moved ≤ 200 m quickly resumed normal foraging and reproductive behavior and over-wintered successfully. Brown et al. (2009) found that Western Rattlesnakes (*Crotalus oreganus*) translocated 500 m returned to the general area from which they had been removed, but did not home to their precise capture locations. Translocated snakes moved more than control snakes, but exhibited no negative effects in terms of condition, behavior, or mortality. Holding et al. (2012) translocated Northern Pacific Rattlesnakes (*Crotalus o. oreganus*) 255 m and found that many snakes homed to their capture sites. Also, relative to controls, translocated snakes had larger activity ranges in the two months following release and, associated with the greater use of space, had a larger mean volume of the medial cortex of their telencephalon (part of the squamate homologue of the avian and mammalian hippocampus). Collectively, these studies suggest several tentative conclusions regarding short-distance translocations. First, although translocated snakes may alter movement patterns relative to control snakes, the changes appear minor enough that the snakes are unharmed. Second, given that the goal of short-distance translocations is to remove snakes from potential harm that could result from a conflict with humans, lack of homing to capture locations in three of the four studies means that translocation was successful in those cases. Understanding the causes of homing (i.e., is it a species-specific trait or related to the circumstances of where a snake is caught?) requires further research. Third, fidelity of translocated snakes to original home ranges means that the same snakes may eventually end up back where they were initially captured (despite the lack of an immediate homing response when translocated). This could require that the snake be translocated again in the future, so this approach does not provide a long-term solution. Other authors have expressed similar reservations about the long-term efficacy of short-distance translocation for Timber Rattlesnakes (*Crotalus horridus*; Sealy 1997), Blacktailed Rattlesnakes (*Crotalus molossus*; Hardy et al. 2001), Diamondback Rattlesnakes (*Crotalus atrox*; Hardy et al. 2001), and Gila Monsters (*Heloderma suspectum*; Sullivan et al. 2004).

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