NATIONAL RECOVERY

PLAN FOR THE

EASTERN MASSASAUGA

Prepared by the

Eastern Massasauga Recovery Team

K. Prior, Canadian Wildlife Service (Chair)

R. Black, Ontario Ministry of Natural Resources

K. Cedar, Ojibway Nature Centre

K. Frohlich, Niagara Peninsula Conservation Authority

B. Gray, Ontario Ministry of Natural Resources

B. Johnson, Toronto Zoo

J. Middleton, Environmental Policy Institute, Brock University

C. Parent, Ontario Ministry of Natural Resources

F. Burrows, Bruce Peninsula National Park

P. Pratt, Ojibway Nature Centre

D. Upton, Georgian Bay Islands National Park

A. Yagi, Ontario Ministry of Natural Resources

P. Zorn, Georgian Bay Islands National Park

for the

Recovery of Nationally Endangered Wildlife Committee

Approved:

Date:

Disclaimer

This is a review draft of the National Recovery Plan for the Eastern Massasauga. It has been prepared in consultation with members of the Eastern Massasauga Recovery Team, to define recovery actions that are deemed necessary to protect and recover the species. It does not necessarily represent official positions of the agencies or the views of the individuals involved in the plan's formation. The goals, objectives, and recovery actions identified in the recovery document are subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations, as well as to modifications resulting from changed objectives or new findings.

Acknowledgements

Background research by M. Oldham, H. Parsons, and W. Weller (Weller and Parsons 1991, Weller and Oldham 1988, 1993) provided an essential foundation on which to base this document. We appreciate their initiative and thank them for their efforts in recording the distribution and decline of the Massasauga in Ontario. Thanks also to the following people for valuable discussion, information, and/or critical review of this manuscript; A. Breisch, G. Casper, J. Delahanty, H. L. Gibbs, R. Hay, G. Johnson, R. King, P. Mackenzie, M. Oldham, C. Parent, S. Parker, B. Porchuk, H. Reinert, R. Seigel, J. Szymanski, J. Wegner, G. Watkins-Colwell, D. Wilks, and D. Wynn. Parks Canada (Ontario Region) provided the financial support required to complete this report.

Table of Contents

Recovery plan summary

Canadian populations of the Eastern Massasauga (*Sistrurus c. catenatus*) are restricted to Ontario where they are legally protected under the Fish and Wildlife Conservation Act (1997). The sub-species is listed as *threatened* in the province and *threatened* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Massasaugas are known to persist in Ontario in four geographically distinct population localities of unequal size and extent. Two relatively small populations occur in the isolated natural communities of Wainfleet Marsh (1500 ha, peatland) and Ojibway Prairie (4 parcels totaling ca. 456 ha, primarily tallgrass prairie). In contrast, moderately large regional populations occur on the Bruce Peninsula (ca. 1963 km^2, mixedwood plains ecoregion) and along the islands, shores, and inland portions of eastern Georgian Bay (ca. 5484 km^2, mixedwood shield ecoregion).

The goals of this recovery plan are to (1) maintain or restore viable populations of Massasaugas in tallgrass and peatland ecosystems in 30 years and (2) retain the current distribution and connectivity among local populations throughout the Bruce Peninsula and Georgian Bay regions in perpetuity. Depending on a variety of factors (e.g., changing landuse practices, socio-economic priorities, catastrophes) our ability to meet the goal of securing viable prairie and peatland populations in Ontario may require active repatriation of populations to currently unoccupied localities.

The plan identifies five major strategies for sub-species recovery; tactics aimed at realizing our goals. First, *public education and outreach* will receive high priority. The second strategy is to *conduct research* to (a) quantify habitat use and availability within the Ojibway and Wainfleet ecosystems, (b) evaluate population viability, and (c) determine the prospects and actions required for population recovery. The third recovery strategy is to *monitor and manage populations* to reduce vulnerability. The fourth strategy is to establish a broad *shelter areas network* for Massasaugas across all population regions. Fifth, we plan to develop an internet-based *communications and coordination* strategy to facilitate (a) informed and complimentary actions among team members, (b) direct collaboration with individuals and agencies engaged in recovery of tallgrass and peatland ecosystems, and (c) cooperation with US counterparts for global recovery of the sub-species.

We estimate the cost for full implementation of the recovery plan (Priority actions 1-3) over five years to be ca. $622,000.00. The highest priority actions are initially estimated to cost a total of ca. $315,000.00. Where possible, we expect that cost-sharing arrangements (information and labor exchanges) will allow Massasauga recovery actions to be integrated within ecosystem-based management plans (e.g., Wainfleet Bog Management Plan), thereby reducing total financial expenditures and increasing conservation efficacy.

Finally, this recovery plan is written in the pro-active style specified in the recovery plan format guidelines (e.g., PVAs *will* be done rather than, PVAs *should* be done). Ideally, all recovery actions (or revisions thereof) will be carried out. We encourage those using this document to keep these considerations in mind and to propose and support revisions of the plan where warranted by new research findings, evaluations of population status, and changes in social, economic, and political realities.

Section I

Background and status evaluation

Introduction

The Eastern Massasauga Rattlesnake (*Sistrurus c. catenatus*) is the only extant venomous snake found in Ontario - the only province in which it occurs in Canada. As a member of the Family Viperidae, Eastern Massasauga Rattlesnakes (hereafter, Massasauga) can be distinguished from other Ontario snakes by the presence of a segmented rattle at the tip of the tail and a heat-sensitive pit or opening located between the eye and nostril. Massasaugas are relatively small rattlesnakes measuring up to ca. 76 cm in total length as adults. Their grey to brown background colour is overlaid by a row of dark brown to black dorsal blotches and three alternating rows of smaller lateral blotches. Several of the posterior blotches may join to encircle the tail and some individuals display a broad dorsal stripe (Cook 1984; Ernst and Barbour 1989).

Habitat loss and a maligned reputation have contributed to the decline of the Massasauga across its' entire range (Greene and Campbell 1992). Massasaugas were afforded province-wide legal protection through the Ontario Game and Fish Act in May 1990, legislation which prohibits their being harassed, taken, or killed. In April 1991, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the species as "threatened" in Canada based on the status report prepared by Weller and Parsons (1991). A dramatic decline in the species' range in Ontario over the past three decades (i.e., 1960 - 1990; Weller and Oldham 1993) was the principle evidence used in support of the recommendation for a threatened status.

Massasaugas are perhaps less secure in the U.S., although federal status as a species at risk is still pending. As in Ontario, evidence in the U.S. of distribution-wide habitat loss and fragmentation, population isolation and extirpations, and range contraction have prompted urgent concern for the future of this species (Greene and Campbell 1992; Greene 1994). While accurate size estimates are unavailable for any local populations, distribution records and the occurrence of appropriate habitat suggest that the largest and likely the most viable populations remaining probably occur at the very northern edge of the species' distribution in Ontario, and perhaps the northern

portion of Michigan's lower peninsula. These facts point to the need for a coordinated, international recovery effort if the species is to be conserved across its' range.

Safety and negative public attitudes towards venomous snakes are among the most important obstacles we face in recovering rattlesnakes in Ontario. As a result, we recognize the need to inform and engage local communities in recovery planning and action. First and foremost people need to know that rattlesnake venom is a highly evolved haemotoxin which is injected through a bite (via retractable, hollow fangs) during prey capture and defense. Despite having a potent venom, all evidence suggests that bites from Massasaugas are both uncommon (Prior and Weatherhead 1992) and rarely life-threatening in humans - a full recovery being the normal outcome (Greene and Campbell 1992; C. Parent - pers. comm.). Nevertheless, all those suspected of being bitten by a Massasauga should seek medical attention immediately. Treatment of venomous snakebite in Ontario is coordinated by the Poison Control Centre at Sick Children's Hospital in Toronto. The Ontario Ministry of Health distributes antivenin, used in the treatment of Massasauga envenomation, to depots throughout the range of the species in the province.

Evaluation of current status

Factors influencing vulnerability and status

Biological considerations

Status of populations

We are unaware of any study that has rigorously assessed local population size anywhere across the species' range. Qualitative estimates of declines in population size and consequent extinctions are all that are currently available (e.g., Reinert and Bushar 1993). In Ontario, perhaps as much as half the historic range of the species has been lost over the past two centuries (Weller and Oldham 1993). There is no evidence that any local populations in the province are experiencing population increases. In the absence of recovery actions (public education, habitat protection, and population management), the expectation is that local population isolation and extinctions will continue throughout Ontario. In particular, we believe the *Ojibway population* to be in extreme

jeopardy of extinction. The *Wainfleet population* may be in a relatively lower risk category simply because it occupies a relatively larger habitat area.

