The Eastern Massasauga Rattlesnake: A Handbook for Land Managers

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PURPOSE & OBJECTIVES OF THIS DOCUMENT

In October1999, the U.S. Fish and Wildlife Service (FWS), added the eastern massasauga (hereafter referred to as massasauga) to the candidate species list. Candidate species are those that are in danger of extinction within the foreseeable future. Such species warrant threatened or endangered status pursuant to the Endangered Species Act of 1973 (ESA) but are awaiting processing while higher priority listing actions are addressed. Although candidate species are not yet afforded the protection of the ESA, FWS strives to initiate conservation actions to slow or halt the decline of such species during this interim period.

During an analysis of the massasauga's range wide status, FWS discovered that many populations persist on protected land (i.e., publicly owned or land purposely set-aside by non-governmental entities for long-term preservation). This is very fortunate because the decline of the massasauga can be slowed, perhaps even halted, by considering the biology of this species during management of these sites.

To facilitate incorporating massasauga biology into existing management strategies, we solicited the assistance of massasauga experts from across the species range to develop practical management guidelines for land managers. The objectives of this document are to provide a basic understanding of massasauga habitat needs and to provide recommendations of how to consider massasauga in routine management activities. Because of the variability in habitat use across the species range, these guidelines are not management prescriptions. Rather, this document should be viewed as a primer for land managers. To successfully incorporate massasauga biology into management plans, both area- and population-specific factors must be considered. We envision that these guidelines will provide a foundation from which land managers, with assistance from massasauga experts, can identify sound conservation actions for this species at their sites. It is also important to work closely with your state's endangered species staff to obtain guidance and necessary permits, as massasaugas are protected to some degree in every state and province they occur.

Although this handbook is focusing on protected lands, we are not dismissing the value of private lands in conserving the massasauga. In fact, we believe private lands, particularly those adjacent to protected properties, are necessary for the long-term stewardship of the massasauga. Although protected lands provide the core of the remaining habitat, massasauga populations in many situations use and depend on non-protected lands for foraging, reproduction, and perhaps hibernation as well. We recognize, however, that conservation efforts on private lands can be limited by economic and social factors. Thus, our efforts will initially focus on protected lands.

The context and organization of this document, we hope will meet the needs of most land managers. We begin with a detailed discussion about the biology of massasaugas, and for a quick reference provide a bulleted summary of the important components of its life history. In sections 2 and 3, we provide an in-depth description of the primary factors affecting massasauga populations and suggested practices to minimize such impacts. Again, for a quick reference, we also provide bulleted summaries at the end of each section. Lastly, we have included several appendices with helpful information and examples of various issues discussed in the text.

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SECTION I: EASTERN MASSASAUGA BIOLOGY

Range-wide Population Status & Trend

The range of eastern massasauga (*Sistrurus catenatus catenatus*) is described as western New York and southern Ontario extending westward to Iowa and southward to Missouri, with zones of intergradation between eastern and western massasauga in southwestern Iowa and extreme western Missouri (Conant and Collins 1991). Recent morphological (Rich Seigel, Southeastern Louisiana University, pers. comm. 1996) and genetic research (Steve Mackessy, Colorado State University, pers. comm. 1996), however, suggests that all massasauga populations in Missouri, and likely Iowa too, are eastern massasauga. Thus, range of eastern massasauga (hereafter refer to as massasauga) includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, and Wisconsin (Figure 1).

Throughout its range, the massasauga has declined. The magnitude of decline varies across state/provincial lines, with 33 percent of Michigan's to 100 percent of Minnesota's known historical populations extirpated. Only a few (22%) of the remaining populations are considered viable in the long-term (Szymanski 1998). The primary causes of the decline are habitat loss and persecution (Szymanski 1998). Due to the magnitude and extent of habitat loss and persecution that has occurred, the adverse effects caused by further habitat destruction and mortality will have an extraordinary impact on the species. Unfortunately, incompatible land use and persecution are still prevalent today (Szymanski 1998).

Habitat Requirements

Massasaugas have been reported from a number of habitats: wet prairie (Seigel 1986), fens and sedge meadows (Minton 1972; Johnson 1995; Kingsbury 1996, 1999), peatlands (Johnson 1995), coniferous forest (Weatherhead and Prior 1992; C. Parent, personal communication) and meadows and old fields (Reinert and Kodrich 1982, Wright 1941, Smith 1961). Some of this diversity is a matter of semantics, as various authors and researchers use terms differently. However, it is also apparent that habitat use varies regionally, and is also somewhat site dependent even within a particular region (Wright 1941, Minton 1972, Reinert and Kodrich 1982, Seigel 1986, Weatherhead and Prior 1992, Johnson 1995, Kingsbury 1996 and 1999). Readers should keep this variability in mind during any discussion of the characteristics of good massasauga habitat.

Despite this variation between sites, we can describe several common attributes of the habitats frequented by massasaugas. Preferred habitats tend to have a generally open vegetative structure relative to surrounding areas. Over most of their range, massasaugas tend to avoid heavily wooded areas (Wright 1941, Bielema 1973, Reinert and Kodrich 1982, Seigel 1986,

Figure 2: Approximate Range of the Eastern Distinct Population Segment of *Sistrurus catenatus* ☀

☀ Eastern Distinct Population Segment includes portions of Ontario, Canada

Kingsbury 1996 and 1999), although some investigators have associated them with gaps in bottomland hardwoods (Johnson 1995, King 1997) or coniferous woodlands (Weatherhead and Prior 1992, Johnson 1995, C. Parent 1998, personal communication). Sites are also typically open in terms of the shrub layer. This vegetative structure, where tree and shrubs are thinly distributed, provides a desirable thermoregulatory mosaic. The openness of the habitat also increases prey (rodent) densities for the snakes by enhancing the growth of sedges, grasses, and herbs. Within relatively open habitat, massasaugas often select microsites near isolated trees or shrubs (Bielema 1973, Johnson 1995). This may be related to the shade provided by the vegetation, as well as, protection from aerial predators.

Another common aspect of massasauga habitat is the proximity of water. This attribute is observed across most of the species' range (Missouri: Seigel 1986, Wisconsin: King 1997, Indiana: Minton 1972, Kingsbury 1996 and 1999, Pennsylvania: Maple 1968, Reinert and Kodrich 1982, New York: Johnson, 1995). The association with wetlands is especially interesting, given that massasaugas are not even semi-aquatic. In fact, rattlesnakes as a taxon are generally associated with relatively xeric habitats. Massasaugas do tend to avoid open water, and individuals are not regularly found swimming, as would commonly occur with typical water snakes.

Massasaugas often show seasonal shifts in habitat use. The typical pattern is the use of wet prairie and meadow habitats in spring and fall, and activity in higher, drier, habitats in summer (Bielema 1973, Reinert and Kodrich 1982, Seigel 1986, Johnson 1995). The snakes then return to the wetter habitats in the fall. Other populations do not appear to show a seasonal shift in habitat use, with individuals remaining in wetlands all year (Wright 1941, Maple 1968, Kingsbury 1999). In some populations, only the gravid females move (King 1997).

Ending up in wetlands in the fall seems to be a consistent trend for massasaugas, regardless of where the snakes were during the activity season. This aspect of habitat use relates to the selection of hibernation sites, which are typically in areas where the soil is saturated but not inundated. Over much of their range, massasaugas use crayfish burrows to hibernate (Maple 1968, Seigel 1986, Kingsbury 1999). Sphagnum hummocks (Johnson 1995) are also used.

As alluded to above, another factor influencing habitat use is the reproductive condition of females. Non-gravid females tend to behave similarly to males while gravid females often exhibit a tendency to select sites with a more open canopy (Johnson 1995, King 1997, C. Parent 1998, personal communication). Several females may be found together in such gestation sites (Reinert and Kodrich 1982, King 1997, C. Parent 1998, personal communication). The advantage to such sites is very likely tied to their thermal properties, in that they facilitate the maintenance of temperatures advantageous for the development of young. Paralleling the use of more open sites is the tendency for gravid females to move very little until parturition (i.e., bear young).

To summarize, massasaugas appear to prefer habitat with open canopy and a sedge or grass ground cover. Sphagnum is also often a significant component of the substrate. Massasauga habitat is typically associated with shallow wetland systems. While individuals may move to drier environs in the summer, they almost always return to wetlands to hibernate. Gravid females are the most likely to move to more exposed warmer sites for the summer until they bear their young.

<u>Massasaugas in Time and Space</u>

Phenology. The active season of massasaugas shows some variation with latitude across its range, but also may vary annually within a population or among individuals within a population. For example, during a study from 1989-1993 at Cicero Swamp in central New York, the earliest a radio-tagged massasauga was reported aboveground was 15 April 1991 while the latest date for spring emergence was 29 April 1991 (Johnson 1995). The latest a telemetered snake was observed aboveground in any active season in Cicero Swamp was 24 October 1990 and the earliest a radio-tagged snake initiated fall ingress was 11 September 1991. Near the southern extreme of its range, at Squaw Creek National Wildlife Refuge in Missouri, the earliest date of emergence was 31 March and the latest date of activity was 31 October, however, most individuals are near where they will overwinter by mid-September. In a study at Killbear Provincial Park in Ontario, near the northern limits of the massasauga range, the earliest date of emergence was 5 May and the latest date was 2 June (Parent 1997). Massasaugas in Wisconsin were reported to enter hibernation as early as 1 September and as late as 27 October (King 1997).

The mean length of the active season and the hibernation period for seven individuals in Cicero Swamp was 158 days and 207 days, respectively. The maximum length of the active season for any radio-tagged snake was 185 days while the longest overwintering period was 229 days. Active seasons of massasaugas at Cicero Swamp are shorter than those reported for Missouri (197 days, Seigel, 1986) and Pennsylvania (192 days, Reinert, 1978). Considering massasaugas may emerge even earlier and enter hibernation later than these dates, a useful rule of thumb for predicting the length of the active season is April 1 - November 1 in the northern part of the range and March 15 - November 15 in the southern part of the range.

Massasaugas are generally thought of as being diurnal, although this pattern will vary seasonally and possibly with latitude. Over most of their range, massasaugas in spring and autumn tend to be most active during the warmer parts of the day while during the summer months they are most active in the afternoon, evening and morning hours (Seigel 1986, Reinert 1978, Johnson 1995). While some (e.g. Swanson 1930, Wright 1941) believed that massasaugas are crepuscular or active at night, Johnson (1995) and Linke (1985) found no evidence of nocturnal activity in New York and Ontario, respectively. Reinert and Kodrich (1982) suggested cooler night temperatures over most of the range of massasaugas limited nocturnal movements.

Movements and Activity Range. Following their initial egress from their overwintering sites in Cicero Swamp, massasaugas typically remained in the immediate vicinity (within 5 m of the site) for at least 10 days (x = 15.2 days) before making a movement greater than 10 m. This pattern has been observed in Wisconsin (King 1997) and Ontario (Parent 1997) as well. Similarly, at the end of the active season, massasaugas are often observed aboveground in the vicinity of their overwintering location for several weeks before entering hibernation.

Studies using radiotelemetry have shown clear activity ranges in many species of snakes (e.g., Fitch and Shirer 1971, Reinert and Kodrich 1982, Madsen 1984, Shine and Lambeck 1985, Tiebout and Cary 1987, Shine 1987, McCartney et al. 1988, Slip and Shine 1988). Activity range (or home range) may be defined, in general, as that space used by an animal over some time period, typically a year or a season, to acquire enough resources to meet its needs for survival, growth, and reproduction. The size and shape of an individual's activity range is related to several factors, however, the most pervasive to all members of a population is the distribution of resources throughout the available space. The most important resources for the massasauga is the distribution of prey, gestation sites, overwintering sites, and basking sites (especially for gravid females), as well as, the distribution of receptive females for male snakes. If the distribution of food resources contributes most to the seasonal size of a snake's activity range, then the strategy employed for finding food is also related to the size of an activity range. The commonly observed pattern exhibited by males and nongravid and postpartum females at Cicero Swamp in New York was a long movement followed by periods of little movement and then another long movement (Johnson *in* press). Such patterns suggest that they are essentially ambush or sit-and-wait foragers but spend some considerable time actively seeking patches with prey. Other researchers have found rattlesnakes in general to be ambush predators (Fitch and Twinning 1946, Klauber 1972, Reinert et al. 1984).

Table 1 shows the variation in movement patterns and activity ranges of massasaugas at four geographic locations. Table 2 shows movement data partitioned by sex and reproductive condition for massasaugas in Wisconsin and New York. Johnson (2000) and King (1997) present the results of radiotelemetric studies of the spatial ecology of massasaugas in central New York and central Wisconsin, respectively. At the New York site, all members of the

Table 1. Means of movement and activity measures for *Sistrurus c. catenatus*, at four locations across its range (western Pennsylvania - Reinert and Kodrich 1982; Bruce Peninsula, Ontario - Weatherhead and Prior 1992; Cicero Swamp, central New York - Johnson 1995; Wisconsin - King 1997).

Location	Frequency * of movement (%)	Total distance moved/season (m)	Distance moved/day (m)	Range length (m)	100% minimum convex polygon (ha)
Bruce Peninsula Ontario (n=11)	67.1	1823.6	56.0	1030.4	25.0
Western Pennsylvania (n=25)	----	----	9.1	89.0	1.0
Cicero Swamp New York (n=15)	68.9	2751.3	19.5	797.0	26.2
Wisconsin (n=26)	66.3	851.6	100.5	226.4	21.2

*Percent of observation where location changed more than 5.0 m from previous location.

Table 2. Means of movement and activity measures for male, nongravid female and gravid female eastern massasaugas in Cicero Swamp, central New York (Johnson 1995) and central Wisconsin (King 1997).

Group/ Location	Total distance moved (m)	Distance moved/day (m)	Range length (m)	100 minimum convex polygon (ha)
Male				
New York	2940	20.5	812	27.8
Wisconsin	6057	67.7	1331	161.5
Nongravid Female				
New York	3712	26.9	1212	41.4
Wisconsin	1484	10.4	334	6.7
Gravid Female				
New York	751	7.1	296	2.0
Wisconsin	1034	6.2	653	2.8

population restrict overwintering activity to a 37 ha peatland within a larger wetland complex and gravid females remain there from spring emergence to parturition as well. Mean 100% minimum polygon activity range size for gravid females was 2.0 ha. Gravid females moved less total distance (45.5 m), mean distance per day (7.1 m), and less often (45.5% of observations) than male or nongravid females, who exhibited no differences in these measures. This reduction in vagility associated with gravidity has been observed in other live-bearing snake species (Brown et al. 1982, Reinert and Zappalorti 1988, Secor 1994, Viitanen 1967, Fitch and Shirer 1971). One hypothesis offered to explain this phenomenon is that gravid massasaugas are selecting a location that maximizes thermoregulatory opportunity to reduce gestation time. King (1997) also found differences between gravid females and males and nongravid females in Wisconsin, although the differences between female groups were not very pronounced. In Wisconsin, gravid females moved away from overwintering sites following emergence, presumably to find suitable open-canopy basking sites that were not available near hibernacula. Weatherhead and Prior (1992) found that female massasaugas had significantly smaller activity ranges and other movement parameters than males at their site in Ontario, however, it was unknown or unclear if any of the females were gravid. Reinert and Kodrich (1982) found no differences between gravid female massasaugas and other classes in most movement parameters in Pennsylvania, however, tracking periods were short and snakes were force-fed transmitters, potentially inducing thermophily and reducing movement.

No significant differences were detected between male and nongravid female activity ranges in Cicero Swamp (composite mean 100% activity range = 29 ha) (Johnson 2000). Males and nongravid females did show a difference in range length (812 m for males, 1212 m for females), which may be explained by the more straight-line, back and forth general movement pattern from emergence to hibernation by the females or simply an artifact of the small sample size. Males appear to wander more, perhaps related to the dual need of foraging and mate location. Male massasaugas tracked for multiple years generally showed significant overlap in yearly movements, however, core areas of activity varied. However, King (1997) found significant differences between the sexes in several movement parameters and nongravid females had significantly smaller activity ranges than males. Several other studies of snakes have detected no differences between the sexes (e.g. Clark 1970, Plummer 1981, Michot 1981), while some studies find clear differences (Madsen 1984, Slip and Shine 1988), with the females generally possessing smaller activity ranges.

Only one study (King 1997) has included data on movement from radio-marked neonate massasaugas. In his study, neonates made considerable movements, averaging similar distances per move and per day as nongravid females. Total distance moved per season and home range areas were similar to adult female massasaugas as well, although neonates were tracked for a shorter period of time. One pattern observed by King (1997) and others (Johnson 1995, Parent 1997, K. Prior pers. comm.) is that newborn massasaugas remain at their birthplace for about 10 days before making their first movements. These initial movements are preceded by the first postpartum molt.