Past and current distribution

The historic range of the Massasauga in Canada probably extended throughout much of southwestern and west-central Ontario. Their pattern of post-glacial invasion into Ontario likely mirrored the successional advance of scattered mesic prairie and wetland habitats (Schmidt 1938; Bleakney 1958; Cook 1993), communities with which they are often associated today (Reinert and Kodrich 1982; Seigel 1986; Weatherhead and Prior 1992; Middleton 1993; Pratt *et al*. 1993). Local extinctions, resulting in an initial range contraction and the isolation of populations in Ontario (and elsewhere), undoubtedly began in response to climatic cooling and the succession of vegetation communities following the hypsithermal interval (i.e., 8500-5000 B. P., Schmidt 1938; Pielou 1991). However, European settlement is thought to have precipitated drastic changes in the distribution of Massasaugas over the past two centuries (see Ojibway Nature Centre website for animated illustration - http://www.city.windsor.on.ca/ojibway/rattler.htm). In particular, major landscape-scale changes in habitat availability resulted from land-clearing and the drainage of wetlands for agriculture. Correlated patterns of wetland losses, population isolation and extinctions have been documented by Weller and Oldham (1988, 1993) through the use of both museum records, published papers, unpublished reports, and recent (herpetofaunal) survey data. As much as 20 to 30 percent of southwestern Ontario may have been covered by wetland habitats during the early 1800's (Snell 1987). Current estimates suggest that less than 25 percent of the original wetland area remains intact today (Weller and Oldham 1993).

Massasaugas are currently known to persist in four regions of Ontario: (1) the eastern shores of Georgian Bay and Manitoulin Island; (2) the Bruce Peninsula; (3) Wainfleet Marsh near Port Colborne; and, (4) the Ojibway Prairie complex in Windsor (see Fig. 1).

The *Georgian Bay regional population* follows the eastern shores of Georgian Bay (from near Port Severn north to Killarney; ca. 44°47'-46°0'N, 79°0'-83°0'E), thus falling within the Ontario municipal counties of Simcoe, Muskoka, Parry Sound, and Sudbury. Beyond the Georgian Bay shore, Massasaugas may occur inland as far as ca.

50 km and can also be found on many of the islands in the bay itself (e.g., Beausoleil Island). Massasaugas found between the French River and Killarney may represent the northernmost occurrence (46°N) for the species across its entire distribution. Collectively, the Georgian Bay population is larger and occupies a greater area than any other extant regional population in Canada. While suitable habitat occurs throughout much of the Georgian Bay area, Massasaugas across this region are probably organized in a series of local *sub-populations*, many of which may be both demographically and genetically isolated (Gibbs *et al*. 1997). For example, Massasaugas at Killbear Provincial Park are genetically distinct from those at Beausoleil Island (part of Georgian Bay Islands National Park), ca. 50 km to the south. We suspect that these data may be representative of a general pattern of fine-scale genetic structure found in all large regional populations of Massasaugas.

The *Bruce Peninsula regional population* is confined to the Bruce Peninsula and Cove Island on the western side of Georgian Bay (and perhaps scattered localities around the periphery of Manitoulin Island). Historically common (LeRay 1930), Massasaugas in this population still occur from near Wiarton (44°45'N) north to the tip of the peninsula (45°15'N) in Bruce (and perhaps Manitoulin) County. As with the Georgian Bay population, habitat heterogeneity and the behavioural ecology of Massasaugas have probably given rise to a series of demographically and genetically isolated local sub-populations across the peninsula (the pattern of sub-population distribution remains undocumented at present). Importantly, prior to about 1950 the Bruce Peninsula and Georgian Bay populations are thought to have formed a single, very large regional population, connected via the southern shore of Georgian Bay (Fig. 1, Weller and Oldham 1993). However, the high degree of genetic divergence between the Bruce Peninsula and Georgian Bay populations suggests that these two regional populations were *genetically isolated* from one another long before the arrival of Europeans and any major changes to the landscape (Gibbs *et al.*1997).

The *Wainfleet* population is highly isolated, being restricted to Wainfleet Marsh (42°55'N, 79°18'E), a 1500 ha peatland, surrounded by roads and agricultural lands located near Port Colborne, Niagara Region (Fig. 2). The next closest known population

occurs about 100 km to the east in Bergen Swamp near Byron, New York. In early June 1998 two adults were observed together at the northern end of the Wainfleet peatland, one of which was illegally removed (and subsequently returned) by an amateur herpetologist (B. Johnson - pers. commun.).

Massasaugas are thought to have been moderately common around Windsor, Ontario as recently as the 1940's. Until that time, suitable habitat (tallgrass communities) may have extended for as much as 50 km^2 to the southwest of the city (Lumsden 1966; Pratt *et al.* 1993). Today, the *Ojibway* population is confined to a complex of three relatively small habitat patches within the city limits of Windsor and LaSalle (Essex County, ca. 42°14'-42°16'N, 83°02'-83°05'E, Fig. 3). Massasaugas are regularly reported from both Spring Garden Prairie (140 ha) and Sandwich West Woodlot (235 ha). These sites are separated by about 1 km of unsuitable habitat (paved urban roadways and residential housing). Confirmed sightings of Massasaugas from these sites are moderately common. Importantly, the highest concentration of confirmed sightings of Massasaugas in the Ojibway population over the past 30 years has come from the Sandwich West Woodlot (Pratt *et al*. 1993).

The third habitat remnant included in the Ojibway complex is actually composed of two adjacent sites; Ojibway Prairie Provincial Nature Reserve (65 ha) and Tallgrass Prairie Heritage Park (16 ha), both located about 1 km west of Spring Garden Prairie. There have been no confirmed sightings of Massasaugas at the Nature Reserve/Heritage Park site since the mid 1970's. However, no intensive surveys have been conducted and suitable Massasauga habitat appears to be available at this site.

Because habitat patches composing the Ojibway complex are relatively isolated from one another Massasaugas occupying these sites are probably demographically isolated and should be considered as such from a management perspective. The next closest free-ranging population of Massasaugas occurs ca. 60 km to the west (across the Detroit River) at the University of Michigan's Matthaei Botanical Gardens in Ann Arbor, Michigan.

There are several additional localities in Ontario with potentially suitable habitat for Massasaugas (e.g., Durham/Markdale [44°15N, 80°45'E], Greenock Swamp

[44°07'N, 81°22'E], Canard River Valley [42°10'N, 83°02'E]). However, none of these sites have been carefully surveyed in recent years. These and other locations may harbor (isolated) populations of Massasaugas since the species is known to have remained undetected in some regions for considerable periods of time (H. Reinert, pers. comm.). Any areas found to have appropriate habitat (but no extant populations) should be considered as candidate sites for population repatriation.

In the U.S., the Eastern Massasauga occurs in 10 states; Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin. As in Ontario, distribution of the species throughout this range in the U.S. was at one time more extensive. Human-induced habitat loss over the past +300 years, specifically the alteration and elimination of wetland, prairie, and savannah communities, is seen as the principal cause of population isolations, extinctions, and range contraction (Greene and Campbell 1992; Greene 1994). Although the survival outlook in the U.S. varies from state to state, many populations may be declining and/or are relatively small and geographically isolated (see Johnson and Breisch 1993; Mierzwa 1993; Reinert and Bushar 1993).

Habitat considerations

Overview of habitat requirements

Our understanding of the habitat requirements of Massasaugas in Ontario (and elsewhere) offers two important insights for population management and species recovery. First, there are predictable temporal (seasonal) and individual differences in habitat use among local populations. Most Massasaugas tend to overwinter in damp or water-saturated sites (e.g., seeps or small peatlands), often characterized by the presence of Sphagnum moss (*Sphagnum* spp.). Following spring emergence (May-June), gravid females (inseminated during the previous active season) move toward open, often rocky gestation sites which they occupy until parturition (August-September). By contrast, males and non-gravid females (females appear to reproduce every second or third season) move toward structurally more-complex vegetation communities including mixed coniferous-deciduous forests, grassy shrublands, and beaver meadows to forage,

court, and mate. In late summer and early autumn males and females (regardless of reproductive status) make the return trip to overwinter habitats. As a result of differential habitat needs Massasaugas are obliged to move among various vegetation communities. Where these habitats are distributed in fragmented patches Massasaugas are required to cross roads, agricultural landscapes, and other open habitats thereby increasing the probability that they will encounter predators, humans, and automobiles. Thus, effective habitat protection and management for Massasaugas will often require that planners adopt a relatively coarse landscape-scale perspective (Dunning *et al*. 1992).