The observed variation in the spatial ecology across the range of the massasauga has several conservation implications. First, as Weatherhead and Prior (1992) suggest, management for a particular population or a regional population should be based upon local movement characteristics. In the absence of this information, it may be best to use the average or maximum male activity range of the nearest known population, since most studies suggest male snakes use the largest ranges and show the greatest range lengths. Second, gravid females probably use the smallest activity range and make the fewest movements, but may have the broadest habitat requirements over the course of a year, requiring more basking opportunity in addition to quality foraging habitat and overwintering habitat (see Section 1 Habitat Requirements). This suggests that habitat management should focus on the thermoregulatory needs of gravid females and even small manipulations may be effective.

Reproductive Biology

Most snakes are difficult study subjects because their secretive behavior and frequent periods of inactivity limit opportunities for observation under normal field conditions (Parker and Plummer 1987). Consequently, the reproductive biology of many snakes remains poorly understood. However, a number of recent studies have provided considerable insight into massasauga reproduction.

Most published accounts suggest that female massasaugas attain sexual maturity at three or four years of age (Wright 1941, Keenlyne 1978, Seigel 1986). However, these figures are not entirely reliable because they are based on the untested assumption that differences in snout-vent length accurately reflect differences in age. A long-term study of snakes of known age in Killbear Provincial Park, Ontario suggests that most females do not begin to reproduce until they are at least five, and perhaps even six or seven years old (C. Parent unpub. data).

Early authors stated that massasaugas mate in the spring (see Wright 1941, Keenlyne 1978) but these claims were based on morphological examinations of dissected snakes or studies of captive individuals. In contrast, observations of free-ranging animals implanted with radio transmitters suggest that mating occurs from mid-July to mid-September (Reinert 1981, Johnson 1995, C. Parent unpub. data). Like many other snakes, receptive female massasaugas are thought to produce pheromone trails to attract potential mates.

During the mating season, males often make long distance, spatially direct moments to locate females (Johnson 1995, C. Parent, unpub. data). Courtship and mating may be accomplished in hours, but males often remain with females for several days following the encounter (C. Parent unpub. data). Behavioral observation of snakes equipped with radio transmitters in Killbear Provincial Park, Ontario suggests that male snakes will mate with more than one female in a season (C. Parent unpub. data). In contrast, limited genetic data from the same population suggest that females mate with only one male per reproductive episode (Gibbs et al. 1998).

Courtship and mating take place in the summer but ovulation and fertilization do not occur until the following spring. Massasaugas bear live, fully developed young. During gestation gravid females move less often, and over shorter distances, than males and non-gravid females at most sites (Johnson 1995, Parent and Weatherhead *in* review).

In at least some populations, the sedentary nature of gravid females apparently results from their tendency to remain at specific gestation sites whose structural characteristics differ markedly from the habitat of males and non-gravid females (Reinert 1981, Johnson 1995, C. Parent unpub. data). The properties of these gestation sites vary from location to location, although all exhibit below average canopy cover, which is thought to confer thermoregulatory advantages to their occupants (Reinert 1982, Johnson 1995). In several locations, gravid females tend to occupy gestation sites located nearby their traditional hibernation sites (Johnson 1995, C. Parent unpub. data).

Throughout their range, massasaugas generally give birth from mid-August to early September (Wright 1941, Keenlyne 1978, Reinert 1981 and 1985, Seigel 1986, Johnson 1995, C. Parent unpub. data). However, parturition dates may be strongly influenced by climate. For example, in 1996, most massasaugas in Killbear Provincial Park emerged from hibernation in the second week of May, and gravid females gave birth at the end of August. In contrast, in 1998, snakes from the same population emerged from hibernation in mid-April, and gravid females gave birth from late July until mid-August. The sex ratio at birth (the primary sex ratio) does not appear to differ significantly from 1:1 (Klauber 1972, Parker and Plummer 1987).

Considerable debate exists concerning the reproductive potential of massasaugas. The number of young (brood size) may vary from 3 to 19 (Seigel 1986) and is positively correlated with female snout-vent length (Seigel 1986, Parent and Weatherhead in review). Brood size may also exhibit geographic variation, although available sample sizes are insufficient to control for potentially confounding ecological factors (Seigel 1986). For example, snake brood size may vary annually as a result of fluctuating prey availability (Seigel and Ford 1987) or variation in climatic conditions (Seigel and Fitch 1985).

Similarly, the frequency of female reproduction apparently varies across the snake's range. Females appear to reproduce annually (Keenlyne 1978, Bielema 1973) in some populations and every second year (biennially) in others (Reinert 1981, Seigel 1986, Johnson

1995). Whether these differences are the result of genetic variation between populations, ecological factors or biased sampling methods remains unknown (Seigel 1986). In one laboratory study, massasaugas produced two broods in a year, which suggests ecological rather than genetic factors influence reproductive capability (Johnson 1988).

Mother and young typically remain at the location of birth for several days after parturition, but the neonates receive no direct parental care. Approximately one week after birth, the young snakes shed their skin for the first time, and then gradually disperse (Johnson 1995, King 1997, C. Parent unpub data).

Predator and Prey Ecology

Predators on adult massasaugas include most carnivorous mammals, as well as birds-of-prey, great blue herons (*Ardea herodias*), and ophiophagous (snake-eating) snakes (Ernst and Barbour, 1989). Chapman and Castro (1972) report a 41 cm (SVL) desert massasauga taken by a loggerhead shrike (*Lanius ludovicianus*). Due to their smaller size, neonates and juveniles are probably susceptible to a wider array of predators.

The massasauga's diet consists primarily of endotherms, especially small mammals, although juveniles may accept small snakes (Keenlyne and Beer 1973, Seigel 1986, Johnson 1995). Other vertebrates, such as birds, lizards, and anuran amphibians have been reported, as well as incidental reports of insects, crayfish, and centipedes (Gloyd 1940, Wright and Wright 1957, Klauber 1972, Froom 1972, Vogt 1981, Cook 1984, Hallock 1991, Ernst 1992). Like most rattlesnakes (e.g. Reinert et al. 1990), adults are believed to be sit-and-wait foragers following a period of actively searching for areas containing rodents.

Adler (1960), Swanson (1930), Keenlyne (1968), and Johnson (1995) all found that captive neonates accepted rodents as food. Neonates of western massasaugas (*S. c. tergeminus*) have been observed using a caudal luring strategy to attract frogs (Schuett et al. 1984), however, Keenlyne (1968) and Johnson (1995) found captive neonates refused frogs when offered. Seigel (1986) and Keenlyne and Beer (1973) found evidence that neonates and juveniles are ophiophagous and may undergo ontogenic shifts (i.e., age-specific changes) in diet similar to those observed for other rattlesnakes (Wallace and Diller 1990).

Population Biology

Demography. Population demography remains one of the least-understood aspects of snake ecology (Parker and Plummer 1987). Reasons for the lack of information on populations include relatively high longevity (which makes life-table construction difficult), difficulty in obtaining density estimates through mark-recapture methods, and a very limited number of long-term studies (Parker and Plummer 1987, Seigel and Sheil 1999). Unfortunately, data on the population biology of massasaugas are sparse even compared with snakes in general. Only limited data on sex ratios, growth rates, and population size/age structure have been gathered in the field for massasaugas (Pennsylvania: Reinert 1981, Wisconsin: Keenlyne 1978, Ontario: C. Parent pers. comm., Missouri: Seigel 1986), and there has been only one study published on long-term changes in population biology (Seigel et al. 1998). In addition, because massasaugas inhabit such a broad geographic range, findings at one locality may not apply to a different population. Sweeping generalizations regarding the population demography of massasaugas are therefore difficult. Notwithstanding this caveat, massasauga populations have the following general features:

1) Age at maturity-estimates vary from 3-8 years, with a great deal of variation from different parts of the range. Seigel (1986) suggested a likely age at maturity of 3-4 years in northern Missouri. Conversely, C. Parent (pers. comm.) found maturity delayed up to 8 years in Ontario, although some neonates were able to mature at three years of age. Thus, age at maturity is probably not a "fixed" trait, but likely depends on growth rates, which are, in turn, controlled by food availability, length of the activity period, availability of suitable basking sites, and possibly genetic effects (Ford and Seigel 1994).

2) Sex ratio - Sex ratios varied widely over time in Seigel's study in Missouri, from biased in favor of females to biased in favor of males following a major flood event (Seigel et al. 1998). Sex ratio estimates can easily be biased by sampling error, since males and females may utilize different habitats at different times of the year (Reinert and Kodrich 1982, Szymanski 1998).

3) Survivorship-Virtually no published data are available for natural populations. Seigel and Pilgrim (unpubl. data) have marked animals that have survived at five years after reaching sexual maturity, suggesting total longevity of at least 8-10 years in the wild. A recent Population Viability Model (PVA: Seigel and Sheil 1999) suggested that stable populations in Missouri would have adult survival rates of 80 percent per year and neonate survival rates of 20 percent per year. However, C. Parent (pers. comm.) has found much higher rates of survival among juveniles in Ontario (80 percent per year). This suggests that the longer ages at maturity of Ontario populations may be balanced by higher annual survival, but this requires confirmation.

4) Density - As noted, estimating densities of snakes has proven difficult. Although several authors have provided unpublished density estimates (see review in Szymanski 1998), low recapture rates, coupled with the use of simple models that cannot deal with

open populations, make these estimates starting points for future work, rather than definitive records. Most existing estimates indicate a range of 0.5-2.5 snakes/ha (Szymanski 1998).

Seigel and Sheil (1999) used a PVA to examine the sensitivity of massasauga populations to changes in various life history and demographic variables. They found that massasauga populations were highly sensitive to even small changes in adult and juvenile mortality rates. Although their specific model is limited to massasauga populations in Missouri, it is likely that most populations of *S. catenatus* will have similar demographic constraints.

Genetic Structure. All available evidence (Gibbs et al. 1994, Gibbs et. al 1997, Gibbs et al. 1998) suggests that massasauga populations are genetically structured at an extremely fine scale. Using data from six microsatellite DNA loci from three populations in Ontario and one each in New York and Ohio (Gibbs et al. 1997), it was found that all sampled populations differed significantly in allele frequencies although two populations are only 50 km apart and are part of a larger, presumably continuous population. These five populations had an average of 22.7% of alleles that were population-specific. Data from a different kind of genetic analysis (RAPD alleles; Gibbs et al. 1994) essentially provided the same results. A more detailed examination of snakes within a single population (Killbear Provincial Park, Ontario) amplifies this finding of extremely fine-scaled subdivisions of populations (Gibbs et al. 1998).

These studies suggest that a significant proportion of the total genetic diversity in massasauga populations may be found at the level of isolated populations. It also suggests that gene flow between populations is very restricted and populations are genetically isolated and that this isolation occurred prior to European settlement of massasauga range. Conservation implications of these findings include: (1) each extant geographically-separated massasauga population (which is the case for the majority of populations) should be protected because of the unique genetic diversity found within, (2) large regional populations are probably composed of genetically and demographically isolated subpopulations and each should be treated as separate management units, (3) natural repatriation to areas where massasaugas have been extirpated is unlikely to occur quickly, and (4) massasauga populations may be genetically "pre-adapted" to population isolation and may be significantly impacted genetically by human-induced gene flow caused by purposeful among-population transfers.

Summary of Massasauga Biology

- A critical point to reiterate when summarizing the habitat requirements of massasaugas is that habitat use varies over their range. That said, massasauga habitat is associated with shallow wetland systems, such as, sedge fens, wet meadows, peatlands, or forested bottomlands and adjacent uplands.

- Preferred habitats are generally open (less than 50% canopy cover). The habitat matrix is coarse with trees and shrubs in clusters rather than dispersed throughout the area.

- Open habitat is necessary for metabolic processes that require active thermoregulation, including gestation, digestion, and shedding.

- The ground cover should be predominated by grasses or sedges. Sphagnum may also be a significant component of the substrate cover.

- Massasaugas may prefer drier, more open habitat in the summer. Gravid females typically show a greater tendency to make this selection. Populations exhibiting such a pattern will need adjacent suitable habitat in both uplands and lowlands.

- Hibernation typically occurs in areas with saturated soils and an abundance of crayfish burrows. Identifying and protecting hibernacula will be critical to protecting the population.

- A critical question to ask when assessing habitat availability is whether all of the suitable habitat components are accessible in relatively close proximity, such as foraging, gestation, and overwintering habitats.

- Prey includes primarily small mammals but also birds, lizards and amphibians.

- Massasauga movement is variable regionally and within populations. In absence of site-specific information, it is best to use average or maximum male activity range estimates from the nearest known population.

- Gravid females likely have the broadest habitat requirements, thus, habitat management objectives should at least focus on the needs of the gravid cohort. That is, wetland areas for hibernation and open canopy areas for thermoregulation and gestation.

- Massasaugas have very low reproductive rates and long ages at maturity. Thus, even low levels of human-caused mortality (e.g., collection, road kills) can have major impacts on massasauga populations.

- Age of sexual maturity varies between 3 to 8 years of age depending on growth rates (i.e., food availability).

- Mating varies regionally but occurs between mid-July to mid-September. Fertilization occurs the following spring and birth in mid-August to early September.

- Brood size also varies from 3 to 19 young, and appears related to female size.

- In most populations, females reproduce biennially (every 2nd year).

- Massasauga populations are highly sensitive to changes in adult and juvenile mortality rates.

- Recent genetic data suggest that large, geographic populations are composed of genetically unique subpopulations, which rarely experience genetic interchange. This indicates that natural recolonization of extirpated subpopulations is unlikely to occur.

SECTION II: EASTERN MASSASAUGA HABITAT MANAGEMENT

During peer review of this handbook, several State land managers expressed concern about focusing management on massasauga. Specifically, their primary question pertained to their legal obligation to manage for wild birds and mammals. While lands acquired or managed with Sport Fish or Wildlife Restoration funds must continue to serve the purpose for which they were acquired, management activities on such properties must not adversely affect federally listed or candidate species. Although Federal Aid-acquired lands cannot be managed solely for massasauga, management actions that are consistent with the purposes for which the land was acquired and that are beneficial to massasaugas are permissible and encouraged.

Overall, we believe massasauga conservation can be compatible with sport hunting and fishing management. In fact, instituting massasauga-friendly management can improve the quality and quantity of habitat for many wild birds and mammals. As you will read in subsequent pages, many of the current management objectives and techniques are compatible with massasauga conservation. In most situations, the frequency or timing of a particular action may be the only modification needed to eliminate detrimental effects to massasaugas.

Threats to Massasauga Habitat and Management Strategies

Vegetative Succession. Natural succession of plant communities from relatively open seres to closed-canopy conditions will result in habitat loss or reduction of habitat quality for many species adapted to early-successional stages (Anderson 1979, Thomas 1982, Richardson and Gibbons 1993). Several studies have documented this habitat loss phenomenon for massasaugas (Reinert and Bushar 1993, Johnson and Breisch 1993) and anecdotal information has suggested it (e.g. Bushey 1978, Middleton 1993, T. Jaworski pers. comm., Cedar Bog, Ohio; A. Breisch pers. comm., Bergen Swamp, New York, T. Anton pers. comm., Ryerson Woods, Illinois). In the past, natural processes such as wildfires, grazing and browsing, and flooding events assured that some habitat was available for early-successional species. At many locations now, however, these phenomena are tightly controlled by humans and no longer operate at historical temporal and spatial scales. In addition, succession may be accelerated by management prescriptions or other practices designed to benefit one set of wildlife species at the expense of another or to achieve an older seral stage for some other purpose while rendering the habitat less suitable for massasaugas and other species with similar niche requirements.

Specifically, loss of open habitat due to succession may affect massasaugas in at least three ways. First, areas exposed to the sun are required by all age and sex classes of temperate snakes for thermoregulation (Peterson et al. 1993) and are especially important to gravid females. Data from Cicero Swamp in New York show that gravid females spend significantly more time basking than nongravid females and males and consistently maintained temperatures above ambient while gravid (Johnson 1995). Charland and Gregory (1990) found similar thermoregulatory patterns among northern Pacific rattlesnakes (*Crotalus viridis oreganus*). These studies support the hypothesis that viviparous (i.e., producing live offspring) female snakes can exert some thermoregulatory control over embryo development. This ability may be especially critical at the northern extremes of their range where aboveground active periods are reduced. Also, ecdysis (or shedding) and feeding often induces thermophily (i.e., selection of elevated temperatures) in snakes (Slip and Shine 1988, Gibson et al. 1989, Lutterschmidt and Reinert 1990), presumably to increase metabolic rates, and may cause them to seek open areas to potentially increase body temperature by active basking.