The second general contribution offered by studies of habitat use is the recognition that populations across the species' range occupy strikingly different ecological communities. For example, in Ontario alone Massasauga populations are found within deciduous, coniferous-deciduous, tallgrass *and* peatland communities. Thus, in many cases habitat protection and management actions within the province will need to be population-specific (Weatherhead and Prior 1992; Mierzwa 1993).

Massasaugas appear to hibernate singly though individuals may cluster in favorable habitats (e.g., water-saturated soils and wet depressions; Parent and Weatherhead unpubl. data). Individuals show hibernation site fidelity between years, although exceptions have been observed (G. Johnson - pers. commun.; R. King - pers. commun.).

As noted above, gravid females tend to be relatively sedentary, focusing their activities around various types of cover (large rocks, overturned stumps, brush or debris piles; Reinert and Kodrich 1982; Johnson 1995; C. Parent - unpubl. data; K. Prior - unpubl. data) in open areas. Local gestation sites may be used by several females in a given season and appear to serve as traditional sites, being occupied by the same individuals in successive breeding years.

Detailed assessments of habitat use and activity patterns of Massasaugas in Ontario have only been conducted for the Georgian Bay and Bruce Peninsula populations (Weatherhead 1984; Weatherhead and Prior 1992; Parent 1998). We know little about the specific micro-habitats used or the proportion of total area occupied by Massasaugas at either Wainfleet or Ojibway. However, studies of the spatial ecology,

habitat preferences and management of Massasaugas at Cicero Swamp, New York (Johnson 1995; Johnson and Leopold 1998) may serve as a model for Wainfleet and other peatland populations.

Activity ranges average 25 ha on the Bruce Peninsula (Weatherhead and Prior 1992) and are of a similar size in Cicero Swamp (26.2 ha - Johnson 1995). Working in old field and meadow habitats in Pennsylvania, Reinert and Kodrich (1982) found Massasauga activity ranges to be considerably smaller (1 ha). Females exhibit significantly smaller ranges than males (Weatherhead and Prior 1992; Johnson 1995). As with many other species, gravid Massasaugas generally have smaller activity ranges than non-gravid individuals (Reinert and Kodrich 1982; Johnson 1995; Parent 1998).

Status of essential habitat

There are no estimates of the amount of essential habitat available within either the Georgian Bay or Bruce Peninsula population regions. However, studies currently underway to assess potential habitat in the greater Georgian Bay ecosystem (P. Zorn, pers. commun.) and the landscape ecology of the sub-species distribution (K. Prior, unpubl. data) will shed light on habitat discontinuities and sub-population disjunctions (see also Hutchinson *et al*. 1993). High quality habitat for Massasaugas is apparently secure in both Georgian Bay or Bruce Peninsula population regions within the boundaries of provincial (e.g., French River, Grundy Lake, Killbear, Massasauga) and national (i.e., Bruce Peninsula, Fathom Five, Georgian Bay Islands) parks. Nevertheless, these areas comprise only a small part of the total distribution of Massasaugas within these two regions of Ontario (< 5%), and habitats (and populations) found in parks *per se* are not immune to disturbance and negative impacts.

Wainfleet Marsh (1500 ha) has been designated as a Class 1 wetland by the Ontario Ministry of Natural Resources (OMNR) and the least disturbed sections of the bog (ca. 200 ha) have ANSI status (Area of Natural or Scientific Interest). Until recently the majority of the bog was controlled by a single landowner (Erie Peat Company) and was mined for peat as recently as 1980 (Jonsson-Ninniss and Middleton 1991; see Fig. 3). Large-scale peat extraction was curtailed for economic reasons (the peat is a short-

fiber type of low-quality) and the land is now considered commercially worthless for this purpose. Purchase of this privately held portion of the bog was recently negotiated by the Nature Conservancy of Canada, the Niagara Peninsula Conservation Authority, and OMNR. A draft co-management plan for the bog has been prepared which aims to restore ecological integrity to this provincially significant community (Niagara Peninsula Conservation Authority 1998). A small portion of the bog (< 10 ha) is owned by a garden-supply operation (Fay Farms) which extracts loose peat on a small scale (J. Middleton - pers. commun.). It is currently unknown which portions of this peatland receive most use by Massasaugas and how large an area would be required to sustain a viable population there.

The Ojibway Prairie complex has mixed ownership. The Spring Garden Prairie site (140 ha, see Fig. 4) has ANSI status and is considered an Environmentally Significant Area (ESA) by the Essex Region Conservation Authority (ERCA). The majority of this site is owned privately. Sandwich West Woodlot has also been designated an ESA by ERCA. However, this 235 ha section is privately owned by approximately 250 landowners and portions of it were recently re-zoned for residential development. The Ojibway Prairie Provincial Nature Reserve (65 ha) is owned by the Province of Ontario, while the City of Windsor owns the Tallgrass Prairie Heritage Park (16 ha) - as such, both are considered protected and generally secure (see Pratt *et al.* 1993).

Existing and future land use conflicts

Outside protected areas, the development and use of industrial, residential, agricultural, and recreational properties (cottages) and roads (expansion, surfacing) within the Georgian Bay and Bruce Peninsula regions represent important land-use conflicts with respect to the conservation of Massasaugas. Throughout the Georgian Bay and Bruce Peninsula population regions, forest management activities including timber harvesting, access road construction, mechanical and chemical site preparation and tending operations occur to varying degrees on both Crown and private lands. Within protected areas, the expansion of roads, hiking trails, and other facilities will undoubtedly increase

the frequency of encounters between people and Massasaugas, resulting in greater disturbance, increased mortality rates, and possibly the incidence of snakebite. Regardless of increases in direct development within Massasauga habitats, human presence inside protected areas has increased significantly in many areas. For example, Bruce Peninsula National Park recorded a 150% increase in the number of visitors between 1988 and 1994 (18,858 vs. 45,781; D. Wilks pers. commun.). Such increased activity has undoubtedly had negative repercussions for snake populations in at least some parts of this park.

G. Johnson (pers. commun.) has documented the death of a Massasauga as a result of plowing on agricultural lands adjacent to Cicero Swamp, New York. Agricultural activities and road traffic probably cause Massasauga mortalities on lands adjacent to Wainfleet Marsh. Ditching and draining associated with peat extraction operations have seriously affected the local watertable and drainage patterns. These changes have contributed to an alteration in structure and composition of the vegetation communities available for Massasaugas (Jonsson-Ninniss and Middleton 1991).

The main land-use that could affect the Ojibway Prairie population are urban housing development, road improvement, and traffic on adjacent roads.

Effects of human activities

Urban and rural development

Development of urban and rural lands can affect Massasauga populations both directly by causing habitat loss (land-clearing, wetland drainage) and fragmentation (roads), and indirectly by increasing the frequency of encounters with humans and raising background mortality rates. Preliminary viability analyses suggest that a minimum 83% adult survival rate is required to maintain a stable population of Massasaugas (Seigel and Sheil 1995).

Recreation

Increasing recreational activity in essential habitats like hibernacula and gestation sites may have costs for Massasauga populations including abandonment of traditional activity ranges and direct mortality (see Parent 1998).

Private collecting and pet trade

Private collecting of Massasaugas from the wild is known to have occurred in Ontario and elsewhere in recent years (M. Lachine - pers. commun.,) and removal for the pet trade is a potentially important problem effecting some populations (A. Breisch - pers. commun.). That collectors may be able to target gravid females at traditional gestation sites at Ojibway and Wainfleet should be cause for concern among local resource managers. The removal of even a few (e.g., 4-6) reproductive females from small populations could significantly reduce recruitment and jeopardize future viability (Seigel and Sheil 1995).

Prevention of catastrophes

Natural catastrophes may have significant effects upon particularly small and isolated populations of Massasaugas. For example, wildfire burning of prairie and old field habitats in the Ojibway complex could lead to significant mortality and the extinction of this population (see Seigel 1986). When planning prescribed burn schedules managers should carefully consider the possible impact on snakes. Record flooding of Squaw Creek National Wildlife Refuge in northwestern Missouri during the spring of 1993 resulted in a major disturbance to plant communities and significant changes in population structure, sex ratio, and reproductive frequency of the local Massasauga population (Seigel *et. al*. 1998).

The role of the Massasauga in ecosystems and interactions with humans

Ecological considerations

Ecological role

Massasauga populations in Ontario are representative components of significant ecological communities. In particular, the Wainfleet and Ojibway populations are characteristic members of increasingly threatened, remnant natural communities (e.g., tallgrass communities; Rodger 1998). Nevertheless, the ecological role(s) played by snakes are often unrecognized, in large part due to their inconspicuous nature.