Second, successional changes in vegetation may alter overwintering situations for massasaugas. In peatlands, massasaugas use the spaces that occur under moss or shrub hummocks (Johnson 1995). As peatland vegetation succeeds, hummock-hollow topography gradually levels out and these overwintering opportunities vanish. In wet prairies and riparian bottomlands, use of crayfish burrows for overwintering is nearly universal. As these habitats succeed to dense shrubs or trees, conditions may become less favorable for the crayfish, and consequently, eastern massasauga hibernacula burrows may disappear. Although some crayfish construct burrows under closed canopies, use by massasaugas will decline under such conditions.

Lastly, prey communities may change with changing vegetation communities and it is possible that foraging opportunities may decrease and cause snakes to increase seasonal movements, potentially into or across unfavorable habitat.

A prerequisite for implementing a successful management strategy for massasauga is the need for explicit, lucid goals. While goals will depend upon the specific set of circumstances at any given site, land managers should establish a general goal of providing a complex of interspersed, relatively open habitat (areas where most vegetation cover is less than 0.5 m tall) with areas of relatively greater cover (grass, shrub or tree cover greater than 0.5 m tall). The relative proportions may vary but at least 50% of the cover should be relatively open.

The choice of a specific strategy or combination of strategies to use in retarding plant succession will, of course, depend on a) the stage of succession, b) the nature of the vegetation and substrate at the site, c) the areal extent of the available massasauga habitat, d) other management applications in place, and e) cost. Unfortunately, there are no simple sets of rules to guide every case. However, there is a wealth of literature about practices designed to retard succession, particularly in the management of rights-of way (ROW) and in prairie restoration efforts. In general, tools available to managers include, but are not limited to: 1) fire, in the form of controlled burns, 2) mechanical treatments, including cutting, brush-hogging, mowing and disking, 3) altering water tables, 4) treatment with herbicides, and 5) some combination of the preceding four practices. The following discussion provides more detail on these practices.

Fire may be the preferred alternative in wet prairie, fens or old field habitats (see Section II Mowing, Disking, and Prescribed Burning and Appendix A: Jennings Management Plan). In peatlands and other forested conditions, fire alone may not be practical. It is often difficult to get the right conditions to begin a burn and it is more difficult to control conditions, such as temperature, once the fire starts. Peatlands and forests present another hazard because peat and wood are fuels and the timing of burning is critical. Burning after a period of drought can result in large unmanageable burns causing more problems for massasaugas than doing nothing. In these habitats, it may be preferable to use some form of mechanical treatment followed by burning of cut material after a period of "seasoning" of the fuel. This was the preferred alternative at Cicero Swamp in central New York, a large peatland dominated by shrubs and black spruce (*Picea mariana*) (Johnson and Leopold 1998). Mechanical treatments followed by burning are a much more labor-intensive technique than simply burning. Under these conditions, it may be preferable to scale-down the size of the project to manageable units of area and then develop a rotational scheme that allows all critical areas to be burned. The schedule of rotation will be very site-specific (see Appendix A: Jennings Management Plan).

At Cicero Swamp (Johnson and Leopold 1998), material was cut in mid-winter, piled to a height of 1-2 m in the center of cut plots (75m x 75 m) and burned two weeks later when wind conditions were acceptable (less than 7 mph on the Beaufort scale). Peat soil was saturated (and frozen) to the surface at the time of the burn. Five-gallon water tanks were available in each plot to control surface fire. The burning was designed to test the effects on vegetative regrowth with the goal of creating open areas for as long as possible. In general, burning following cutting was more effective for a longer period of time than simply cutting alone (Johnson and Leopold, 1998). If possible, fire temperatures should be monitored to help guide future management efforts. Areas where individual massasaugas are known to be overwintering need not be avoided as a burn site. In one of the burn plots at Cicero Swamp, a live massasauga was observed as, or soon after, it emerged from hibernation. Its location was under the direct center of a large burn pile, which was burned one month earlier. However, caution is clearly needed (see Section II Mowing, Disking, and Prescribed Burning).

Mechanical treatments may be used in all habitat types (see Appendix A: Jennings Management Plan) and may be most desirable in peatlands and forested areas where burning is not practical, but it is more labor intensive. Many states have readily available work crews in the form of prison inmates, although it may be difficult to administer the programs and convince authorities to cooperate. An advantage to cutting is that it can be done whenever practical, even when snakes are aboveground and active, although this is not recommended. A drawback to cutting is that it needs to be repeated at regular intervals, although application of appropriate herbicides to cut stumps will increase the time between cutting intervals. Reseeding to grasses or sedges may prolong the positive effect of cutting. Cutting may be accomplished with hand tools, an assortment of power tools including chain saws and brush cutters (e.g. weed whackers fitted with saw blades), or brush hogs. Some larger devices, such as wheeled diskers, cut fairly deep into the soil and proper timing and care must be used to prevent snake mortality. Brush hogs have the advantage of ease in use and more completely affect shrubs.

Water level manipulations as a management tool is not practical or possible at all locations and may be prohibitively expensive in many situations unless water control structures are already in place. Timing of flooding and drawdowns are, of course, critical (see Section II Fluctuating Water Levels).

While herbicides effectively kill plants and are used extensively to retard succession and control exotics, relatively little is known about the effects of herbicide use on snakes, other vertebrates, and on plant community dynamics, especially in wetlands. At this time we advocate caution in their use and suggest they should be investigated further for use on woody vegetation. Johnson and Leopold (1998) experimented with several application methods in a peatland with a formulation of glyphosate approved for wetland use and found that broadcast spraying is most effective (but perhaps least desirable); wick application to cut stems works reasonably well and spread of the herbicide can be controlled better. Herbicide is best applied at the end of the growing season, but before leaffall in the north, at the time plants are drawing carbohydrate reserves into root tissues. Application of herbicides to cut stems in the dormant season may be effective but early spring through mid-summer applications should be avoided. The use of herbicides as a management tool is clearly growing due to its effectiveness and relative ease of application. Choices about which herbicide to use, application method, application rate, and time between applications must be made carefully. For more information on their use in controlling undesirable vegetation, we recommend consulting The Nature Conservancy's Wildland Weeds Management and Research Program website (http://tncweeds.ucdavis.edu/esadocs.html).

Combinations of the above methods may be most desirable, especially when dealing with woody vegetation (see Appendix A: Jennings Management Plan). At the very least, use of a combination of techniques allows for a site-specific evaluation of alternatives and will provide better information for future management efforts.

A potential problem when creating open habitat through a disturbance, or via herbicide application, is that invasive and aggressive non-native vegetation may infiltrate and dominate the site. Examples for wetland habitat include reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*). While it is not currently known if these species create unsuitable habitat directly for massasaugas, many form monotypic stands with concomitant reductions in diversity and provide little value for small mammals and possibly crayfish. The Wildland Weeds Management and Research Program website (see above) has a great deal of information about exotic plants and control methods.

Thus far the discussion has focused on herbaceous and woody shrub vegetation. In many situations, it is also possible to increase the amount of available habitat to massasaugas by cutting or harvesting standing timber adjacent to higher quality habitat. There are several silvicultural options available to achieve this but the first question that needs to be addressed is whether the tree cutting is primarily for timber yield, to benefit massasaugas, to maintain or increase biodiversity at one or more levels, or for some combination of these goals. Here, we will primarily discuss ecological forestry designed to benefit massasaugas (and other early-successional species) and will not focus on extensive or sustained-yield timber production. Options that create the two extremes of a silvicultural continuum (i.e. clearcutting with intensive site preparation and single-tree selection) will benefit massasaugas the least. Ideally, a system that will keep part of the site relatively open (25 to75%), and interspersed to the highest degree possible, with another part of the site in older age classes of trees will benefit massasaugas the most. Several studies have shown massasaugas will use forested habitats that are adjacent to open habitat, presumably as foraging space (Weatherhead and Prior, 1992; Johnson, 1995; Parent 1997). Depending on the size of the potential area available for massasauga management, patch sizes, rotation lengths, and cutting intervals can be established so that there is always at least 50% of the available forest in relatively open conditions (< 20 years old). It is also recommended that snags, some cut tree boles and slash be left in place or in piles to increase cover and foraging habitat for small mammals (Seymour and Hunter, 1999).

Regardless of the management technique(s) used, a detailed plan should be developed for all managed land that supports massasaugas. This plan should outline treatment type, treatment size, patch dynamics, and rotational schemes based upon the best available information. Often, research must be done to determine this information. There are additional concerns, more on the landscape level, that need to be included in management plans, including juxtaposition and interspersion of necessary habitat ingredients (i.e., summer and overwintering habitats) and effects of changes to the hydrological regime of the site. Habitat for crayfish and small mammals need to be considered as well. In some instances, creation of new areas of suitable habitat may be necessary.

Fragmentation. Habitat loss has clearly been a major factor in the decline of massasaugas. However, less apparent is the more subtle effect of these losses if the remaining habitat becomes subdivided or fragmented. The reason for this is that the relative value of a unit of suitable habitat tends to decrease as it becomes more isolated. Thus, two or more habitat "patches," which together equal the size of a larger patch, may not be as valuable as the larger patch. There are several reasons for this. First, there is the initial hazard of small fragment size. Smaller habitat patches, though apparently of excellent quality, may be inadequate to support massasaugas. Individuals can have substantial spatial demands. As detailed in Section 1 (Movement and Activity Range), massasaugas may move substantial distances and range over 25 ha in a season. Even if fragments are large enough to support some massasaugas, small patch size can continue to be a factor. The smaller the patch, the smaller the population size, and small populations are more vulnerable to environmental, demographic or genetic challenges (Shaffer 1981 and 1987, Lande and Barrowclough 1987, Westemeier et al. 1998). Given the apparent fine scale of the population structure of massasaugas (see Section 1 Genetic Structure), the greatest threats to massasaugas may be environmental or demographic variability, rather than inbreeding depression.

Fragmentation can also occur between habitats required at different times of the year. As explained previously (see Section 1 Habitat Requirements), massasaugas may exhibit a seasonality to their habitat use. Areas used by individual snakes may be as far a kilometer apart (Weatherhead and Prior 1992, Johnson 1995, King 1997, see Section 1 Massasauga in Time and Space). If required habitat components are isolated from one another, then massasaugas may not be able to get to them, or have to take risks to do so. Consider, for example, a road that passes through old fields next to a wetland. If the snakes endeavor to migrate to the old fields in the summer, they must cross the road. When they return to the wetlands in the fall, they must cross the road again. For snakes making these crossings, this poses a serious risk due to vehicular mortality (see Section IV Road Mortality), as well as to increased predation.

Depending on how habitat was lost during the fragmentation process, the value of what remains might be further reduced if the gaps between the patches are especially inhospitable. If that is the case, there will be new barriers to the movements of the snakes, as in the road example given previously. Barriers can come in different forms, and are perhaps best thought of in terms of their "hardness" or "permeability". Highways are clearly hard, impermeable boundaries. However, even gravel roads can form barriers, either because the openness intimidates animals that consider crossing them or because there is an actual risk. Snakes may be run over or collected by people using the road. More subtly, agricultural areas may also form barriers, though no doubt they would be more permeable than highways per unit width. Massasaugas may not be willing to cross farm fields if they are too expansive, and, as with roads, may also be subjected to increased risks in such areas. Case in point, farmers (at least in the past) have found massasaugas baled right along with their hay at harvest-time (Minton 1972, Kingsbury 1996).

Land managers have several opportunities to avoid or minimize the influence of habitat fragmentation. Ideally, massasauga habitat should not be removed if at all possible. When habitat loss is unavoidable, an effort should be made to avoid bisecting an existing fragment. For example, placing a deep-water impoundment on the edge of suitable habitat is preferable to putting it in the middle. When considering how to avoid dividing existing habitat, keep in mind the seasonal habitat shifts that might be anticipated in the region. Furthermore, the overall spatial distribution of suitable habitat fragments should be considered. The manager should think in terms of habitat complexes rather than simply thinking about each patch independently. This will foster keeping these fragments linked rather than encouraging their isolation.

Land managers may also have opportunities to "repair" fragmentation either by outright restoration efforts or by the development of suitable corridors. Two adjacent habitat fragments might be isolated from one another due to the placement of a strip of feed plots between them. However, leaving a strip of fallow fields or forest in the most direct route between the two patches might relieve the problem. Corridors that contain habitat attractive to the snakes will have the greatest likelihood of being used. Although the science behind corridor design is relatively undeveloped, studies have shown that they are often effective (Beier and Noss 1998). The design of a corridor will depend upon the species, and will be influenced by a variety of factors, such as home range size and minimum corridor width (Harrison 1992). Although corridor designs have not been established for massasaugas, an intuitive notion is that corridors with small length to width ratios will be the most effective. Snakes that have to travel the least distance between suitable habitat patches will be better off. Maximizing the width aspect of this ratio is less straightforward but relates to minimizing the edge to core ratio of the corridor. The center of a corridor may be more attractive to the snake and safer (Gates and Gysel 1978, Andren and Angelstam 1988).

Fluctuating Water Levels. Water level fluctuations can have catastrophic effects on massasaugas if poorly timed or result in permanent habitat loss. The most dire concern is lowering water levels while snakes are inactive, i.e., during hibernation. Fluctuating water levels during the overwintering period can cause mortality in two ways. First, hibernating in an aquatic environment ensures that massasaugas remain in ambient temperatures greater than 0^{B} C; thus, lowering the water table during hibernation exposes massasaugas to sub-freezing temperatures (Carpenter 1953, Maple 1968). Second, hibernating snakes are susceptible to desiccation but by overwintering in aquatic environments dehydration can be avoided (Costanzo 1989b). Thus, lowering the water table during hibernation can lead to a premature depletion of massasauga lipid stores and cause dehydration and mortality. Furthermore, submerging in water conserves lipids and liver-stored nutrients, which are not only important for inhibiting desiccation (Roberts and Lillywhite 1980, Graves et al. 1986), but also provide an energy source for reproduction following spring emergence.

Even situations where the impacts of such water level manipulation are confined to small areas devastating effects can occur. Although the constituent elements of suitable hibernacula are not completely known, research suggests that massasaugas have stringent overwintering requirements, and thus, are limited in their choices of overwinter locales. For example, at Jennings Environmental Center, 80 percent of the population concentrates its hibernating activity in a quarter acre area. This is also true for massasauga populations in Indiana (Bruce Kingsbury pers. comm.). Obviously, if water levels were lowered in this area, or even a portion of it, the population could be decimated.

Increasing water levels during hibernation has not proven detrimental. The physiology of snakes during hibernation allows them to tolerate a lack of air for an extended length of time. Several researchers, for example, found no ill effects from increased water levels after the snakes entered hibernation (Dunn 1999). However, sudden, extreme increases in water levels during the active season have had adverse effects. An entire cohort (sub-adults) of massasaugas, for example, was eliminated by a single flood event that occurred in Missouri (Seigel 1994).

In addition to these salient impacts, water level fluctuations can indirectly affect massasauga survival, particularly if such changes are permanent. Lowering water levels can encourage succession, and if unimpeded, succession will lead to unsuitable closed-canopy forest (King 1997). Even slight changes in vegetative composition can impact massasauga habitat. Either increases or decreases in water levels can reduce or eliminate crayfish habitat. By decreasing the suitability of an area for crayfish, the number of hibernation structures available for massasaugas could decline as well.

To avoid or minimize adverse effects due to water level manipulations, it is important to consider the temporal and spatial needs of massasaugas. An obvious management strategy to prevent direct mortality is to avoid lowering the water table during the hibernation period (for pertinent temporal information see Section 1 Massasauga in Time and Space). If winter water level manipulation is desirable for other management reasons, it is important to have knowledge of the spatial distribution of the massasauga population, and if possible, to restrict water level manipulations to unoccupied areas. If avoiding occupied habitat is impractical, managers should try to avoid affecting all available habitat simultaneously (i.e., within the same overwintering year). Although lowering the water table in summer is more favorable, as it allows for opportunities to choose alternate overwintering sites, it is important to consider the habitat constraints of the population and possible unforeseen circumstances. For example, at a site in Wisconsin, water level manipulations during the active season are believed to have caused extensive mortality. Massasaugas were routinely seen at this site during the 1980's. In fact, this site accounted for nearly 28 percent of all Wisconsin massasauga records during the 1980's (Hay et al. 1993). In 1989, all water impoundments were drained to replace the water control structures and were allowed to refill in the fall. A severe drought that year, however, prevented full pool recovery, leaving the adjacent wetland much drier throughout the winter. Despite intensive survey efforts, massasaugas have not been seen on the property since 1989.

Altering vegetative composition and structure can be avoided by preventing permanent water level manipulations. The effects of already permanently-lowered water tables may be reversed through wetland restoration. In restoring suitable wetland habitat, it is important to moderate the change in water levels both in vertical depth and horizontal extent. This allows massasaugas and other species to respond to such changes (Dunn 1999). Ideally, it is best to restore the "natural" water regime including levels and fluctuations but, at a minimum, re-establishing a high and dependable water table is essential.

Finally, if new impoundments or similar water control structures are necessary, it is advisable to select areas of poor quality (in terms of massasauga habitat) or areas near the periphery of occupied habitat.

Mowing, Disking & Prescribed Burning. At many prairie sites, mowing of some habitats (dike roads, old fields adjacent to prairies, occasionally the prairie itself) is practiced routinely. In addition, disking of prairies and old field habitats may be necessary for control of invasive species such as reed canary grass. Although we recognize that such practices may be important for wildlife management activities and in maintenance of prairie habitats, these activities have been known to impact massasaugas (and other snakes) through direct mortality (G. Johnson pers. comm., R. Seigel pers. observ.). Thus, managers should reach a balance between the need for these management practices and the possible negative effects on massasaugas and other species. Preventive measures that can reduce or eliminate mortality from mowing and disking include the following:

a) Raise mowers so that the vegetation is cut no lower than 4-6" above the ground. This will miss most massasaugas and other snakes.

b) Mow during periods when snakes are less active, preferably before snakes become active in the spring or after activity has ceased in the fall. Check with locally knowledgeable species experts for temporal information within your area (see Appendix B).

c) Mow during periods of the day when snakes are inactive, mainly between 11a.m.-3p.m. during the summer. Most snakes will be well under cover during these periods.

d) Disking may kill a large number of snakes in a short time period, especially in the early to mid spring when snakes are near the surface in order to bask. Thus, disking should occur only when massasaugas are seasonally inactive (winter) or when they are known to have left the habitat following spring/summer migrations. Detailed studies may be needed to determine if massasaugas are present in a given habitat and what the best period for disking may be.

It is now widely accepted that fire plays a vital role in maintaining the balance in a prairie community. Fire is considered to be a natural catalyst for biotic stability within the realm of modern prairie and savanna management. A prescribed burn reduces encroachment of the larger woody vegetation, retards undesirable species, and stimulates the response of prairie species. The use of controlled fire enhances conditions that support the prairie plants, herbivorous rodents, and massasauga rattlesnakes. Conversely, increased mortality of massasaugas can result from direct exposure to fire and increased predation due to lack of suitable cover during emergence in the spring. Direct deaths have been observed at several sites (e.g., Squaw Creek NWR in Missouri). This is usually the result of burning after massasaugas have already emerged from hibernation, and can be eliminated or reduced by burning before snakes become active.

Little research has been conducted on indirect mortality resulting from fire. The few mark-recapture studies that have been conducted on massasaugas have not indicated decreased survival following a controlled burn, but additional research (perhaps using radio-telemetry) is vital in this area. Notwithstanding the above, suggestions to minimize deleterious effects from fire are described below.

Mortality caused by prescribed burning can be prevented by burning either before the first emergence of massasaugas in the spring or by burning on days when massasaugas are unlikely to be active. The first option is strongly preferred whenever possible. At the Jennings Prairie in Pennsylvania, area managers protect pre-emergent and emerging massasaugas by measuring soil temperatures at a depth of 6" in both dry and saturated soils. Soil temperatures should not exceed 20^{B} C (64^{B} F) if a burn is to be started. (Note, soil temperatures for massasauga activity will differ among sites, so these temperatures should not be used as strict guidelines. Seek advice from regional species experts (see Appendix B). At many sites, specific dates of emergence may be another guideline; unless weather conditions are abnormal, burns conducted before 15 March should not result in massasauga mortality. Burn dates as late as 15 April may be possible in northern localities but guidance from an experienced massasauga biologist is critical in determining dates for burning.

Hibernaculum Alteration. An important, yet often unconsidered, habitat of the massasauga is the hibernaculum. While we focus our attention on creating foraging habitat, or on assuring that corridors exist between upland and lowland areas, we might overlook the innocuous little areas where the snakes spend the winter. Unfortunately, this is like protecting wetlands for turtles but forgetting that they nest on land, condemning the population despite other conditions being favorable. Not considering where the snakes are hibernating could of course have dire consequences if the area is modified while the snakes are there. More subtly, however, the hibernacula rather than the snakes themselves may be destroyed or rendered unusable by seemingly unrelated management practices.

Discussion of hibernacula "management" must be prefaced by emphasizing how critical it is to avoid disturbing them in the first place. Furthermore, given that it will not be possible to identify all hibernacula, protective efforts should include apparently suitable areas as well as known sites. What we do know about hibernacula is reviewed in section 1 (see Habitat Requirements). Hibernacula that have been studied are limited in their spatial extent, and individuals return to the same areas over and over again. This implies that suitable sites are not generally available and/or that there is a cultural component to site selection, much like leks in some birds. As a result of such factors, massasaugas become highly concentrated from the time they return to the area to prepare for hibernation, to the time they disperse in the spring. The loss of one snake is thus potentially indicative of the loss of many. All of these factors support the notion that losing any hibernaculum will have an unusually heavy impact on the local population.

Habitat alteration effects around hibernacula can be divided into direct and indirect types. An obvious direct effect would be the loss of the hibernaculum as a consequence of large-scale habitat manipulations. Mowing or burning hibernacula when the snakes are concentrated there would also have direct, obvious consequences. Such direct effects can be avoided by steering activities clear of known or potential sites, or timing activities to have them be the least detrimental. Activities that indirectly influence hibernacula may occur remotely. For example, habitat manipulations that influence the hydrology of the site may threaten it. Diversion of flow, either above or underground, could have such effects.

Given our lack of understanding of hibernacula characteristics, we currently lack the capability to add them as part of a restorative effort. Thus, mitigative efforts should not at this time depend upon hopes to do so. Should removal of hibernacula occur, it must be assumed that most of the snakes will die. However, to improve the chances that snakes might find alternative sites, removal should occur during the middle of the activity season, when most or all of the snakes are away from the area. Reconstructed areas should be designed with the characteristics of active hibernacula in mind. The level of the area should be near that of the water table to promote maintenance of a saturated, but not flooded, state. As we discover more about the needs of native crayfish, we should promote soil and hydrological attributes that encourage their colonization of the area. Whatever our success in creating suitable hibernacula, we should also anticipate a delay in their colonization. The snakes do show site fidelity, and we do not know how interested they will be in what we provide.

Monitoring the effectiveness of habitat management strategies

Once a management strategy has been implemented, it is necessary to monitor the effectiveness of the strategy and to adapt accordingly. All habitat management strategies should be based upon very specific objectives. If these objectives are presented in a quantified form (e.g. increase preferred massasauga habitat by 100%; double massasauga population size), it becomes possible to formulate some simple predictions. However, predicted effects are usually based upon limited data and managers and biologists will need to monitor the resource. Monitoring a habitat management strategy is a cyclic phenomenon in which periodic data collection is followed by further evaluation, and with a corresponding fine-tuning of the original plans (i.e., adaptive management).

There are several methods available to monitor and evaluate a habitat management strategy to determine its relative success. The preferred option is to determine if the existing population of massasaugas is responding by increasing in numbers or demonstrating increased survivorship. This, of course, requires obtaining reliable estimates of population size before and periodically following a specific action. If estimates of population size or density prior to an action are known, then the same methods used to obtain those estimates should be used at each subsequent monitoring period. Annual population monitoring is preferable, however useful information will be obtained from less frequent monitoring. We suggest obtaining estimates at least every three years, the minimum age at sexual maturity for massasaugas.

Since reliable estimates of massasauga population size are generally not available, it will become necessary to obtain it prior to an action or to use a suitable and reliable index of abundance. Suitable indices may include sightings/unit effort (e.g. snakes observed/person-hour in suitable habitat; snakes observed/km road/day or season). If estimates of massasauga abundance are not known for a particular site and it is not reasonable to determine this prior to implementation of habitat prescriptions, it will be necessary to conduct some level of survey effort that is repeatable at regular intervals post-implementation. A model survey protocol is currently being developed (Casper et al. in prep). Since gravid females show reduced vagility, care should be taken not to count gravid females multiple times.

An alternative to evaluating population changes directly is to determine if the habitat alterations resemble some unbiased estimator of preferred massasauga habitat. The best approach here is to develop a habitat model, preferably partitioned by sex and reproductive condition, using snake locations generated by radiotelemetry at the location of interest (see Reinert 1984 and 1993 for methodology). This has been done for two massasauga populations (Johnson 1995, King 1997) and their models can be used if no other information is available. However, those models have been developed for a peatland and bottomland hardwoods, respectively. Once models are developed or agreement has been reached on whether a published model is suitable, it is simply a matter of determining how closely the conditions created by the management prescriptions resemble the models. Care must be taken to measure habitat variables in an identical fashion to those used to develop the initial model. See Johnson and Breisch (1999) for a preliminary evaluation of a habitat management strategy for massasaugas eight years post-implementation of treatments to vegetation. They compared habitat models developed pre-treatment to conditions following treatment.

Summary Of Management Considerations

General Management Considerations

- Appropriate management for massasaugas also means appropriate management to maintain prairie, bog, woodland, and peat ecosystems in a near-natural state. Thus, management for massasaugas does not conflict with appropriate ecosystem management.

- Work closely with your state's endangered species staff (see Appendix C).

- Establish a working relationship with biologists experienced with massasauga biology and involve them in the decision-making process as early as possible. These biologists will be eager to work with you to improve management for massasaugas and other native species found in massasauga habitats.

- Establish a public education/outreach program in your area, hopefully with the cooperation of an experienced massasauga biologist. The more the public is involved with management issues, the greater the support is likely to be.

- Our understanding of massasauga ecology and management is still fairly limited and answers to some basic questions still require additional research.

- Massasauga habitat varies regionally, and thus, these recommendations provide general guidelines. To ensure appropriate management strategies are employed, work closely with locally knowledgeable massasauga experts.

Natural Succession

- Suitable massasauga habitat should have site canopy cover between 25 and 50 percent.
- A combination of cutting and herbicide application to woody shrubs shows promise to most effectively maintain or increase high quality massasauga habitat.

- In some situations, judicious use of prescribed burning and water level manipulations may be used. Timing, however, is critical.

- Maintaining a particular successional stage requires active management and periodic monitoring.

Fragmentation

- Habitat removal impacts massasaugas beyond the initial loss of habitat and the individuals that were there. Gradual, degradative effects will continue due to the isolation of remaining habitat fragments (patches).

- Habitat availability must be adequate for a population, not for a few individuals.

- Small fragment value will increase as connectivity to other fragments is improved. Where possible, management decisions should address fragments in terms of their arrangement in complexes rather than as individual patches.

- If massasaugas exhibit seasonal shifts in habitat use in your area, then fragments of all needed types must be adjacent or navigation between them must be feasible and safe.

- Barriers between fragments must be as permeable as possible.

- Fragments of only a few hectares that are isolated from other suitable habitat by permanent, impermeable boundaries are not going to support viable populations of massasaugas.

Fluctuating water levels

- Suitable hibernacula may be confined to specific areas, thus, knowledge of the population's spatial distribution is critical in minimizing harm.

- Lowering water levels during hibernation can have devastating effects.

- Temporary increases in water levels during hibernation do not appear to be problematic; however, permanent increases may be.

- Sudden increases in water levels during the active season can cause adverse impacts.

- Although decreases in water levels during the active season are generally acceptable, possible unforeseen events (such as a drought) can be problematic. Thus, it is advisable to avoid changes to occupied areas.

- If new impoundments are necessary, it is best to place such structures outside or on the periphery of suitable habitat.

Mowing, disking, and prescribed fire

- Avoid burning prairie habitats after massasaugas have become active in the spring.

- Avoid disking or mowing during periods when massasaugas are active if at all possible. If necessary, raise mowers 4-6" above ground.

- Do not assume that massasaugas only utilize the habitat where they are found in the early spring; massasaugas may move long distances to summer habitats, which are often quite different from their overwintering areas.

Hibernaculum alteration

- Identifying and protecting hibernacula will be critical to protecting the population.

- Vigorous preservation of hibernacula is critical to massasauga conservation.

- Hibernation sites are apparently limited in availability; they are often spatially constrained, and massasaugas show fidelity to a particular area by returning year after year.

- Given that all hibernacula cannot be identified, potential hibernacula should also be protected.

- Unavoidable activities involving hibernacula should be scheduled to avoid the time period when snakes are likely to be there.

- In addition to direct impacts on hibernacula such as removal, they may be destroyed indirectly by actions such as water level manipulation, even if remote.

- Our understanding of hibernacula is limited, and we do not have the capacity to recreate them at this time. Mitigative efforts should not rely on hibernacula restoration.

SECTION III: REINTRODUCTION, TRANSLOCATION AND HEADSTARTING

Population Management Strategies

Population Augmentation and Manipulation. Although augmenting populations through headstarting captive-bred animals or via translocation of wild-caught individuals has proven effective for some game species, the effectiveness of these techniques for reptiles remains unproven (see reviews by Burke 1991, Dodd and Seigel 1991, Reinert 1991). For example, Seigel and Dodd (in press) found that relocations of gopher tortoises have generally proven ineffective, largely due to the high sensitivity of such long-lived species to changes in mortality rates. Recent studies on timber rattlesnakes (Reinert 1999) and hognose snakes (Plummer and Mills, in review) showed that mortality rates of translocated individuals were higher than those of residents. In addition, there are serious concerns regarding the possibility of disease transmission among populations via translocation or headstarting (see Section IV Disease Transmission). Finally, because there may be substantial genetic differences among populations of massasaugas, moving individuals from one site to another may have unexpected consequences in terms of genetic structure. Thus, the feasibility of augmenting massasauga populations as a management tool remains uncertain.

Despite these uncertainties, there may be valid reasons to consider augmentation in the future. Examples include situations where all massasaugas have been eliminated from a given area or when populations have fallen below the likely threshold of a viable population size (Seigel, in press). In such cases, one can argue that augmentation will have no effect or may help the population. This is especially true if (a) other management methods have been shown to be ineffective and (b) when the reasons why the "host" population has declined are understood and addressed. Although in most situations it is not advisable, augmentation may be the only option available to conserve severely inbred populations. In all cases, we believe it is prudent to follow IUCN’s protocol for reintroduction (World Conservation Union 1994).

A major restriction to using augmentation as a management tool is a lack of basic data on the behavior and survival of either translocated or headstarted snakes (snakes raised in captivity until large enough to avoid high mortality). We consider it essential that such data be collected before augmentation can be accepted as a management tool. Thus, additional research on this topic is of high value. Some of the key questions that need specific attention are:

1) What is the survival rate of headstarted or translocated massasaugas compared with residents?
2) Can headstarted or translocated massasaugas find suitable hibernacula?
3) Can disease transmission be prevented?
4) What are the genetic differences between translocated and resident snakes?

Population Monitoring

Reliable estimates of massasauga population sizes are not generally available, nor will it be feasible to make such estimates in most areas. However, it should be possible for an experienced surveyor to obtain a relative index of the population size at a particular site. Comparing indices before and periodically after management efforts should provide a method of assessing success. Contact a regional species expert for further detail on developing a survey/monitoring program. A survey protocol is being developed by a team of massasauga experts lead by Gary Casper (Milwaukee Public Museum). Species experts (see Appendix B) and agency endangered species staff (see Appendices C and D) will have copies of this protocol when available (expected in spring 2000).

Although we would not discourage personnel from searching for massasaugas, any survey that is conducted with the intent of obtaining a valid index of abundance should adhere to the following general guidelines:

- Individuals experienced with massasaugas should conduct the surveys. Massasaugas are very secretive and large discrepancies have been observed in the ability of different individuals to find the snakes. A list of experts is provided in Appendix B.

- Massasaugas are much easier to see at certain times of the year or life cycle. Surveys should be conducted at ideal times to maximize the chance of observing as many snakes as possible. Although timing will vary from site to site, the best time to search for these snakes will be warm days in early spring. Searches for gestation sites in the summer may also be productive, as would searches at the end of the activity season.

- Survey protocols should be designed to be repeatable and easily compared to findings from other dates and times. The protocol itself should be designed in collaboration with a regional expert, but should include information that would allow determination of:
    1. the precise location of the survey,
    2. how many snakes were observed per survey effort (snakes/hour and-or km searched),
    3. the macro and microhabitat characteristics of the site where each snake was observed, and
    4. weather conditions during the survey.