There is no evidence that snakes routinely reduce prey populations (but see Rodda *et al.* 1997). As such, Massasaugas probably exert only minor pressure on

vertebrate prey populations (principally rodents and to a lesser extent shrews, ground-nesting birds, snakes and frogs - Keenlyne and Beer 1973; Seigel 1986; Hallock 1991). Feeding rates are apparently quite low with fewer than 35% of specimens analyzed containing any food items (Missouri - Seigel 1986; Michigan - Hallock 1991). Hawks, owls, corvids, large wading birds and carnivorous mammals all represent potential predators of Massasaugas. Other snake species and owls may be particularly important predators of neonates in some areas (Ernst and Barbour 1989; R. King - pers. commun.).

Taxonomic position

Geographic variation in the Massasauga is so poorly understood that there is currently no basis for identifying any particular portion of the range in terms of phylogenetic significance (Greene 1994). Three subspecies are currently recognized (i.e., *Sistrurus c. catenatus*, *Sistrurus c. tergeminus*, and *Sistrurus c. edwardsii*), based on vaguely defined clinal variation (Minton 1983). On-going molecular systematics research may provide a genetic basis for classification (S. Mackessy - pers. commun.).

Socio-political considerations

Public appeal and intrinsic value

Snakes in general, and rattlesnakes in particular, tend to evoke either a sense of curious fascination and wonder, or repugnance, if not overt hostility. A dislike of snakes by some members of the public is an important issue that must be addressed if populations of Massasaugas are to persist and recovery is to be successful. Humans throughout the province continue to readily kill Massasaugas (and other species) on sight (see Sutton 1992). We recognize that the ultimate causes of the species decline in Ontario over the past 150 years are human attitudes and activities. If the species is to be saved in the province, then a positive view of the species as a valued component of our natural heritage must be cultivated in the public through a long-term and assertive education and outreach campaign.

A major challenge facing the recovery of Massasaugas is the need to actively increase the number of people who respond positively toward rattlesnakes and instill in

the public a greater personal responsibility for conservation of this species and its' habitats. (An important first step in this process should include a quantitative assessment of public attitude; see Tear *et al.* 1995). The Massasauga is the only venomous snake remaining in Ontario. This species perhaps typifies in the extreme an objective of all recovery plans: to demonstrate that wildlife and an informed public can share habitat. For some, the Massasaugas' presence is symbolic of Ontario's wilderness experience itself. The elements which draw so many people to Ontario's natural areas include; windswept white pines, the glacial-scoured rock of the Canadian shield, the haunting call of loons, *and* Massasaugas. That a newly designated provincial park on eastern Georgian Bay has been named after the species is perhaps indicative of the increasing public appeal of rattlesnakes and a positive shift in attitudes. (An undesirable test of the relative success of a program aimed at cultivating public support for Massasauga recovery might be the type of public response evoked by a serious, if not fatal, human envenomation). Isolated rattlesnake populations persisting in Wainfleet Marsh and the Ojibway Prairie complex are particularly valued as representative components of remnant ecosystems.

Utilitarian value

National and provincial park staff have become increasingly aware of the intrinsic and utilitarian value of Massasaugas. Each year more visitors to Killbear Provincial Park indicate a specific interest in seeing Massasaugas in the wild. In 1996, one visitor actually demanded a refund because he failed to see a Massasauga during his visit to the park (C. Parent - pers. commun.). Massasaugas have the potential to become a major draw for visitors to parks and reserves across their range and are a valued subject for photographers and wildlife enthusiasts who annually contribute to local economies. Internationally recognized author and wildlife photographer Michael Runtz recently visited Bruce Peninsula National Park with the specific objective of photographing free-ranging Massasaugas (see Runtz 1995).

Massasaugas are currently on exhibit in a variety of zoological collections (e.g., Toronto Zoo) and natural history interpretation centres (e.g., Science North), and may be specifically credited with attracting 1000s of visitors annually.

Commercial exploitation of Massasaugas for the pet trade may become an issue in Ontario, as is the case in parts of the U.S. (A. Breisch - pers. commun.). Opportunistic, private collecting is known to occur in the province and should be curbed.

Incidence and risk of snakebite

All evidence suggests that with proper precaution and awareness, bites and envenomation from Massasaugas is relatively rare and poses only a minor safety risk. (Prior and Weatherhead 1992). Victims in Ontario have usually provoked the snake (e.g., handle or step on the snake), are often under the influence of alcohol, and are typically male (G Harpur, pers. commun.). The regions of Bruce Peninsula and Georgian Bay record an average of 2-3 bites per season. Envenomation is rarely life-threatening in humans - a full recovery being the normal outcome (Greene and Campbell 1992; C. Parent - pers. comm.). Only one reported death in Ontario has been recorded as attributable to Massasauga envenomation. Nevertheless, all those suspected of being bitten by a Massasauga should seek medical attention immediately. Treatment of venomous snakebite in Ontario is coordinated by the Poison Control Centre at Sick Children's Hospital in Toronto. The Ontario Ministry of Health distributes antivenin, used in the treatment of Massasauga envenomation, to depots throughout the range of the species in the province.

Legal considerations

The Eastern Massasauga Rattlesnake is legally protected in 9 of the 11 provincial or state territories in which it currently exists (i.e., IA, IL, IN, MN, MO, NY, ON, PA, WI vs. MI, OH). Province-wide protection in Ontario is afforded by the *Fish and Wildlife Conservation Act* (formerly the Ontario Game and Fish Act). However this act also allows certain activities that may negatively affect Massasaugas and other vulnerable and threatened species including possession of one specimen for the purpose of personal

educational purposes. It is the opinion of the Recovery Team that this Act should be amended to exempt vulnerable and threatened wildlife species from legal possession and propagation for any personal or recreational purpose. The Ontario Endangered Species Act provides protection from incompatible development in significant portions of habitat occupied by Massasaugas and other threatened and endangered species. Federal listing in the U.S. is under consideration and is required to insure protection across the entire range of this species.

Proportion of range in Canada

The four Ontario populations span more than half the latitudinal range of the sub-species, suggesting that Canada has a major role and responsibility in effecting the global conservation and recovery of the Massasauga. With many of the U.S. populations persisting in isolated habitat patches and at relatively low numbers, recovery of the species across its range will require a cooperative effort between Canada and the U.S.

Recovery potential

Review of major causes of threat and the likelihood of continuation

Habitat loss and fragmentation, due to direct development and human activity, is a major threat for all populations and is expected to be so in the future. Historical trends and the future expectations for habitat loss must be quantified at a regional scale. Among the four Ontario populations, the effects of habitat fragmentation are currently most severe for Massasaugas persisting at the Ojibway Prairie complex where the population has been effectively sub-divided among three, isolated habitat patches. It is unlikely that populations occupying these relatively small (235 ha, 140 ha, 81 ha), remnant habitat patches are capable of long-term viability in the absence of intensive management. The likelihood of future housing development on the Sandwich West Woodlot (the largest of the Ojibway habitat patches) is an issue of serious concern. Population and habitat viability analyses will help clarify the degree of conservation priority that should be afforded the Ojibway population. Should these analyses reveal that local populations are too small to ensure long-term viability, or that the available habitat is too limited to

support viable population sizes, then recovery objectives directed toward Ojibway should be re-evaluated.

The loss of habitat through vegetation succession is also considered a main threat to populations confined to isolated habitat patches. The absence of natural disturbance regimes (e.g., fire, flooding) has lead to a reduction in the suitability of habitat for Massasaugas at Wainfleet Marsh and Ojibway Prairie. Likewise, a lack of neighbouring habitat patches to which populations may shift when conditions beome inappropriate has forced some populations to occupy increasingly inappropriate habitats. Field experiments at Cicero Swamp suggest that the availability of openings in an otherwise closed-canopy shrub layer are critical for basking by gravid females (Johnson and Breisch 1993; Johnson 1995, Johnson and Leopold 1998). Johnson (1995) concludes that the management implications from his study may be applicable at Wainfleet. In the absence of information from studies of communities similar to Ojibway, it will be necessary to develop habitat models and management techniques based on direct study (e.g., telemetry, evaluation of habitat). Without such information it will be difficult to effectively identify, protect, maintain, or restore essential habitat elements.

Direct mortality, either accidental (roadkills) or deliberate (wanton killing) is also a major threat faced by all populations and is expected to be an important concern in the future. Road traffic may result in high mortality rates especially where roads cut across seasonal movement routes of local populations (Seigel 1986). Road mortalities make up a large proportion of the snakes actually observed during field studies in some areas (e.g., 30% - Weatherhead and Prior 1992; 23% - Seigel 1986). Not surprisingly, the frequency of road mortality tends to vary seasonally and is positively correlated with traffic volume (Seigel 1986; Parent unpubl. data; see also Dalrymple and Reichenbach 1984). Deliberate killing of Massasaugas continues in all population regions of Ontario.