SECTION IV: PUBLIC OUTREACH AND EDUCATION

Threats to massasauga survival

Persecution. "Manifest Destiny" had significant ecological consequences for the massasauga. Early European settlers killed massasaugas with vigor. McKenney (1827), for example, wrote about the abundance and persecution of massasaugas while portaging between the Fox and Wisconsin rivers. "This whole country is full of them; and so constant is the noise of their rattles . . . that the ear is kept half the time deceived by what seems to be the ticking of watches, in a watch-makers window." Numerous references to the historical abundance and persecution of massasaugas exist. For example, there are reports of hundreds massasaugas killed in Milwaukee, Wisconsin area in the 1830s (Olin 1930) and thousands killed in Portage, Wisconsin in 1849 (Western His. Co. 1880). These are only two of many such incidences that occurred during this time period. Fear and hatred of rattlesnakes did not wane in subsequent years. In fact, massasauga exploitation reached even greater levels in the 20th Century. For the first time, governments made massasauga persecution public policy. Official bounty systems were developed in Illinois, Iowa, Minnesota, and Wisconsin (Vogt 1981, Szymanski 1998). Although the exact number of snakes harvested is unknown, records from a few locales in Minnesota and Wisconsin suggest these efforts were successful. For example, bounty was paid for 4,955 rattlesnakes, some timber and some massasauga, in Houston County, Minnesota (Szymanski 1998); in Buffalo County, Wisconsin 427 rattlesnakes (timber and massasauga) were bountied in just three years (1971-1973); and in Juneau County, Wisconsin, 4,286 massasaugas were bountied between 1952 and 1972 (King 1997).

The impact resulting from this level of persecution is exacerbated by the fact that gravid female massasaugas are most susceptible to capture. As described previously, gravid females maintain high body temperatures to facilitate embryo development. To control their body temperature, females seek open areas to bask, and thus, are more vulnerable to collection. Evidence of gravid female susceptibility to collection is best illustrated by a quote from a past rattlesnake hunter, "I always thought it was peculiar that every massasauga I ever bountied was pregnant." Notably, bounties were raised from $1 to $3 for gravid females because so many hunters began holding gravid females until parturition so they could be credited for the young as well (Keenlyne 1968).

Although bounties no longer exist (the bounty in Wisconsin was terminated the same year the massasauga was State-listed as endangered), fear and hatred, and thus, persecution continues today. Undoubtedly, as the densities of massasaugas decline so too does the number of incidences of persecution. However, most populations now persist at such low densities that even the loss of a few animals (particularly, gravid females) can push a population below the minimum viable population threshold. Currently, there is evidence of persecution occurring at numerous sites across the species' range (Szymanski 1998).

Given that the contemporary decline of the massasauga is largely the result of human activities, conservation of the species will require changes in human behavior. Education is perhaps the best means to affect such changes, because it promotes conservation through voluntary compliance rather than legal coercion. Education promotes understanding and a "live and let live" philosophy, which in turn can reduce persecution, collection, and to some extent, the incidence of road mortality.

A necessary (though often overlooked) first step in the development of conservation education is the need to "convert" the very staff who are in the best position to deliver educational programs to the public. Wildlife biologists, game wardens, and land managers are often unaware of, or in some instances unsympathetic to, the declining status of the massasauga. Obtaining their cooperation is critical to the success of any education program.

Second, providing factual information to visitors is instrumental in reducing intentional killing on and off protected land. Effective educational material provides consistent, jargon-free messages. Ideally, educational material should be available in multiple formats, such as videotapes, printed brochures and Internet web sites (see Appendix D). Personal presentations by knowledgeable individuals are perhaps the most effective means of communication. Unfortunately, under-staffing forces many agencies to focus on the science of conservation, and neglect the communication aspects. Demand for educational material is surprisingly strong. As one Killbear Provincial Park visitor commented, "People never seem to tire when it comes to the massasauga. They thrive on any information that is available..." However, it is important to recognize that the public's interest in rattlesnakes generally does not stem from an appreciation of their natural history. Rather, their interest is piqued because of safety concerns. To be credible, any education program must not be dismissive of these concerns and openly address the issue of snakebites (see Appendix D).

At present, educational programs are, for the most part, simply assumed to contribute positively to conservation efforts. To ensure success, the impacts of education programs should be measured, and the feedback used to improve their effectiveness. Meaningful outreach efforts are time-intensive and often do not produce immediate results. Managers who wish to adopt such a program must be prepared to commit significant staff hours and be patient in awaiting results. Self-help educational resources (e.g. pamphlets) are less time-intensive and can contribute to public education but are not as effective as one-on-one contact with a knowledgeable professional.

Despite the clear need for public education, there are some inherent risks that managers should be aware of. Raising the profile of massasauga at a given site may attract collectors. The degree to which the snakes are publicized should depend on: (1) availability of on-site staff to monitor visitor activities; (2) site size (snakes are less vulnerable to discovery in larger parks) and (3) perceived vulnerability of the population in question (i.e., populations "on the brink" should not be subject to additional potential pressures).

Road Mortality. The combination of increasing road densities and the often high degree of movements of many species of snakes is a potentially lethal combination. Indeed, the adverse effects of road mortality are well documented in the literature (e.g., Fitch 1949, Campbell 1956, Dodd et al. 1989, Bernardino and Dalrymple 1992). A recent study (Rosen and Lowe 1994) suggested that road mortality on a highway in Arizona results in the equivalent of all snakes being killed from local area 5 km^2 in size.

Massasaugas are highly susceptible to road mortality for two reasons. First, massasaugas frequently spend the late spring, summer, and early fall in habitats distinct from where hibernation occurs. When roads bisect these habitats (as is often the case), road mortality may be severe (e.g., Seigel 1986, G. Johnson pers. comm.). Second, studies using Population Viability Analysis (Seigel, unpubl.) suggest that massasaugas populations are highly sensitive to increased rates of adult or juvenile mortality, such as might occur as the result of road traffic. An otherwise stable population of massasaugas might be rendered non-viable as a result of even a 5% increase in adult mortality. This combination makes road mortality of high concern in the management of massasauga populations.

Unfortunately, management measures to mitigate or eliminate road mortality can be expensive or politically difficult to implement. In the early 1980's, for example, Seigel (1986) documented high rates of road mortality in Missouri. The only management measure amenable to the manager was posting of signs asking visitors to watch for snakes but unfortunately this strategy was ineffective in substantially reducing road mortality.

The best solution for reducing road mortality on managed areas is likely a combination of public education and limited road closings. For example, managers at some National Wildlife Refuges (e.g., Mingo NWR in southeastern Missouri) have successfully closed refuge roads for short periods to allow snakes to cross safely. Outreach efforts can be successful in minimizing negative reactions from the public.

The closure of public roads presents a more difficult problem, since closure of these roads may not be legal and a higher percentage of the local human population is affected. In such cases, the choice may be between a "high-tech/high cost" (culverts) versus a "low-tech/high cost" (paying workers to drive along roads and "escort" snakes to the other side) solution. The latter solution may not be as difficult to implement as it seems; migrations between hibernation and other sites may follow a predictable pattern, both spatially and temporally, minimizing the time and effort needed to "escort" snakes across the road. “Escorting” has been conducted on a limited scale at Squaw Creek National Wildlife Refuge in Missouri. Road culverts will cost more to install and could require maintenance and inspection. Thus, "escorting" snakes may be both more cost-efficient, as well as, allowing a great deal of data to be collected on the population being managed.

Levees and Dikes. Although levees and dikes are clearly artificial habitats, they may be important to maintaining current populations of massasaugas. Historically, massasauga populations were probably impacted by large flood events. Individuals that were able to find refugia in trees or adjacent upland habitat were able to repopulate wetland habitats following flood events. As more wetland habitat was destroyed and populations became further fragmented, there were probably fewer areas of refugia for snakes to move to during flood events and fewer snakes to recolonize areas.

In Missouri, man-made levees have been extremely beneficial to massasaugas on two National Wildlife Refuges. While catastrophic losses from extreme flood events can still occur (as previously mentioned), these man-made levees are probably essential to the species persistence in Missouri (and perhaps other sites).

Collection. Massasaugas are popular in some circles of the pet trade, despite the fact that they are venomous. Collection of live snakes may at times occur on a casual basis by snake fanciers wanting one or more for themselves. More seriously, individuals may collect massasaugas for sale to others. Massasaugas often bring $50 or more to the collector who can sell them to pet dealers, who then turn around and sell them for $100-200 or more (Tony Wilson, Conservation Officer, Indiana Department of Natural Resources, pers. comm.).

Scientific collection may also be problematic. Study animals are often required for ecological studies, scientific collections, or as voucher specimens to provide hard evidence that the snakes reside in the area. While some projects may have a trivial impact on a population, others have had devastating effects. Keenlyne and Beer (1973), for example, sacrificed 300 adults and 800 neonates during an ecological study of massasaugas in Wisconsin. Not surprisingly, this research significantly reduced the population and recovery has not occurred in the 25 years following their study (Bob Hay, Wisconsin DNR, pers. comm.). Today, presumably the risk of such studies would be assessed as part of the permitting process although not all activities in all States require permits. In any case, property managers should be aware of the details of scientific activities on their properties to ascertain whether projects threaten populations.

The problem with collection relates to the fact that populations are often small. As outlined in Section 1 (Range wide Population Status and Trend), it is critical to avoid any further losses to populations. In the end, any removal of massasaugas, be it from road mortality, disease, or collection, affects the local population in the same way- there are fewer animals in that population.

Personnel should be suspicious of anyone with a pillowcase or snake tongs, the tools of the snake-collecting trade. A person who lacks binoculars, a camera, or hiking gear, and is in massasauga habitat, may have just dumped their poaching gear. Snake poachers, perhaps like other poachers, are often quite friendly. They will chat with knowledgeable individuals, including academics and property personnel to get the information they want. Specific details of massasauga locations should not be given out to anyone who is unfamiliar. Scientific collecting is typically a permitted process, so personnel can request to see identification and a copy of the permit. Personnel should also be wary of persons claiming to work with established scientists. Collectors often know who is doing scientific research and will use that knowledge to get locality information. Unless the scientist has introduced the individual to property personnel, their claims to be assistants or volunteers should be viewed with skepticism. As a final thought, certain individuals may prove to be much more devastating to a population than others. Conservation officers may be aware of these individuals and be able to provide the land manager with specifics about them.

Disease Transmission. Whenever humans move animals from one place to another for any purpose, either indirectly through increasing connectivity between populations or directly through translocation, an important concern is the threat of increasing disease transmission. There are numerous examples in the literature about contagious diseases that have decimated wildlife populations due to increased connectivity among populations (Hess 1996) and there is a growing concern that disease is a major factor to consider in efforts to conserve threatened species (Dobson and May 1986, Holt 1993, Wolff and Seal 1993). Enhancing connectivity between fragmented populations is attractive to conservation biologists because increasing movement between populations may reduce the probability of extinction of subpopulations and of the metapopulation. While it may not be a major concern among species with relatively low vagility, one negative consequence of increased connectiveness is enhancement of the spread of infectious diseases.

Another way to increase connectivity is to actively transport individuals from one population to another. This may include augmenting depleted populations from other, larger populations and "headstarting" newborn individuals from the source population by a period of captivity where mortality can be reduced (see Section III Population Monitoring). In either case, the concern is that there is an increased disease risk as animals are moved from captive to wild populations and between wild populations (Reinert, 1991). Captive conditions, however brief, may magnify disease due to artificial diets and stresses associated with captivity. New diseases may be introduced into the wild population from the donor population and diseases in the recipient population may also affect the donors. In addition, translocated snakes may acquire diseases from other animals that were concurrently transported or previously housed in the same container. Among reptiles, there is evidence that release of captive pet desert tortoises (*Gopherus agassizii*) and gopher tortoises (*G. polyphemus*) into wild populations has greatly contributed to the recent and ongoing epidemic of upper respiratory tract disease in these species (Jacobson 1994). Ophidian *Paramyxovirus* has been identified in several captive populations of the Aruba Island rattlesnake (*Crotalus unicolor*) resulting in significant mortality (Odum and

Goode 1994). Captive populations of massasaugas held at the Metro Toronto Zoo have exhibited the protozoan parasite *Cryptosporidiosis* spp., which has resulted in fatalities (Prior and Weatherhead 1996).

In the past, massasaugas have been relocated from their original population into other populations by both well-meaning, but misguided, individuals, as well as, by those with little regard for the consequences. While there is little documentation of large-scale relocations, there is anecdotal evidence that a large, but undetermined, number of massasaugas originating from sites in Michigan were released at a site in central Ohio (Terry Jaworski, Cedar Bog, Ohio, pers. comm.). To date, no published translocations of massasaugas by the scientific or management community exist. At this time, the authors of this handbook do not advocate translocation of massasauga for any purpose other than to conduct careful research on the translocation process (see Section III Population Management Strategies).

Clearly, managers must try to prevent the importation and release of massasauga into areas under their management authorities. It will be difficult to monitor or detect these kinds of activities, however, managers of areas with well-documented massasauga populations should be more aware of the possibility that people may release captive massasaugas there and must increase vigilance among field personnel to the extent possible. There may be times and conditions where massasaugas must be taken from the field, for example to use as part of a naturalist-led demonstration, or to implant radio-transmitters or collect blood or fecal samples by researchers. If massasaugas must be held in captivity for any length of time, it is best to maintain them in reasonably strict quarantine conditions. Animals should always be housed individually in aseptic environments. Cages should be cleaned with bleach or a comparable antiseptic fluid and rinsed before a new individual is introduced to it. If animals are kept for periods more than just a few days, blood and fecal samples should be taken and examined for protozoan, bacterial or viral infections by qualified personnel.

<u>Summary of Management Considerations</u>

Persecution

- Persecution continues to be a significant factor in the range-wide decline of massasaugas

- Populations at most sites occur at very low densities; thus, the loss of a few animals could irreparably imperil the population.

- Due to their thermoregulatory needs, gravid females are most vulnerable to persecution and collection.

- Internal education is typically first need in minimizing persecution. Often staff is unaware of the precarious status of massasauga.

- Individual communication is the most effective public outreach strategy but educational materials are useful as well.

- There can be risks to increased visibility, such as attracting collectors.

Road Mortality
- Road mortality can be a significant mortality factor for massasauga populations.

- If feasible, road closures during specific migration times should be implemented. If this is not feasible, road culverts or "escorts" may be helpful in reducing road mortality.

Collection
- From a biological standpoint, removal of individuals from a population equates to permanent loss ("death") of those animals.

- Massasaugas are viewed as a valuable commodity by hobbyists and by the poachers who hunt for them.

- Individuals claiming to be associated with scientific studies should be able to demonstrate that such is the case. Do not allow commercial or private collectors to hunt snakes on sites where massasaugas are present unless all appropriate permits have been obtained.

- Poachers will use management staff, scientists, and the literature to identify the best places to find massasaugas.

- Scientific collection may need to be scrutinized if the removal of those individuals collected will threaten the viability of the population from which they came.

Disease Transmission
- Moving individuals from one location to another introduces the risk of disease transmission.

- Captive conditions, regardless of duration, may magnify disease due to artificial diets and stress associated with captivity.

- Managers should prevent attempts of importation and release of individuals into areas under their management jurisdiction.

- If specimens must be taken into captivity, holding containers should be sterilized before and after use.

LITERATURE CITED

Adler, K.K. 1960. On a brood of *Sistrurus* from northern Indiana. Herpetologica 16(1):38.

Andren, H. and P. Angelstom. 1988. Elevated predation as an edge effect in habitat islands: experimental evidence. Ecological applications 69: 544-547.

Anderson, S.H. 1979. Habitat structure, succession, and bird communities. Pp. 9-21 in R.M. DeGraaf and K.E. Evans (eds.), Management of north central and northeastern forests for nongame birds. USDA For. Serv. Gen. Tech. Rep.NC-51.

Ashley, E.P. and J.T. Robinson. 1996. Road mortality of amphibians, reptiles and other wildlife on the Long Point causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110:403-412.

Atkinson, D. A., and M. G. Netting. 1927. The distribution and habits of the massasauga. Bull. Anitvenin Instit. Amer. 1(2).

Beier, P. and R. F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12: 1241-1252.

Bernardino, F. S. Jr., and G. H. Dalrymple. 1992. Seasonal activity and road mortality of the snakes of the Pa-Hay-Okee wetlands of Everglades National Park, USA Biol. Conserv. 62:71-75.

Bielema, B. J. 1973. The eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*, in west-central Illinois. M.S. Thesis, Western Illinois Univ. 80pp

Brown, W.S., D.W. Pyle, K.R. Greene, and J.B. Friedlaender. 1982. Movements and temperature relationships of timber rattlesnakes (*Crotalus horridus*) in northeastern New York. J.Herpetol. 16(2):151-161.