Permanent and temporary removal of snakes by naturalists and herpetofaunal hobbyists currently takes place (M. Lachaine - pers. commun.) and should be curbed. Such removals could have significant negative impacts on small, isolated populations by (1) altering demographic structure (e.g., through selective removal of gravid females), (2) promoting the transmission of infectious disease (Dodd and Seigel 1991; Flanagan

1992), and (3) contaminating gene pools (i.e., when individuals are translocated between wild populations).

There are a variety of other potentially significant threats faced by populations of Massasaugas, including: skewed demographic composition (e.g., few reproductive individuals); inbreeding depression (see Madsen *et al*. 1996); and high levels of predation on young by abundant carnivores (e.g., *Felis catus*, *Procyon lotor*).

Current habitat protection and recovery efforts

Massasauga habitat and populations found within conservation areas, national, and provincial parks and reserves are moderately secure from human-induced changes such as direct land conversion for agriculture, development, and forestry. Development and activities within provincial parks is contingent upon individual Park Management Plans (reviewed every 10 years) and within-park zoning (e.g., nature reserve zone). Development and activities within national parks are constrained by National Parks Policy and the Environmental Assessment and Review Process (EARP). Habitat management for Massasaugas at both Bruce Peninsula and Georgian Bay Islands National Parks is currently limited to controlling human access to sensitive communities (e.g., Dorcas Bay Fen at BPNP).

The Ontario Endangered Species Act provides protection from incompatible development in significant portions of the habitat of endangered and threatened species. The identification of significant habitat areas is necessary to allow municipalities and resource managers to successfully implement this policy. As such, there is an urgent need to identify/map all area harboring Massasauga populations across both the Bruce Peninsula and Georgian Bay regions. Such an exercise would also enable important regional population clusters to be recognized (see Mierzwa 1993) and populations to be ranked with respect to their relative vulnerability.

The majority of the 1500 ha Wainfleet Marsh is now protected from development by virtue of a draft co-management agreement contributed to by NCC, NPCA, and OMNR (Niagara Peninsula Conservation Authority 1997). A baseline assessment of the

response of vegetation to the intense disturbance associated with peat extraction was conducted by Jonsson-Ninniss and Middleton (1991).

A total of 81 ha (65 ha Ojibway Prairie Nature Preserve + 16 ha Tallgrass Prairie Heritage Park) of potential habitat is protected in the Ojibway complex, leaving 375 ha (235 ha Sandwich West Woodlot + 140 ha Spring Garden Prairie) of occupied habitat vulnerable to development. Recovery and management of the native tallgrass prairie and pin oak (*Quercus palustris*) savannah communities at the Ojibway Prairie Provincial Nature Reserve calls for regular, prescribed burns in order to arrest the invasion of woody plants. Management burns of the Squaw Creek cordgrass (*Spartina spp*.) prairie in Missouri have resulted in mortality of Massasaugas when conducted on cool days during the active season when snakes are out basking (Seigel 1986). Thus, active management of vegetation communities (prescribed burns, mowing, cutting) should take into account local environmental conditions in order to avoid unnecessary mortalities (Erwin and Stasiak 1979).

A cooperative vegetation inventory involving the City of Windsor, the Ministry of Natural Resources, and the Natural Heritage Information Centre (NHIC) was conducted at the Spring Garden Prairie site during the growing season of 1994. It is the intent of NHIC that this inventory (and subsequent management) will result in an increased level of protection for this prairie remnant. The recently drafted Tallgrass Communities Recovery Plan (Rodger 1998) has important implications for the management and persistence of Massasauga populations.

Degree of habitat management required

Maintaining the peatland vegetation community and in particular, open areas for gravid females may be a key to the persistence of the Wainfleet population (Johnson 1995). There is some evidence that the character of the bog vegetation is changing (e.g., invasion by birch, *Betula* spp.) in response to altered drainage patterns and a lowered watertable resulting from ditching (done during peat extraction) within the bog itself and on neighboring agricultural lands (Jonsson-Ninniss and Middleton 1991; Middleton 1993; Niagara Peninsula Conservation Authority 1997).

Experimental management of the peatland community at Cicero Swamp appears to have increased the availability of high quality habitat for gravid females found there (Johnson 1995; Johnson and Leopold 1998). Assuming that Cicero and Wainfleet have similar vegetation communities and that the two populations exhibit common behavioural patterns we recommend that similar experimental trials be conducted at Wainfleet in order to maintain or restore habitat.

Maintenance of tallgrass prairie, early successional field, and oak savannah habitat is probably critical for the persistence of the Ojibway population - though this has not been tested yet and points to the need for a baseline telemetry study and habitat model development. Any active management of vegetation communities (prescribed burns, mowing) must take into account local environmental conditions in order to avoid direct mortality of snakes and other fauna (Seigel 1986; Erwin and Stasiak 1979). Undoubtedly, much can be learned (and applied) from the collective experience of managers of prairie/Massasauga reserves in the U.S. (Jaworski 1993).

Careful consideration should be made of situations in which Massasaugas are found to be using disturbed habitats and anthropogenic debris. For example, vegetation clearing associated with peat extraction at Wainfleet Marsh may to some degree mimic the natural or management-created openings required for basking by Massasaugas. Similarly, junk and brush piles currently serve as gestation and birthing sites at Ojibway and Killbear Provincal Park. As such, these materials should certainly not be removed under the guise of "habitat improvement".

We currently know little about how human disturbance might affect habitat quality for Massasaugas. Recent evidence suggests that the affects may be subtle and that human activities should be controlled in essential habitats (Prior and Weatherhead 1992; Parent 1998). More research is required to understand these potential stress factors since many Massasauga populations will face increasing exposure to humans in the future.

Biological considerations affecting recovery

Recruitment rate

Detailed studies of recruitment and survivorship rates have not been done for Massasaugas. However, certain demographic and life history patterns are apparent as a result of comparative and indirect data. The brevity of the active season in Ontario, at the northern edge of the species' range, has led to relatively slow growth rates, delayed sexual maturity, and infrequent (female) reproduction. In Ontario, females are thought to breed every second or third season, reaching sexual maturity at the age of four or five (Seigel and Ford 1987; Parent and Weatherhead - unpubl. data). Reproductive frequency is largely dependent on seasonal variation in resource abundance and the ability of females to regain energy reserves following parturition. (See Farrell *et al.* 1995 for detailed discussion of reproduction in *Sistrurus miliarius barbouri* and the effect of climate on life history characteristics). Young Massasauga are susceptible to a broad suite of predators such that first-year survivorship may be quite low (e.g., 12% for *Vipera berus*; Parker and Plummer 1987).

These features of Massasauga life history imply that local recruitment may be constrained to fairly low levels (i.e., the contribution of a few females in any given year). As such, populations probably have very little capacity to withstand even minor increases in background mortality rates, especially those impacting adult females (as modeled by Seigel and Sheil 1995). Habitat loss and fragmentation both serve to increase encounter rates between Massasaugas and humans leading to higher mortality rates through deliberate killing and incidental death (e.g., roadkills). There is also some evidence that gestating females and dispersing neonates may be subjected to higher predation risks in low-quality habitat mosaics (R. King - unpubl. data).

The relative isolation of the Wainfleet and Ojibway populations means that local population extinctions will not be compensated by natural re-colonization or immigration. Should Massasaugas become critically depleted or extirpated from these localities, re-population will require active translocations from either wild or captive donor populations. Even within more or less contiguous habitats, dispersal and recruitment among local populations may be extremely low as suggested by data on genetic population structure (Gibbs *et al.* 1997).

Population viability

Three basic applications of population viability analyses (PVA) have been realized including their use in (1) assessing the vulnerability of small populations to stochastic events (relative impact of various threats) based on details of the species' life history, (2) scoping the consequences of alternative management strategies (e.g., reserve size and design), and (3) modeling the behaviour of populations at low density and under various regimes of fecundity and mortality. It is important to recognize that PVAs are not designed to test hypotheses about *why* populations or the species declined to low numbers (i.e., became endangered) in the first place. As such, they are incapable of prescribing how to get numbers back up to a healthy level.