Burke, R. L. 1991. Relocations, repatriations, and translocations of amphibians and reptiles: Taking a broader view. Herpetologica 47:350-357

Bushey, C. L. 1978. Man's effect on a colony of *Sistrurus catenatus catenatus* in northeastern Illinois (1834-1976). Proc. Midw. Prairie Conf. 5:96-103.

Bushey, C.L. 1985. Man's effect upon a colony of *Sistrurus c. catenatus* (Raf.) in northeastern Illinois (1834-1975). Bull. Chicago Herpetol. Soc. 20:1-12.

Carpenter, C. C. 1953. A study of hibernacula and hibernating associations of snakes and amphibians in Michigan. Ecology 34:74-80

Chapman, B.R. and S.D. Casto. 1972. Additional vertebrate prey of the loggerhead shrike. Wilson Bull. 84(4):496-497.

Charland, M.B. and P.T. Gregory. 1990. The influence of female reproductive status on thermoregulation in a viviparous snake, *Crotalus viridus*. Copeia 1990:1089-1098.

Christiansen, J. L. 1993. Survey for new populations of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus* in eastern Iowa. Final Rep. Iowa Dept. Natur. Recour. 38pp.

Clark, D.R., Jr. 1970. Ecological study of the worm snake, *Carphophis vermis* (Kennicott). Univ. Kansas Publ. Nat. Hist. 19:85-194.

Conant, R.C. 1938. The reptiles of Ohio. Am. Midl. Natural. 20:1-197.

Conant, R.C. and J.T. Collins. 1991. A field guide to reptiles and amphibians: eastern and central North America. 3rd ed. Houghton Mifflin Co., Boston, Massachusetts. 450 pp.

Cook, F.R. 1984. Introduction to Canadian amphibians and reptiles. Natl. Mus. Canada, Ottawa. 200 pp.

Costanzo, J. P. 1989a. A physiological basis for prolonged submergence in hibernating garter snakes *Thamnophis sirtalis*: evidence for an energy-sparing adaptation. Pysiol. Zool. 62:580-592.

Costanzo, J. P. 1989b. Effect of humidity, temperature, and submergence behavior on survivorship and energy use in hibernating garter snakes, *Thamnophis sirtalis*. Can. J. Zool. 67:2486-2492.

Costanzo, J. P., J. B. Iverson, M. F. Wright, and R. E. Lee Jr. 1995. Cold hardiness and overwintering in an assemblage of northern turtles. Ecology 76(6):1772-1785.

Crawford, R. 1936. A study of the massasauga as found in Trumbull County, Ohio. M. A. Thesis. Univ. South. Calif. 83pp.

Dobson, A.P. and R.M. May. 1986. Disease and conservation. In M.E. Soule (ed), Conservation biology: the science of scarcity and diversity, pp 345-365. Sinauer Associates, Sunderland, Massachusetts.

Dodd, C. K., and R. A. Seigel. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: Are they conservation strategies that work? Herpetologica 47:336-350

Dodd, C. K. Jr., K. M. Enge, and J. N. Stuart. 1989. Reptiles on highways in north-central Alabama, USA. J. Herpetol. 23:197-200.

Dunn, S. 2000. Snakes in bogs and other wetland ecosystems *in* "Second International Symposium and Workshop on the conservation of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*: population and habitat management issues in urban, bog, prairie and forested ecosystems." B. Johnson and M. Wright eds. Toronto Zoo, Toronto, Ontario.

Ernst, C.H. 1992. Venomous reptiles of North America. Smithsonian Institution Press, Washington. 236pp.

Ernst, C.H. and R.W. Barbour. 1989. Snakes of eastern North America. George Mason Univ. Press, Fairfax, Virginia. 282pp.

Fitch, H.S. and H. Twinning. 1946. Feeding habits of the Pacific rattlesnake. Copeia 1946:64-71.

Fitch, H.S. and H.W. Shirer. 1971. A radiotelemetric study of spatial relationships in some common snakes. Copeia 1971:118-128.

Ford, N. B., and R. A. Seigel. 1994. An experimental study of the trade-offs between age and size at maturity: Effects of energy availability. Functional Ecology 8:91-96.

Froom, B. 1972. The snakes of Canada. McCelland and Stewart, Toronto. 128 pp.

Gates, J. E. and L. W. Gysel. 1978. Avian nest desertion and fledgling success in field-forest ecotones. Ecological Applications 59: 871-883.

Gibbs, H.L., K.A. Prior and P.J. Weatherhead. 1994. Genetic analysis of threatened snake species using RAPD markers. Molecular Ecology 3: 329-337.

Gibbs, H.L., K.A. Prior, P.J. Weatherhead and G. Johnson. 1997. Genetic structure of the threatened eastern massasauga rattlesnake, *Sistrurus c. catenatus*: evidence from microsatellite DNA markers. Molecular Ecology 6: 1123-1132.

Gibbs, H.L., K.A. Prior and C. Parent. 1998. Characterization of DNA microsatellite loci from a threatened snake, the eastern massasauga rattlesnake (*Sistrurus c. catenatus*) and their use in population studies. J. Heredity 89:169-173.

Gibson, A.R, D.A. Smucny, and J. Kollar. 1989. The effects of feeding and ecdysis on temperature selection by young garter snakes in a simple thermal mosaic. Canadian Journal of Zoology, 67:19-23.

Gloyd, H.K. 1940. The rattlesnakes, genera *Sistrurus* and *Crotalus*. Chicago Acad. Sci. Spec. Publ. (4):1-266.

Graves, B. M., D. Duvall, M. B. King, S. L. Lindstedt, and W. A. Gern. 1986. Initial den location by neonatal prairie rattlesnakes: functions, causes, and natural history in chemical ecology. In Chemical signals in vertebrates. IV. (eds.) D. Duvall, D. Muller-Schwarze, and R. Silverstein. Plenum Press, New York, pp.285-304.

Greene, H.W. and G.V. Oliver. 1965. Notes on the natural history of the western massasauga. Herpetologica 21:225-228.

Gregory, P. T. 1977. Life-history parameters of the red-sided garter snake (*Thamnophis sirtalis parietalis*) in an extreme environment, the Interlake region of Manitoba. Natl. Mus. Nat. Sci. (Ottawa), Publ. Zool. 13:1-44.

Gregory, P.T, J.M. Macartney, and K.W. Larsen. 1987. Spatial patterns and movements. Pp. 366- 395 in R.A. Seigel, J.T. Collins, and S.S. Novak (eds.), Snakes: ecology and evolutionary biology. McGraw Hill, New York.

Guthrie, J. E. 1926. The snakes of Iowa. Agric. Exper. Station. Bull. Iowa State Coll. Agric. Mechanical Arts 239:145-192.

Hallock, L.A. 1991. Habitat utilization, diet and behavior of the eastern massasauga (*Sistrurus catenatus*) in southern Michigan. Unpubl. M.S. Thesis. Michigan State Univ. East Lansing, Michigan. 40 p.

Harrison, R. L. 1992. Toward a theory of inter-refuge design. Conservation Biology 6: 293-295.

Hay, O. P. 1887. The amphibians and reptiles of Indiana. Ann. Rep. Indiana State Board of Agric. 28pp.

Hay, R., D. Nederlo, and D. Kopitzke. 1993. Stutus survey for the massasauga rattlesnake *Sistrurus*c *catenatus*) in Wisconsin, 1993. Wisc. Dept. Nat. Resourc., Bur. Endang. Resourc. 47pp

Hess, G. 1996. Disease in metapopulation models: implications for conservation. Ecology 77: 1617-1632.

Higley, W. 1889. Reptilia and batrachia of Wisconsin. Trans. Wisc. Acad. Sci., Arts and Lett. 7:155-176.

Hirth, H. F. 1966. Weight changes and mortality of three species of snakes during hibernation. Herpetologica 22:8-12.

Holford, C. N. 1900. History of Grant County, Wisconsin. Lancaster. 782pp.

Holt, R.D. 1993. Infectious diseases of wildlife, in theory and practice. Trends in Ecology and Evolution 8:423-425

Jacobson, E.R. 1994. Cause of mortality and diseases in tortoises: a review. J. Zoo Wildl. Medicine 25:2-17.

Johnson, B. 1988. Combat and courtship of the eastern massasauga rattlesnake – comparison of field and captive behavior. *In* M.J. Rosenbry (ed.), Proc. 12th International Herpetological Symposium on Captive Propagation and Husbandry, Zoological Consortium. Thormont, Maryland.

Johnson, B., B. Porchuk, and J. Gedif. *in litt*. Survival of translocated eastern massasauga rattlesnakes (*Sistrurus catenatus catenatus*).

Johnson, G. 1995. Spatial ecology, habitat preference, and habitat management of the eastern massasauga, *Sistrurus c. catenatus* in a New York weakly-minerotrophic peatland. Dissertation. State Univ. New York, Coll. Env. Science Forest., Syracuse, New York, 222pp.

Johnson, G. 2000. Spatial ecology of the eastern massasauga (*Sistrurus c. catenatus*) in a New York peatland. J. Herpetol. in press.

Johnson, G. and A.R. Breisch. 2000. Preliminary evaluation of a habitat management plan for the eastern massasauga in a New York peatland. Pages 155-159 *in* "Second International Symposium and Workshop on the conservation of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*: population and habitat management issues in urban, bog, prairie and forested ecosystems." B. Johnson and M. Wright eds. Toronto Zoo, Toronto, Ontario.

.

Johnson, G. and A.R. Breisch. 1993. The eastern massasauga rattlesnake in New York: occurrence and habitat management. Pages 48-54 *in* B. Johnson and V. Menzies (eds.). Proceedings of the International symposium and workshop on the conservation of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*. Metro Toronto Zoo,West Hill, Ontario. 141 pp.

Johnson, G. and D.J. Leopold. 1998. Habitat management for the eastern massasauga in a central New York peatland. J. Wildl. Manage. 62:84-97.

Johnson, T. R. And D. E. Figg. 1993. Massasauga rattlesnake conservation in Missouri. Pages 78-79 *in* B. Johnson and V. Menzies (eds.), Proceedings of the International symposium and workshop on the conservation of the eastern massasauga rattlesnake *Sistrurus catenatus catenatus*. Metro Toronto Zoo, West Hill, Ontario. 141pp.

Keenlyne, K.D. 1968. The massasauga (*Sistrurus catenatus catenatus*) in Buffalo County, Wisconsin. M.S. Thesis, University of Minnesota. 86 pp.

Keenlyne, K. D. 1978. Reproductive cycles in two species of rattlesnakes. Amer. Midl. Natur. 100:368-375.

Keenlyne, K. D. and J. D. Beer. 1973. Food habits of *Sistrurus catenatus catenatus*. Journal of Herpetology 4: 381-382.

King, R. S. 1997. Preliminary findings of a habitat use and movement patterns study of the eastern massasauga rattlesnake in Wisconsin. Unpub. Rep. U.S. Fish and Wildl. Serv. 32pp.

Kingsbury, B.A. 1996. Status of the eastern massasauga, *Sistrurus c. catenatus*, in Indiana with management recommendations for recovery. Proceedings of the Indiana Academy of Sciences 105: 195-205.

Kingsbury, B.A. 1999. Status and ecology of three species of endangered reptile on the Pigeon River Fish and Wildlife Area and recommendations for management. Final report to the Indiana Department of Natural Resources. 114 pp.

Lande, R. and G. F. Barrowclough. 1987. Effective population size, genetic structure, and their use in population management. In: Viable Populations for Conservation, M. E. Soulé, ed. Cambridge University Press, Cambridge. 189 pp.

Klauber, L.M. 1972. Rattlesnakes: their habits, life histories, and influence on mankind. 2nd ed. Univ. California Press, Berkeley. 1533 pp.

Legge, J. T. 1996. Final report on the status and distribution of the eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) in Michigan. Unpubl. Rep. U.S. Fish and Wildl. Serv., Twin Cities, Minnesota 17pp.

Linke, T. 1985. The summer movements and habitat preference of the eastern massasauga, (*Sistrurus catenatus catenatus*) on Beausoleil Island. Unpubl. rep. prepared for Parks Canada. 23 pp.

LeRay, W. J. 1930. The rattlsnake (*Sistrurus catenatus catenatus*) in Ontario. Can. Field Natural. 44(9):201-203.

Lutterschmidt, W.I. and H.K. Reinert. 1990. The effect of ingested transmitters upon the temperature preference of the northern water snake (*Nerodia s. sipedon*). Herpetologica 46:39- 42.

Macartney, J.M., P.T. Gregory, and K.W. Larsen. 1988. A tabular survey of data on movements and home ranges of snakes. J. Herpetol. 22(1):61-73.

MacCulloch, R. D., and D. M. Secoy. 1983. Demography, growth, and food of western painted turtles, *Chrysemys picta bellii* (Gray), from southern Saskatchewan. Can. J. Zool. 61:1499-1509.

Madsen, T. 1984. Movements, home range size, and habitat use of radio-tracked grass snakes (*Natrix Natrix*) in southern Sweden. Copeia 1984:707-713.

Maple, W. T. 1968. The overwintering adaptations of *Sistrurus catenatus catenatus* in northeastern Ohio. M. A. Thesis, Kent State Univ. 64pp.

McKinney, T. I. 1827. Sketches of a tour to the lakes, of the character and customs of the Chippewa Indians, and incidents connected with the treaty of Fond du Lac. Fielding Lucas, Baltimore. Reprinted by Ross and Haines, Inc, Minneapolis (1959). 494pp.

Michot, T.C. 1981. Thermal and spatial ecology of three species of water snakes (*Nerodia*) in a Louisiana swamp. Ph.D. Diss. Louisiana State Univ. 147 pp.

Middleton, J. 1993. The massasauga rattlesnake, *Sistrurus catenatus catenatus* in Wainfleet Bog. Pp. 43-44 in B. Johnson and V. Menzies (eds.). Proceedings of the International symposium and workshop on the conservation of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*. Metro Toronto Zoo,West Hill, Ontario. 136 pp.

Mierzwa, K. S. 1993. Habitat utilization and status of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*, in the Chicago Region. Pages 66-70 in B. Johnson and V. Menzies (eds.), Proceedings of the International symposium and workshop on the conservation of the eastern massasauga rattlesnake *Sistrurus catenatus catenatus*. Metro Toronto Zoo, West Hill, Ontario. 141pp.

Minton, S. A., Jr. 1972. Amphibians and reptiles of Indiana. Indiana Academy of Science, Indianapolis.

Moran, T. 1993. Current status of eastern massasauga rattlesnakes in Michigan. Pages 64-65 in B. Johnson and V. Menzies (eds.), Proceedings of the International symposium and workshop on the conservation of the eastern massasauga rattlesnake *Sistrurus catenatus catenatus*. Metro Toronto Zoo, West Hill, Ontario. 141pp.

Odum, R.A. and M.J. Goode. 1994. The species survival plan for *Crotalus durissus unicolor*: a multifaceted approach to conservation of an insular rattlesnake. In J.B. Murphey, K.

Olin, N. 1930. Reminiscences of Milwaukee in 1835-1836. Mag. Hist. 13:201-223.

Parent, C.E. 1997. The effects of human disturbance on eastern massasauga rattlesnakes (*Sistrurus catenatus catenatus*) in Killbear Provincial Park, Ontario. M.S. Thesis, Carlton University, Ottawa. 123 pp.

Peterson, C.R., A.R. Gibson, and M.E. Dorcas. 1993. Snake thermal ecology: the causes and consequences of body- temperature variation. Pp 241-314 in A.A. Seigel and J.T. Collins (eds.), Snakes: ecology and behavior. McGraw-Hill Inc., New York. 414 pp.

Plummer, M.V. 1981. Habitat utilization, diet and movements of a temperate arboreal snake (*Opheodryas aestivus*). J. Herpetol. 15:425-432.

Pope, T. E. B. 1926. The massasauga in Wisconsin. Milwaukee Pub. Mus., Milwaukee, Wisc. 1:171-181.

Prior, K.A. and P.J. Weatherhead. 1996. Draft national recovery plan for the eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) in Canada. Unpubl. Rep. for the Ontario

Reinert, H.K. 1978. The ecology and morphological variation of the massasauga rattlesnake (*Sistrurus catenatus*). Unpubl. M.S. Thesis. Clarion State Coll., Clarion, Pennsylvania. 173pp.

Reinert, H.K. 1981. Reproduction by the massasauga (*Sistrurus catenatus catenatus*). Amer. Midl. Nat. 105:393-395.

Reinert, H.K. 1984. Habitat variation within sympatric snake populations. Ecology 65:1673-1682.