With the aim of evaluating the relative vulnerability of specific populations to stochastic events, the potential efficacy of different management strategies, and changes in fecundity/mortality rates PVAs should be conducted for what are believed to be the most jeopardized populations in Ontario (i.e., Ojibway, Wainfleet). Key findings arising from a preliminary PVA of Massasaugas at Squaw Creek suggest that minor (5%) fluctuations in adult mortality rates may result in a twenty-fold change in the population size over a 50 year period (Seigel and Sheil 1995).

Genetic population structure

Recent analyses employing high-resolution microsatellite genetic markers have revealed that the geographically isolated populations of Georgian Bay, Bruce Peninsula, and Circero (NY) are highly divergent (Gibbs *et al*. 1997). In addition, genetic structure has been detected *within* the Georgian Bay population. Specifically, Beausoleil Island and Killbear Provincial Park (ca. 50 km apart) have been found to be genetically and thus, demographically distinct. Furthermore, significant divergence was detected at even finer geographic scales (5-10km). Collectively, these data suggest that; (1) geographically separated populations (i.e., the majority of extant populations across the species' range) may be unique genetically and warrant high conservation status, and (2) relatively large regional populations are probably composed of demographically and genetically isolated local sub-populations which may serve as self-defined *management units*. Additional

work will be required to clarify the spatial and ecological scale at which local populations are organized.

Potential for relocation

A common response to the occurrence of Massasaugas on residential or cottage properties is to displace the snake to some remote location. This management practice is formally recommended in the Herpetofaunal Management Plans of both the Bruce Peninsula and Georgian Bay Islands National Parks. The Toronto Zoo has also previously advocated this procedure through their conservation education programs; a campaign that inspired several cottagers associations to adopted Massasauga relocation as a community policy. For example, residents of Snug Harbour in eastern Georgian Bay regularly relocate Massasaugas from their properties to Franklin Island (C. Parent - pers. commun.).

The objectives of Massasauga relocations are to (1) reduce the (perceived) risk of snake-bite and envenomation, and (2) remove the snake from an immediate threat which might otherwise result in either injury or death of the snake. However, this method of dealing with Massasaugas should be re-evaluated for two reasons. First, the risk of snake-bite is typically over-exaggerated. Field research suggests that Massasaugas rarely strike unless handled or otherwise provoked (Prior and Weatherhead 1992), the actual risk may be even further reduced through progressive education and awareness.

A second reason that the current practice of relocation should be reviewed is that snakes often may not survive long distance displacement. Currently, release points are usually a considerable distance (1-2 km) from the point of capture. As such, displaced snakes are often removed from their activity range (ca. 25 ha) and thus, placed in unfamiliar territory. Preliminary experimental evidence suggests that such snakes rarely survive. B. Johnson *et al*. (unpubl. data) relocated 10 Massasaugas into apparently suitable habitat, > 2 km from their point of capture. All the snakes either died overwinter or shortly after spring emergence, probably due to the combined effects of stress and their inability to locate suitable overwintering sites. These results agree with those obtained by Reinert (1991, pers. commun.) in which Timber Rattlesnakes

(*Crotalus horridus*) displaced long distances exhibited abnormal activity patterns and reduced overwinter survivorship, despite the ability of some to actually locate active communal hibernacula. In contrast, Sealy (1995) has found that Timber Rattlesnakes displaced only short distances (200 m) quickly resumed normal behaviour (e.g., foraging and mating).

Thus, long-distance displacement (1-2 km) of Massasaugas probably fails to achieve one of the primary objectives of relocations - to minimize the risk of injury or death of the snake. More often than not, the probability of death may well be increased. As such, we recommend that managers adopt, and educators promote, a policy which minimizes the need for relocations by increasing awareness, tolerance, and safety precautions. In cases where intervention seems unavoidable, Massasaugas may be either briefly confined (i.e., 1-2 hours in a shaded garbage can) and then returned to the point of capture or immediately displaced a short distance (i.e., 10-20 m). It is encouraging to note that the protocol outlined in the Emergency Plan for Killbear Provincial Park suggests that staff respond to human-snake conflicts by temporary removal and subsequent return of Massasaugas *to their point of capture* (C. Parent - pers. commun.). Similarly, an educational video recently produced by the Toronto Zoo (*Living with Wildlife: The Eastern Massasauga Rattlesnake*) instructs the public in precautionary, short-distance displacement of nuisance snakes.

Potential for captive breeding

The removal of individuals from the wild for captive breeding can potentially fulfill several specific conservation objectives. For example, individuals produced in a captive breeding program may be used to augment depauperate wild populations, repatriate extirpated populations, or educate the public via interpretive displays and education programs. Captive breeding programs should guard against the possibility of detrimental artificial selection.

There is good potential for the successful captive breeding of Massasaugas. The Toronto Zoo has bred wild-caught and both first and second generation captive-bred Massasaugas on several occasions (Johnson 1988). Free-ranging females probably reach

reproductive maturity during their third or fourth summer (ca. 34 months; in Wisconsin, Keenlyne 1978) and exhibit either biennial or triennial breeding cycles in Ontario (Parent and Weatherhead - unpubl. data). However, Johnson (1988) observed relatively early reproductive maturity in captive-born females (27 months) and notably, the ability of females to produce two litters within a single (6 month) reproductive season.

The reproductive potential of Massasaugas appears to exhibit considerable geographic variation and high within-population variation (Keenlyne 1978; Reinert 1981; Farrell *et al*. 1995; Parent and Weatherhead - unpubl. data), although litter size is positively correlated with female body size (Seigel 1986; Seigel and Ford 1987). Litter sizes for wild-bred Massasaugas in Ontario have ranged from 8-20 (Weller and Parsons 1991; B. Johnson *et al*.- unpubl. data; Parent and Weatherhead - unpubl. data). Captive-bred litters at the Toronto Zoo have ranged from 3-6 (Johnson 1988).

Propagation of wild Massasaugas by hobbists should not be allowed as they may contribute to important declines in wild populations.

Potential for augmentation and repatriation

The use of population augmentations (release of individuals into an area already occupied by that species) and repatriation (release of individuals into an area previously occupied by that species) for the conservation of snakes has been recently reviewed (see Dodd and Seigel 1991; Burke 1991; Reinert 1991). Population augmentation may enhance the demographic or genetic composition of jeopardized populations through the addition of either captive stock or wild-caught individuals. As such, augmentation may help reduce the risk of extinction for a given population. In contrast, repatriation is usually aimed at re-establishing (restoring) populations following local extinctions. Importantly, experimental repatriations may also serve to test hypotheses about the specific cause(s) of extinction.

Several questions should be considered before augmentations or repatriations are undertaken. For example; too what degree are donor and recipient populations genetically similar? Will augmentations dilute the genetic integrity of repicient populations? How will augmentation improve population viability? What is the risk of

disease transmission between donor and recipient populations? Will there be any cost to donor populations? Is there sufficient high quality habitat and resources at the site of repatriation? Does the program have community support? Have feasibility studies been conducted? Is there support for population monitoring capable of testing program efficacy?

Current public education efforts

Ontario has a strong tradition of locally-based education and awareness programs focusing on the Massasauga. Interpretation programs were initiated in the late 1960's at Killbear Provincial Park with an emphasis placed upon safety awareness and general natural history. Early on, the conservation significance of Massasaugas was not appreciated as the recorded history of encounters between park staff and Massasaugas documents regular purposeful killing (Parent and Willson - unpubl. data). Today, most Ontario Provincial Parks within the species' range offer interpretative programs featuring the Massasauga.

Massasauga interpretation at Georgian Bay Islands National Park (GBINP) began around 1978. Programs at GBINP included the use of information brochures, displays, audio-visual presentations, and seminars (usually with a live specimen) - early emphasis was on identifying key characteristics of Massasaugas and the types of precautions visitors should take to avoid conflicts with rattlesnakes. Conservation research and management became an increasingly important component of public education as specific programs developed (e.g., radio-telemetry research, relocation). A local youth camp became regularly involved in assisting with capture and relocation procedures. Public outreach programs contacted local field crews of Ontario Hydro and Bell Canada which may encounter snakes during the course of their workday.

Bruce Peninsula National Park developed a similar program in 1988, modeled after that at GBINP. Most Ontario parks that fall within the range of the species have recognized, and wisely capitalized on, the public fascination with rattlesnakes. As such, the regular interpretive and education programs focusing on Massasaugas offered by the

parks have become very popular (e.g., as many as 20,000 visitors/season participate in Massasauga programs at Killbear Provincial Park, C. Parent - pers. commun.).