Reinert, H. K. 1985. Eastern massasauga (*Sistrurus catenatus catenatus*) in Genoways, H. H. And F. J. Brenner (eds.), Species of special concern in Pennsylvania. Spec. Publ. Carnigie Mus. Nat. Hist., 11:273-275.

Reinert, H.K. 1991. Translocation as a conservation strategy for amphibians and reptiles: some comments, concerns, and observations. Herpetologica 47:357-363.

Reinert, H.K. 1993. Habitat selection in snakes. Pp. 201-240 in R.A. Seigel and J.T. Collins (eds.), Snakes: ecology and behavior. McGraw-Hill Inc., New York.

Reinert, H. K., and R. R. Rupert, Jr. 1999. Impacts of translocation on behavior and survival of timber rattlesnakes, *Crotalus horridus*. J. Herpetol. 33:45-61

Reinert, H.E. and L.M. Bushar. 1993. The massasauga rattlesnake in Pennsylvania: continuing habitat loss and population isolation. Pp. 55-59 in B. Johnson and V. Menzies (eds.). Proceedings of the International symposium and workshop on the conservation of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*. Metro Toronto Zoo,West Hill, Ontario. 136 pp.

Reinert, H. K. and W.R. Kodrich. 1982. Movements and habitat utilization by the massasauga, *Sistrurus catenatus catenatus*. J. Herpetol. 16(2):162-171.

Reinert, H. K., D. Cundall, and L.M. Bushar. 1984. Foraging behavior of the timber rattlesnake, *Crotalus horridus*. Copeia 1984:976-981.

Reinert, H.E. and R.T. Zappalorti. 1988. The timber rattlesnake (*Crotalus horridus*) of the Pine Barrens: its movement patterns and habitat preference. Copeia 1988:964-978.

Riexinger, P. and A. Peterson. 1982. Biology and status of the massasauga (*Sistrurus catenatus*) at Cicero Swamp, 1980-1982. Unpubl. Rep. Endang. Spec. Unit, New York Dept. Environ. Conserv. 27pp.

Richardson, C.J. and J.W. Gibbons. 1993. Poccosins, Carolina bays, and mountain bogs. Pp. 257- 310 in W.H. Martin, S.G. Boyce and A.C. Echternacht (eds.), Biodiversity of the southeastern United States/lowland terrestrial communities. John Wiley and Sons, Inc.

Roberts, J. B., and H. B. Lillywhite. 1980. Lipid barrier to water exchange in reptile epiderms. Science (Washington, D.C.) 207:1077-1079.

Rosen, P. C. and C. H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. Biol. Conserv. 68:143-148.

Schuett, G.W., D.L. Clark, and F. Kraus. 1984. Feeding mimicry in the rattlesnake *Sistrurus catenatus*, with comments on the evolution of the rattle. Anim. Behav. 32:625-626.

Scott, M.E. 1988. The impact of infection and disease on animal populations: implications for conservation biology. Conserv. Biol. 2:40-56

Secor, S.M. 1994. Ecological significance of movements and activity range for the sidewinder, *Crotalus cerastes*. Copeia 1994(3):631-645.

Seigel, R.A. 1986. Ecology and conservation of an endangered rattlesnake, *Sistrurus catenatus*, in Missouri, USA. Biol. Conserv. 35:333-346.

Seigel, R. A. 1994. Interim report: status and long term changes in populations of massasauga rattlesnakes (*Sistrurus catenatus*) at Squaw Creek National Wildlife Refuge. Unpubl. Report submitted to U.S. Fish and Wildl. Serv., Columbia, Missouri. 6pp.

Seigel, R. A., and C. A. Sheil. 2000. Population Viability Analysis: Applications for the conservation of massasaugas *in* "Second International Symposium and Workshop on the conservation of the eastern massasauga rattlesnake, *Sistrurus catenatus catenatus*: population and habitat management issues in urban, bog, prairie and forested ecosystems." B. Johnson and M. Wright eds. Toronto Zoo, Toronto, Ontario.

Seigel, R. A., C. A. Sheil, and J. S. Doody. 1998. Changes in a population of an endangered rattlesnake (*Sistrurus catenatus*) subjected to a severe flood. Biological Conservation 83:127-131.

Seymour, R.S and M.L. Hunter, Jr. 1999. Principles of ecological forestry. Pp 22-61 in (M.L. Hunter, Jr. ed.) Maintaining biodiversity in forest ecosystems. Cambridge Univ. Press, England.

Shaffer, M. A. 1981. Minimum population sizes for species conservation. Bioscience 31: 131-134.

Shaffer, M. A. 1987. Minimum viable populations: coping with uncertainty. In: Viable Populations for Conservation, M. E. Soulé, ed. Cambridge University Press, Cambridge. 189 pp.

Shine, R. 1987. Intraspecific variation in thermoregulation, movements and habitat use by Australian blacksnakes *Psuedechis porphyriacus* (Elapidae). J. Herpetol. 21:165-177.

Shine, R. and R. Lambeck. 1985. A radiotelemetric study of movements, thermoregulation and habitat utilization of Arafura filesnakes (Serpentes, Acrochordidae). Herpetologica 41:351-361.

Slip, D.J. and R. Shine. 1988. Habitat use, movements, and activity patterns of free ranging diamond pythons, *Morelia spilota* (Serpentes:Boidae): a radiotelemetric study. Aust. Wildl. Res. 15:515-531.

Smith, P. 1961. The amphibians and reptiles of Illinois. Illinois Natural History Survey Bull. 28:1-298.

St. Clair, R. C., and P. T. Gregory. 1990. Factors affecting the northern range limit of painted turtles (*Chrysemys picta*): winter acidosis of freezing? Copeia 1990:1083-1089.

Swanson, P.L. 1930. Notes on the massasauga. Bull. Antivenin Inst. Amer., 4(3):70-71.

Szymanski, J.A. 1998. Range-wide status assessment for the eastern massasauga (*Sistrurus c. catenatus*). U. S. Fish and Wildlife Service, Ft. Snelling, Minnesota.

Thomas, J.W. 1982. Needs for and approaches to wildlife habitat assessment. Trans. North Amer. Wildl. Nat. Resources Conf. 47:35-46.

Tiebout, H.M. and J.R. Carey. 1987. Dynamic spatial ecology of the water snake, *Nerodia sipedon*. Copeia 1987:1-18.

Viitanen, P. 1967. Hibernation and seasonal movements of the viper, *Vipera berus* (L.), in southern Finland. Ann. Zool. Fenn. 4:472-546.

Vogt, R. C. 1981. Natural history of the amphibians and reptiles of Wisconsin. Milwaukee Publ Museum 205pp.

Wallace, R.L and L.V. Diller. 1990. Feeding ecology of the rattlesnake, *Crotalus viridis oreganus*, in northern Idaho. J. Herpetol. 24:246-253.

Weatherhead, P.J and K.A. Prior. 1992. Preliminary observations of habitat use and movements of the eastern massasauga rattlesnake (*Sistrurus c. catenatus*). J. Herpetol. 26(4):447-452.

Weller, W. F. and H. J. Parsons. 1991. Status of *Sistrurus catenatus catenatus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Unpubl. Rep. 38pp.

Western Historical Company. 1880. The history of Columbia County, Wisconsin. Wis. Acad. Sci., Arts, and Lett. 56:29-48.

Whiffen, E. T. 1913. The *Sistrurus catenatus catenatus* in NY State. Bull. Zool. Soc. NY.

Wolff, P.L. and U.S. Seal. 1993. Implications of infectious disease for captive propagation and reintroduction of threatened species. J. Zoo Wildl. Medicine 24:229-230

World Conservation Union. 1994. Guidelines for re-introductions (as approved by the 41st meeting of the IUCN Council, 1995). Re-introduction Specialist Group, World Conservation Union, Gland, Switzerland.

Wright, A.H. and A.A. Wright. 1957. Handbook of snakes of the United States and Canada. Comstock Publ. Assoc., Ithaca, New York, Vols. I and II. 1105 pp.

Wright, B.A. 1941. Habit and habitat studies of the massasauga rattlesnake (*Sistrurus catenatus catenatus* Raf.) in northeastern Illinois. Am. Midl.Nat. 25:659-672.

Appendix A

Forward to Appendix A

The management plan for massasaugas at the Jennings Environmental Education Center serves as a model or template for management plans on other public or private reserves and refuges. The management plan emphasizes not only critical aspects of massasauga biology, but also the need for appropriate habitat (ecosystem) management. The overall success of the Jennings management plan demonstrates that appropriate management for massasaugas is not in conflict with appropriate habitat or ecosystem management.

Although the specifics of any management plan may require modification for local massasauga populations and habitat conditions, current management practices may require only slight or moderate modification in order to help maintain viable populations of massasaugas. Land managers are encouraged to work with an experienced massasauga biologist to implement a similar plan for their reserve.

Jennings Environmental Education Center
Resource Management Plan

PARK RESOURCE MANAGEMENT OBJECTIVES

Resource Management

- To maintain the natural atmosphere of the park's cultural and environmental setting.

- To protect the Relict prairie ecosystem, which is a Pennsylvania, as well as a nationally significant ecosystem.

- To protect status species and key resources (i.e., the massasauga)

- To maintain buffer zones along areas of development or timber sales, whenever possible.

- To prevent degradation of the resource and restore those areas where degradation has occurred.

- To manage recreational areas in ways that avoid over-use problems such as soil compaction, vegetation damage, and soil erosion and to rehabilitate those use areas that exhibit degradation from over-use.

Park Management.

- To maintain and restore the integrity of the center's natural ecosystems.

- To consider the fact that the center's primary resources and key species may be directly and indirectly impacted by outside decisions and actions.

NATURAL RESOURCE AREAS OF CONCERN

Whereas the Jennings Environmental Education Center is strongly oriented as a resource based park, it is extremely important that all features aid in maintaining the natural atmosphere of the park. Special attention should be given to the "modeling" factor of how the public perceives our stewardship and management applications.

Following are the center's primary areas of natural resource concern:

- TO PROTECT AND MANAGE THE RELICT PRAIRIE ECOSYSTEM (This is the primary habitat of the massasauga rattlesnakes at Jennings)

This 20 acre relict prairie ecosystem is a relatively unusual natural community of significant botanical interest in view of its autecology and geo-botanical history. It first rose to scientific concern in the early 1900s, but was not formally protected until 1951. Comprising only six percent of the park's total acreage, it houses nearly all of the park's endangered plant and animal species. It is located on the Western side of PA Routes 8 and 173 and on the north side of PA Route 528. It is bordered on the south by the prairie area day use management unit and on the north, east and west by a firebreak. The relict prairie ecosystem was designated a state park special management area in February of 1996. Due to its unique stature, the relict prairie ecosystem requires a further degree of explanation. In order to understand the prairie ecosystem one must consider the geologic, climatic, and botanical history of the area.

Following is a brief and simplified explanation of the Jennings prairie:

The Jennings prairie site was discovered in the early 1900's by Dr. Otto Emery Jennings. Dr. Jennings was associated with the Carnegie Museum of Pittsburgh and was also the chief naturalist of the Western Pennsylvania Conservancy. When originally discovered, the Jennings prairie was probably a tiny island of prairie species surrounded by woody shrubs and trees. It was through the publications and research of Dr. Jennings that the significance of this relict prairie site became known.

The management of the Jennings prairie has changed significantly over its history. The prairie was originally under the auspices of the Western Pennsylvania Conservancy, a private and-holding conservation group. The western Pennsylvania Conservancy's preliminary management techniques focused primarily on increasing the number of blazing star flowers (*Liatris spicata*) blooming each year. In 1981, Jennings became a state park Environmental Education Center. The park's present management approach is more holistic in nature, incorporating techniques to benefit all prairie species as well as create a stable habitat for the endangered massasauga rattlesnake and other associated fauna. It is now widely accepted that fire plays a vital role in maintaining the balance in a prairie community. A prescribed burn is conducted annually to reduce encroachment of the larger woody vegetation, retard undesirable species and stimulate the response of the true prairie species. The use of this small controlled fire enhances conditions that support the prairie plants and massasauga rattlesnake.

Holistic prairie management techniques in conjunction with concurrent and on-going prairie research are intended to help maintain this relict prairie ecosystem in its natural state. There are three trails wholly or partially within the relict prairie. A detailed vegetative analysis record is available in the park files.

The prairie ecosystem wetland consists of minor open water stand and associated wetland located near the center junction of the four relict prairie ecosystem quads. The wetland is approximately 0.11 acre in size with no major over-story. Some woody growth encroachment is present with more typical wetland vegetation such as cattails, skunk cabbage, marsh marigold, grasses, sedges, and rushes. This wetland is an important structure in that it provides the fundamental hibernacula for the massasauga rattlesnake. It is paramount that this wetland be protected and managed carefully.

MANAGEMENT UNIT OBJECTIVES

The encompassing overall goal of prairie ecosystem management is to protect, maintain and enhance a unique disjunct ecosystem in a holistic manner while maintaining acceptable levels of rare and endangered status holding species in a shared community. Toward this larger goal are a variety of secondary goals supporting specific areas. Conflict arises when a singular secondary goal conflicts with another secondary goal or detracts from the primary goal. In this ecosystem, these conflicts are common and must be resolved with a common denominator approach. Directly opposing or irreversible conflicts must be prioritized and even then often require considerable compromise. One important secondary goal is the maintenance of a safe and durable visitor integration system that will not jeopardize the resource through impact. Some specific secondary goals are; to protect the ecosystem from unnatural vegetative infiltration, maintain species composition, enhance status holding species populations, maintain concurrent research on management prescription effects, control soil water saturation and water based hibernaculum area and to prevent woody growth invasion.

RELICT PRAIRIE WETLAND AREA OBJECTIVES

- To maintain the biotic integrity of the wetland as a massasauga rattlesnake hibernaculum
- To maintain natural water table parameters as determined by historical averages.
- To control the open water area to approximate normal size as determined by historical averages.
- To control and manage the extent and size class of woody encroachment to provide immediate post-hibernation emergence cover for the massasauga.
- To provide stable habitat factors for small amphibians which provide a percentage of the massasauga rattlesnake's diet.
- To manage habitat stability for several vegetative species not found elsewhere in the park.
- To monitor hibernacula area abiotic water quality for possible presence of pollutants toxic to massasauga rattlesnakes or important food chain species. Relict Prairie Prescribed Burning (This section is relevant to Massasauga habitat maintenance)

Controlled burning is a nationally recognized and well- accepted treatment for maintaining and enhancing natural prairie ecosystems. Unlike woodland fire effects, fire is considered to be a natural catalyst for biotic stability within the realm of modern prairie and savannah management. While fire effects on any natural ecosystem are extremely complex, difficult to correlate, and often indicate false correlation, controlled burning in this area is intended to prevent generalized prairie ecosystem decadence by furthering five major objectives; retardation of weedy growth encroachment, profloric response to valued species and vegetation structure, macro-floric response of certain species, retardation of alien species, and aesthetic open space vista and savannah maintenance.

Immediate and longer-term effects of fire on complex vegetative assemblages depends on fire severity, extent and timing as well as on the characteristics of the area. Although forb assemblage fires differ from predominately grass prairies and differ greater yet from woodland fires, this burn is basically a stand maintenance fire regime modified to fit the eastern prairie situation. This regime is characterized by moderate to extremely high intensity surface fire with erratic and sometimes impressive rates.

Dominates (by fuel class) are variably killed back. The degree of mortality is often more important in this class (l.5 caliber and below) than consumption. Dominates are effected physiochemically through rapid desiccation of unhardened woody stems with general mortality achieved of around 25% moisture content reduction. Heat kill in this case is usually limited to instantaneous heating to 55-60 degrees centigrade although severe set back has been observed in fleshier plant parts at 40 degrees centigrade. Most successful quad burns produce around 60-80% mortality from direct injury based on blistered cambium and sap exudation.

Since the fire regime at Jennings must consider other factors as well as just the vegetative management, the burn plan becomes rather complex. Detailed information and past records are contained in the park files. General factors for successful burns are; spring burns only - pre emergence of Massasauga Rattlesnakes (usually March-May 10), alternate quads on alternate years, RH factors of 30 and below wind continuity most important, wind speeds over 20 mph is extremely severe, wind shifts are 90% correlated to counterclockwise (right to left from original wind direction) if in a warm high. Air temperature does not appear to be a severe factor although fuel burn continuity is difficult if under 32 degree Fahrenheit and spot fire hazards are severe if over 70 degree Fahrenheit (incendiary distance nearly doubles). Generally, air temperatures of 60 degrees F and above are associated with good burns. To protect pre-emergent and emerging Massasauga Rattlesnakes, soil temperatures must be measured at a depth of 6" in both dry and saturated soils. Soil temperatures must not exceed 20 degree centigrade (64 degree Fahrenheit).