The Toronto Zoo's Massasauga conservation program began in 1988, largely in response to requests from the public for assistance in dealing with snakes in areas frequented by young children (Johnson 1993). In 1991, the Toronto Zoo produced two posters for distribution throughout the Georgian Bay and Bruce Peninsula regions. The *Wanted Alive in the Wild* and *S.O.S. - Save Ontario Snakes* posters were designed to achieve two primary objectives: (1) the conservation of Massasaugas and other Ontario snakes and, (2) increasing public awareness of the existence of Massasaugas and how to distinguish this species from other snakes in the province. Education kits designed for use by elementary school teachers were produced and distributed and information workshops have been regularly held at the zoo and are well-attended by Georgian Bay and Bruce Peninsula region cottagers and residents. An "International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake" was convened by the zoo in May of 1992. The meeting was attended by government agency representatives, resource managers, and research ecologists. Discussion topics ranged from the species' biogeography, distribution, status, applied research, management practices, and education efforts and the proceedings were subsequently published (Johnson and Menzies 1993). Recently, the Toronto Zoo sponsored the production of an educational video for distribution throughout Ontario. The *Living with Wildlife: The Eastern Massasauga Rattlesnake* video illustrates the species' life history, habitat requirements, keys for identification, and safety practices necessary for coexistence and conservation of rattlesnakes.

Science North, a learning centre located in Sudbury, has developed an interpretative display on Massasauga natural history and conservation. This facility serves as an important focus for conservation education at the northern periphery of the species' range.

The Ojibway Nature Centre, operated by the Windsor Department of Parks and Recreation has maintained an interpretative display and offered environmental programs featuring Massasaugas since the early 1980's. In 1992, the Centre produced and

distributed an information flyer which promoted; (1) species identification, (2) conservation of the species and the local populations through awareness and tolerance, and (3) careful reporting of any sightings. Increased calls from local residents requesting information and the assistance of the Nature Centre when Massasaugas are encountered suggests that education efforts may be having positive results (Pratt *et al.* 1993). In 1996 , a 'door to door' campaign funded by the Environmental Youth Corps targeted all the residents bordering the Spring Garden ANSI and provided information on how to live with rattlesnakes.

Education or outreach efforts directed at residents in the vicinity of the Wainfleet population are just getting off the ground. At present, the draft management plan for Wainfleet calls for the development of an interpretive program including walking trails and a visitor centre (Niagara Peninsula Conservation Authority 1997).

Section II

Recovery strategy

Recovery goals and approaches

The goals of this recovery plan are to:

1. achieve viable populations in tallgrass prairie and peatland ecosystems in 30 years,
2. retain current distribution and connectivity among local populations throughout the Bruce Peninsula and Georgian Bay regions in perpetuity.

In order to achieve these goals the recovery team has adopted the following approaches:

(1) foster public support for recovery through outreach and education,

(2) raise awareness among relevant local governments, land management agencies, and the industry and development sectors

(3) focus recovery on the ecological communities (i.e., tallgrass prairie and peatland) in which the Ojibway and Wainfleet populations reside,

(4) encourage sound management of all populations to maximize long-term viability,

(5) evaluate the relative conservation status (risk of extinction) of all populations and focus resources accordingly,

(6) implement a communications network to improve coordination among recovery teams and various partners,

(7) monitor populations and recovery progress to evaluate efficacy,

(8) collaborate with US partners to effect global recovery

Recovery Procedure

1.0 Improve public outreach and awareness program.

1.1 Improve resource materials.

1.11 Outreach to local governments

1.12 Address public safety issues

1.2 Facilitate workshops to raise awareness and teach skills.

1.3 Form partnerships to strengthen lobby.

1.4 Contribute to and promote media coverage.

1.41 Prepare media package and response.

2.0 Conduct research to acquire crucial information.

2.1 Conduct population viability analyses and risk assessment.

2.2 Conduct human dimensions and economic analyses.

2.3 Determine distribution and status of local populations.

2.4 Evaluate global status of sub-species.

2.5 Define essential habitat requirements.

2.51 Quantify habitat type, availability, and use at Ojibway.

2.52 Quantify habitat type, availability, and use at Wainfleet.

2.6 Develop habitat maintenance and restoration protocols.

2.7 Quantify life history patterns and ecology.

2.8 Characterize genetic population structure.

2.81Identify potential management units.

3.0 Monitor and manage local populations.

3.1 Coordinate with ecosystem management agencies.

3.2 Implement long-term monitoring programs.

3.21 Organize surveys of Wainfleet and Ojibway.

3.22 Review monitoring data and protocol annually.

3.3 Manage habitats for suitability.

3.4 Plan for extreme vulnerability and local extinctions.

4.0 Establish network of shelter areas.

4.1 Survey potential habitat for undiscovered populations.

4.2 Document presence/absence of local populations.

4.3 Map habitat associated with local populations.

4.4 Identify and map primary planning initiatives and arrangements.

4.5 Conduct stakeholder contact and stewardship program.

4.51 Solicit shelter promise from stakeholders.

4.52 Promote adoption of sensitive landuse practices.

4.6 Protect habitat parcels where necessary.

5.0 Improve communications and coordination.

5.1 Review and address legislation and regulation issues.

5.2 Generate and distribute recovery contact list.

5.3 Establish internet-based communications network.

5.4 Create recovery data repository and solicit input.

5.5 Review progress and update recovery pla.n.

5.6 Collaborate with US on global recovery planning.

Narrative

1.0 Improve public outreach and awareness program..

An important aspect of achieving long-term community support for Massasauga conservation will be an emphasis on individual participation and the development of a collective, public responsibility for the recovery of Massasauga populations. Help stakeholders undertake conservation measures on their own land to protect important natural areas. Recognize and publicize participation as a means of stimulating involvement by others.

Assess public attitudes. We urge careful development of education programs in the future. In particular, those charged with this task should be familiar with experimental tests of the effectiveness of programs in changing public attitudes towards snakes (see Morgan and Gramann 1989). Quantify public attitudes towards rattlesnakes and their conservation/recovery in order to tailor outreach material to needs and to assess relative effectiveness of programs in changing attitudes over time.

Conduct stakeholder analysis and community outreach. Population survival will require public support. Achieving such support may be possible through a proactive awareness and education campaign that targets individual landowners, residential community organizations, corporate/industrial tenants (i.e., stakeholders) whose activities and landuse practices may have effects on the viability of Massasauga populations. Killbear Provincial Park has cultivated many positive relationships within the community (e.g., media information day, use of ultrasound facilities at West Parry Sound Health Centre). A survey of all stakeholder and properties throughout all population regions will facilitate comprehensive outreach. Structure outreach to complement programs conducted at permanent facilities (e.g., park interpretative centres). Outreach will be particularly valuable in areas without existing facilities (e.g., Wainfleet). Contact and raise awareness among important economic sectors (e.g., forestry, aggregate extraction, transportation, tourism, residential development, Ontario Hydro, communications) whose activities could have important effects on the viability of Massasauga populations. Offer to assist in the development of conservation measures to protect habitats and mitigate impacts on Massasauga populations. Acknowledge and

publicize program participation and the adoption of policies that promote conservation of Massasaugas. Set regional targets (e.g., 500 residents/county/year) and document contacts made, response, and the total land that contacts control. Employing the assistance of media and communications consultants, educators, and sociologists is recommended (see Clark *et al*. 1994).

1.1 ***Improve resource materials.***

Catalogue resource materials currently available. Identify resource gaps, design (update), and prepare common recovery-based resource materials where required. Distribute to communities surrounding Massasauga populations and other designated localities (e.g., Toronto). Emphasize recovery goals, the application of research findings, heritage values, and the conservation of ecological communities. Promote individual and community participation in specific recovery activities. Where appropriate tailor resource material to the recovery and management of ecological communities and cooperate with other agencies (e.g., Tallgrass Prairie Recovery and Wainfleet Bog Management Plans). Employ Massasauga as flagship for ecological community recovery. Fold species-specific recovery into ecological community level efforts.

Apply minimum standards for captive care. The care of captive Massasaugas in interpretive displays and educational programs should be reviewed at all locations and minimum standards adhered to. Detailed health and safety protocols are available from B. Johnson, Toronto Zoo (posted on SIN http://www.terra-plex.com/sin/). If specimens are drawn from wild populations, consideration must be given to (1) the demographic and genetic impact on source populations, (2) the fate of captives if subsequently released, and (3) the potential for the transmission of disease from captives into free-ranging populations. It has been proposed that the Toronto Zoo provide captive bred specimens on loan for interpretive displays throughout the province.

1.11 Outreach to local governments.

Often, local governments and agencies are simply unawareness of the issues or how best to apply policies or regulations to best protect Massasauga population. Work with local governments to improve awareness and offset negative effects that may arise in cases where policies and regulations of different ministries and departments serve conflicting objectives.