More detailed burn regime information is available in the park files. Fire crews must be properly trained and depending upon burn conditions and crew experience, routine fire training (woodland) is often not sufficient for prairie burns. Direct injury to dominate class from below ground parts is believed to be negligible due to the fire speed resulting in shallow heat penetration. No successful empirical tests however, have been conducted to corroborate soil temperatures.

Subordinate (1 cm and less) vegetation mortality is usually due to consumption. Depending upon fire intensity, aspect, and other factors, even living tissue up to l cm. diameter is generally consumed. Mortality of subordinate vegetation is usually 100% of contacted fuel although some mosaic area may result in less than 100% of the total quad's subordinate vegetation being killed. Indirect and delayed injury through mechanical damage, sensitization, and growth loss is assumed but not monitored directly. Many normal (for woodlands) stand maintenance factors do not apply to prairie ecosystem fire dynamics. Changes to post fire relative abundance of species does occur and must be carefully considered in burn rotations.

General fire regime with specific regard to past fire observations and vegetative analysis is extremely important and present strong implications for long term distortions. Fire baseline data, therefore, is important to concurrent research and future long- term analysis.

RELICT PRAIRIE VEGETATIVE MANAGEMENT

A large component of the relict prairie ecosystem's vegetative management prescription is accomplished directly or indirectly through prescribed burning. Controlled burning is summarized in a separate prescription, and extensive information is contained in the park files.

The retardation of woody growth encroachment is important to relict prairie ecosystems particularly at their eastern extensions. Modern prairie theory embraces a polyphysic prairie concept where even large midwestern prairies were in a constant state of change with woody growth encroachment being a natural component of that change. Due to the diminutive size of the Jennings' prairie however, a natural polyphysic effect cannot be managed without approaching a 50% loss of floristic display. On an area under 50 acres, this would not be sound management. Woody growth encroachment, therefore, must be regularly interrupted and subdued. Enough woody growth should be left to present a natural appearance and teaching model. While controlled burning is the primary technique, it has limitations and needs to be enhanced with other methods. Prescribed burning is an inexpensive, fast and efficient method to slow, but not completely stop, woody growth takeover in open quads. Depending upon the vegetative control success of the fire, another method or a variety of methods must be applied.

Mechanical mowing with a brush hog can be applied to certain areas at certain times of the year, but must be integrated into other management techniques. A sickle bar mower would result in cleaner mowing, more equalized biomass, and provide better fuel thatch, but requires a biennial mow. Presently mowing is limited to fire lanes, some mosaic savannah treatment in quad A-4, and an experimental mow section in the southern section of quad A-1. Trail edge mowing is important to provide an angle of vegetative set back to avoid tunnel effect after heavy rains. This is accomplished through a specially modified sickle bar cutter mounted on a tractor. This cutter is capable of making standing angular cuts up to 35 degrees. Trail edge maintenance must be conducted at intervals from mid-May to early July. Edge cuts should be stopped in mid-July through late August to allow refoliation of trimmed plants. In most seasons, one more edge mowing in late August-early September is sufficient.

(This section applies to human/massasauga confrontation management)

Trail surface mowing of grass trail areas is conducted at regular intervals. Trail turf should not exceed 3 ½ inches and care should be taken to avoid wet conditions. Prairie Loop Trail should be left at a height of 3 ½-4 inches in April to about the first week of May. It should then be trimmed to 3 inches until the second week of July then reduced to 2.5 - 3.0 inches until the end of the third week of August. The remainder of the year the height can increase to 3 ½ inches, with a winter average not to exceed 4 inches of grass height.

Trails with vegetative borders should be maintained at 60" minimum width. Clippings should be directed into the center of the trail cut. This prevents the accumulation of organic thatch along side of the trails that becomes attractive to the massasauga rattlesnake by August creating potential conflict with park visitation and trail use. No limestone should be used in trail surfacing, repairs, etc. due to pH level influences and their subsequent effect on vegetation.

In areas where fire and mowing are not practical, mechanical brush removal by hand is appropriate. This can be accomplished with long handled pruners or by power scythe. Hand clearing is best done when soils are frozen. If mechanical reduction is necessary in the period from April to November, volunteer crews should not be used. Park forces should wear snake chap leg protection and exercise caution in operation. Woody response to fire is a problem with some species. For example, a single Aspen (*Populus tremuloides* michx) of 3" caliper may be killed back in a burn. Stress factors cause suckering and root-clone development resulting in the presence of 8 aspens of .5" caliper in the same area by the next scheduled burn. These areas can quickly expand and should be monitored. There may be some limited practicality in herbicide application under these conditions. It is conceivable that the injection or slash/spotting of a systemic herbicide would be very effective in controlling clones and fire responsive species.

Quads should be closely monitored for the presence of difficult to control alien woody growth such as multi-flora rose (*Rose multiflora*), etc. These should be eradicated as soon as possible and basal stump topically treated with a herbicide. Picloram based herbicide (Tordon) is vegetatively best, but has longer soil retention (2 years). Past experience indicates that any systemic applied at 2%+ concentrations (i.e. Roundup) will work.

Vegetative species of special concern should be monitored closely for ill effects from management techniques and baseline data on their autecology collected. Population distribution is as important as population numbers, particularly in small population management.

Soil water levels are very important to some species and should not be unreasonable tampered with. Baseline tensiometer studies have been conducted on a 10 meter square grid throughout the prairie. Pre and past tensiometer studies should be conducted when any physical changes are made to the prairie's hydrology.

The deliberate or accidental introduction of alien species should be minimized. The profloric effect of the prescribed burning retards alien forbs to a degree. Cool season and Asiatic grasses should be avoided in the prairie and surrounding areas. No non-naturally occurring vegetation (native or alien) should be introduced. No non-native seed or plant introduction of exotic species should be permitted to ensure genetic continuity. No cultivated varieties should be introduced. The integrity of the relict prairie ecosystem's botany is of primary importance and should not be compromised.

In an area whose floristic display attracts thousands of people from the national level, aesthetics is a viable factor. Assuming that none of the above safeguards to the prairie vegetative community are compromised, some overtime management for aesthetic purposes is necessary. Foremost in its attractive quality is the Blazing Star (*Liatris spicata*) bloom that peaks in late July - early August. Tens of thousands of plants in inflorescence are impressive to visitors and have become a visual yardstick of how well they perceived the prairie to be managed. Although this assumption is dangerously incorrect, good blooms of *Liatris* are important to visitor perception and should not be neglected. Ideally, *Liatris* should be well distributed with mosaic clusters.

Groups of primarily yellow composites should be maintained in dense clusters at several sites within alternate burn rotation quads. Other species and bloom color mixes enhance the visual quality of areas but are not as visually important. A sense of openness is important in context to prairie imagery and corridors and view-scapes should be considered. Some open canopy savannah stands are complimentary to prairie image and should be maintained as savannah in quad A-4, (See Resource Management Map). Single shingle oak (*Quercus imbricaria* michx) are acceptable within quad A-4 but should be maintained as independent standings or limited to small loose clusters.

Relict Prairie Ecosystem Management Objectives:

- To manage the relict prairie ecosystem in a holistic approach coordinating vegetative management with all other management considerations.

- To manage the vegetative aspects of the relict prairie ecosystem subordinate to factors relating to the massasauga rattlesnake.

- To encourage vegetative factors supportive of the naturally occurring prairie species.

- To discourage vegetative factors supportive of alien species and naturally occurring woody encroachment.

- To coordinate concurrent research focusing upon the short and long term effects of management prescriptions.

- To conduct prescribed burning of prairie quads on a scheduled basis.

- To maintain the integrity of the Relict Prairie Ecosystem by prohibiting the introduction of any species not occurring naturally.

- To maintain a vegetative pattern maximizing visitor aesthetics where feasible.

- To Protect and Manage the Massasauga Rattlesnake as a Primary component

The Endangered Massasauga Rattlesnake (*Sistrurus Catenatus catenatus*) is a species of exceptional concern at the Jennings Environmental Education Center. Primarily a resident of the relict prairie ecosystem, the massasauga is a very well known and important feature of the park. Once occupying a range extending from New York through Iowa, man-induced environmental changes have eclipsed the population to severe levels. The massasauga rattlesnake reached "Endangered" protective status through the Pennsylvania Fish Commission's Adoption of the Endangered Species List in1978. This amendment to the state's endangered species Act of 1973 instigated several investigations into massasauga habitat and range reduction. Historically the massasauga rattlesnake occurred in six Western Pennsylvania Counties. Extant populations are now recognized in three counties. During 1977, nineteen locations of historical occurrence were surveyed for the presence of massasauga and/or suitable habitat. Extant populations were verified at six localities, and suitable habitat remained at four additional sites. The remaining nine localities either lacked suitable habitat, or had such severely degraded habitat that the presence of the massasauga was considered doubtful. Seven of the localities with extant populations or potentially suitable habitat also exhibited signs of habitat deterioration.

Damming, highway construction, urban expansion, forest succession, surface mining, and agriculture are the six major factors responsible for altering massasauga habitat. This loss of habitat has substantially decreased the geographic distribution of this species in Pennsylvania and may result in the fragmentation and isolation of populations. This presents a severe problem for endangered species populations.

The Jennings Relict Prairie Ecosystem is considered to be one of the best confirmed sites and the only site under state protection with a Massasauga Rattlesnake Management effort. Overt management prescriptions of the relict prairie ecosystem fall into several main areas of concern. These prescriptions often involve other prescriptions and become a complex factor in prescription and technique integration. Prescribed burning must be carefully conducted on spring burns to coordinate the controlled burn prior to the massasauga rattlesnake's emergence from hibernation. This integration of prescriptions is essential to avoid possible large scale mortality and subsequently the severe jeopardy of an isolated population. The controlled burn should not occur with wet and dry soil temperature over 20 degrees centigrade. This factor is extremely accurate and very critical. Other snake species are not good indicators of massasauga hibernation emergence, and are therefore not reliable. Since the burn condition factors of relative humidity, air temperature and wind stability often correlate at the 1-2 p.m. time period, soil temperatures will often "kick over" between the first and second quad burn. Soil temperatures therefore must be rechecked and monitored throughout the burn day and a sensitive decision made if temperatures are too close to converting, by the second quad burn.

Mowing as a management technique must be seriously considered in relationship to massasauga habitat damage. Although a viable vegetative management option, mowing crushes the loose organic thatch and impacts the shallow A horizon to close off crayfish chimneys and tunnels. Mowing should only be conducted when soils are deeply frozen and never in any known or suspected hibernaculum areas. One of the keys to massasauga population stability is habitat stability. Vegetative management techniques and prescriptions must consider the vegetative cover needs of the massasauga. Hibernacula areas should be maintained in l" to 4" caliber cover of at least 36" height to provide adequate emergence cover. Gravid females as well as young breeding age males must have access to low cover, rather open basking area for embryo incubation and sperm production. The massasauga's poikilothermic nature requires access to variety in vegetative cover in order to maintain suitable body temperatures, as well as predator protection during body temperature maintenance. Hibernacula area protection and management is essential. Upwards of 80% of the population concentrates in a ¼ acre area for six months. These areas must be carefully managed for at least a month prior to and during expected hibernation spans. The only acceptable management technique in these areas is careful hand clearing and hydrological stabilization. Since humans are often a more direct threat to a rattlesnake's wellbeing than just through their habitat degradation, visitor pressure and patterns must be seriously considered. Visitors-snake confrontations must be minimized to protect both visitor and snake. Trail locations, lay out, width, surface and curve radius must be considered.

Law enforcement must carefully consider the direct and implied protection of the massasauga. Violations against the massasauga are violations of State Park and Pennsylvania Fish and Boat Commission Regulations. Pennsylvania Fish Commission fines are severe for endangered status species. Violations against massasaugas fall into three main categories. Other than habitat destruction and degradation, the greatest percent of danger comes from visitors who deliberately kill snakes they come in contact with. Motivation is usually fear and a distorted sense of self-protection. The second largest cause of direct human-related massasauga reduction is the live capture of snakes by amateur and paraprofessional individuals for maintenance in captivity or replacement into a "colony". Colony establishment technique is not widely accepted for massasauga populations among professionals and is not supported here. None the less there are professional and paraprofessionals that disagree and try to use the Jennings population as a colony source. For the most part they are aware of our position and operate covertly. The third human-related direct threat to the massasauga population is professional collectors with financial motivation. In some herpetological circles massasauga specimens are very salable. This last category operates extremely clandestinely and is exceptionally difficult to counter.

As a result of the advisory panel put together at the 1985 International Massasauga Symposium held at Jennings, it was agreed that genetic integrity was an important factor in the Jennings population. This discussion, however, was not unanimous and may change, as more complete genetic inter-relationships are understood. For the time being however, it is our position that we will not permit the translocation of individuals or pairs for colonization or the introduction of individuals for augmentation, of our population. Environmental education is a key component to massasauga management in terms of modifying visitor attitudes and behavior. An educated visitor clientele is much more likely to act (and react) in a more positive manner toward snake-visitor confrontations and will better support management objectives and practices. Enlightened visitors often provide information, visitor sighting records, photographs, behavioral descriptions and other usable data. A concurrent study of visitor/snake confrontation behavior is ongoing.

The Jennings massasauga population is undoubtedly the best understood and most researched in Pennsylvania. A complete status and morphological examination was completed by Dr. Reinert in 1977. On-going research has continued by several universities and park staff. Information is on file in the park records.

Reliable experts and authorities on the Massasauga Rattlesnake are still scarce, but there is a growing competency and base of data to compare. Knowledgeable and experienced resource people should be sought out. The park site should remain open to bonafied research efforts and should be receptive to comments, suggestions and changes to its management policies based upon new findings and understandings.

<u>Massasauga Rattlesnake Objectives</u>:

- To maintain the habitat factors primarily associated with the massasauga rattlesnake.
- To monitor and centralize all botanical management around the massasauga rattlesnake.
- To control and manage public access and impact to critical massasauga rattlesnake areas.
- To monitor massasauga rattlesnake population numbers and demographics
- To monitor massasauga rattlesnake population quality factors.

- To continue to conduct concurrent research paralleling management prescription techniques.
- To manage and protect primary food chains as they relate to the massasauga rattlesnake.
- To protect and manage key massasauga rattlesnake hibernacula.
- To control all outside research on the massasauga rattlesnake.
- To maintain and manage primary basking sites utilized by the post-hibernating male and gravid female massasauga rattlesnakes.
- To monitor morphological confirmation of massasauga rattlesnakes as an index to genetic continuity.
- To monitor reproduction rates of massasauga rattlesnakes, percentages of gravid females, male to female ratios, etc.
- To monitor all external factors that could impact massasauga rattlesnakes. Particular attention should be directed toward the watershed.
- To protect individual snakes from destruction, removal and unnecessary stress.
- To monitor and manipulate situations to protect visitors in massasauga habitat areas in a manner not impacting the snake.
- To monitor and where possible, maintain out of boundary corridors to reduce population isolation.

Appendix B

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Appendix D

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Appendix F

Data Collection and Land Managers

Whenever a massasauga is encountered, managers and their staff should attempt to collect the minimal information suggested below. This information may prove useful when making decisions about land use in the future and will be of great value to massasauga experts that may be called on to provide advice.

1. Date, time, general weather conditions

2. Specific location: it is important to accurately record locations, using landmarks, compass bearings from landmarks, road markers, grid points, or with a global positioning system. Specific location will enable land managers, and potentially researchers, to accurately identify important sites of massasauga use within their area of responsibility and help to guide management prescriptions.

3. Keep any dead massasaugas encountered, preferably by freezing the carcass. Valuable demographic and genetic information may then be available to researchers.

Many land managers may wish to collect additional information that will also prove useful; at the very least, collecting this information will help managers understand the massasauga and develop an all important search image for times when they conduct more rigorous searches:

1. weather information including
    - a. % cloud cover
    - b. temperature (air, substrate) at the time of observation
    - c. wind speed
    - d. relative humidity
2. habitat information, including estimates of
    - a. distance to cover
    - b. % vegetative cover at the ground and shrub layers
    - c. distance to nearest logs, rocks, and tree trunks
3. behavioral information, including
    - a. body posture (coiled, looped, outstretched, moving)
    - b. how 1st observed (saw it or heard it)
    - c. response to your presence (did it coil up and/or rattle)
    - d. was it basking, feeding, engaged in courtship or combat, other behaviors
    - e. are other massasaugas nearby; early or late in the active season, this information may help identify overwintering locations

It is relatively easy to design a simple data sheet that can be carried in truck or on one's person so this information may be compiled in a more rigorous and thorough manner.