1.12 Address public safety issues.

Review the circumstances and outcome of Massasauga bites across the province (and elsewhere) in order to prepare for the need to respond to issues of public safety including, the risk of snakebite, safety precautions, and the response to and treatment of snakebite (in humans and pets) by the public and professionals.

1.2 Facilitate workshops to raise awareness and teach skills.

Continue to facilitate public information and skills workshops (on a per need basis). Workshops should strive to cultivate an awareness and appreciation of Massasaugas as well as providing participants with practical skills for how to live safely within Massasauga habitat, while at the same time improving the status of local populations.

1.3 Form partnerships to strengthen lobby.

Identify local and regional associations, agencies, industries, etc. with whom partnering on public outreach might serve common goals. Contact those groups, define common ground, and form action-oriented partnerships. Acknowledge such partnerships & groups as contributing to recovery.

1.4 ***Contribute to and promote media coverage.***

Use existing media sources to get our message out. Prepare regular reports or articles on recovery progress for local, national, and international media.

1.41 ***Prepare media package and response***

Compile a media resource package (e.g., fact sheets, photos, maps) and identify local recovery spokespeople to address unsolicited media attention. Prepare speaking points (sound bites) to offset potential negative publicity that might arise in the event of a serious snakebite. The nature of the response by the media and the general public to serious snakebite will be a true test of the efficacy of the education program.

2.0 Conduct research to acquire crucial information.

2.1 Conduct population viability analyses and risk assessment.

Protecting and managing specific habitat patches for recovery implies that such land parcels (and surroundings) are sufficiently large to support viable populations. This expectation has yet to be tested for Massasaugas and may be particularly relevant to conservation actions directed within the Ojibway complex where rattlesnake populations currently occupy prairie remnants as small as ca. 80 ha. Basic applications of population viability analyses (PVA) include their use in (1) assessing the vulnerability of small populations to stochastic events (relative impact of various threats) based upon details of the species life history, (2) scoping the consequences of alternative management strategies (e.g., reserve size designs), and (3) modeling the behaviour of populations at low density and under various regimes of fecundity and mortality.

PVAs should be conducted for what are believed to be the most jeopardized Massasauga populations in Ontario (e.g., Ojibway and Wainfleet) - with the aim of evaluating the relative vulnerability of specific populations to stochastic events, the potential efficacy of different management strategies, and changes in fecundity/mortality rates. Viability models should be refined as additional data become available. Results of PVAs should inform recovery planning process and may lead to changing recovery action priorities.

2.2 ***Conduct human dimensions and economic analyses***.

Understanding human social processes in practical terms is essential as populations will be recovered only if human social processes (including economic interests) can be made to effectively support restoration. Clark and Wallace (1998) provide a model of such a process (i.e., participants, perspectives, situation, values, strategies, outcomes, effects) and a method of realistically mapping them. Evaluate effectiveness of outreach and education campaigns (see Tear *et al*. 1995).

2.3 ***Determine distribution and status of local populations.***

Evaluate sub-species element occurrences throughout Ontario to delineate local population distribution. Follow-up with site surveys where necessary. Evaluate habitat suitability. Map distribution of population occurrences, habitat, and landuse. Conduct spatial analyses to evaluate relative status of local populations. Cooperative project underway with Canadian Wildlife Service, Georgian Bay Islands National, Natural Heritage Information Centre (ON).

2.4 ***Evaluate global status of sub-species.***

Repeat above at global scale. Cooperative project underway with Canadian Wildlife Service, Georgian Bay Islands National, Natural Heritage Information Centre (ON), and US Fish & Wildlife Service.

2.5 ***Define essential habitat requirements.***

Identify hibernacula and gestation sites where habitat management may be required to protect population viability and mitigate landuse conflicts (e.g., Hwy 69 twinning project). It will be important to determine the affects of selection and shelterwood silvicultural harvest systems on
Massasauga habitat, and make recommendations to minimize negative impacts,
as this land use is occurring throughout the Georgian Bay and Bruce Peninsula regions.
Review existing studies from the Georgian Bay and Bruce Peninsula regions that describe habitat selection and determine what additional research is required to define critical habitat requirements in these regions.

2.51 ***Quantify habitat availability and use at Ojibway.***

Conduct telemetry study to assess movement patterns and habitat needs of Ojibway population. Cooperate with efforts to manage the ecosystem.

2.52 ***Quantify habitat availability and use at Wainfleet.***

Conduct telemetry study to assess movement patterns and habitat needs of Wainfleet population. Employ recommendations of Cicero study where appropriate. Cooperate with ecosystem management efforts.

2.6 ***Develop habitat maintenance and restoration protocols.***

Establish and implement habitat management practices in cooperation with ecosystem recovery initiatives. Needs should be contingent on site-specific habitat use studies. Communicate with U.S. counterparts throughout development and testing of management techniques. Pay special attention to maintenance of gestation, birthing, and hibernacula habitats. Monitor habitat management for efficacy. Consult Hay (1993) and Johnson and Leopold (1998).

2.7 ***Quantify life history patterns and ecology***.

Characterize life history characteristics (e.g., age of maturity, reproductive frequency, post-partum survivorship, sex ratio, age composition) and ecology (e.g., diet, behavioural ecology, thermal ecology) of populations in Ontario. This information will help define the general requirements and norms of populations for persistence by establishing baselines against which future change may be compared.

2.8 ***Characterize genetic population structure.***

Continue research to delineate genetic and demographic structure of local populations. This research will have important implications for assessing effective populations size, the spatial scale at which local populations are organized, defining conservation management units, and the development of accurate population viability models.

2.81 ***Identify potential management units.***

Employ data on genetic population structure, demography, behavioural ecology, and habitat availability in a study of landscape ecology to identify management units across Georgian Bay and the Bruce Peninsula. Consult Moritz (1994).

3.0 Monitor and manage local populations.

3.1 ***Coordinate with ecosystem management agencies.***

Ensure that all population monitoring and management is coordinated with existing ecosystem restoration efforts in order to maximize efficiency and conservation return.

3.2 Implement long-term monitoring programs.

Expand population monitoring program to encompass all regions. Set targets for number of monitoring sites to be established. Develop coordinated proposal to set protocols and objectives, and sell need to agency management. A standardized protocol for inventory and monitoring needs to be developed. Protocols may vary between habitats and regions. Seek commitments for long-term support. Programs currently exist at Bruce Peninsula National Park and Killbear Provincial Park.

3.21 ***Organize surveys of Wainfleet and Ojibway.***

Kickstart population monitoring of Wainfleet and Ojibway by conducting (annual?) multi-party surveys of both populations.

3.22 ***Review monitoring data and protocol.***

Submit monitoring data and protocols to regular review. Forward information to recovery data repository.

3.3 Manage habitats for suitability.

Manage (restore) habitat dependent on findings of site-specific studies or model systems (e.g., Cicero). Cooperate with ecosystem management initiatives.

3.4 Plan for extreme vulnerability and local extinctions.

PVA results and population catastrophe(s) may require intensive management of populations to ensure viability. In advance of such needs, feasibility studies of population augmentation and repatriation options should be conducted. Evaluate potential consequences of major disruptions (e.g., habitat elimination) via thought

experiments or scenerio models. For example, consider the ramifications for viability of the Ojibway population in the event that the Sandwich West Woodlot is entirely developed for residential housing over the next five years? Prepare contingency plans (population rescue, interim captivity, repatriation). Assess potential for habitat recovery. Compensate for major irreversible habitat losses with the identification and protection of unoccupied habitat. Prepare for need to repatriate populations. Assess consequences of and plan response to stochastic, extreme events. For example, how significant a loss would be the extinction of the Ojibway population? How would the recovery team respond? Develop contingency plans to identify cause(s) of disturbance (fire, predators, disease, etc.), assess impact to habitat and population(s), and the potential for recovery. Begin habitat restoration where feasible. Rescue and rehabilitate survivors where required. Release survivors once immediate threat has been mitigated and habitat restoration is complete or, incorporate them into captive stock for breeding, education, augmentation, or repatriation programs, if warranted.

4.0 Establish network of shelter areas.

4.1 Survey potential habitat for undiscovered populations.

Consult with NHIC staff, regional ecologists, field naturalists, etc. to identify and survey potential habitat and search for previously undiscovered populations. Prioritize localities for field investigation and document survey results. Set goals for completion of both region- and province-wide surveys. Adjust recovery priorities in event that relict populations are discovered. Evaluate locations with suitable habitat as possible sites for population repatriation.

4.2 Document presence/absence of local populations.

Conduct thorough field surveys and public interviews in all traditional regions to confirm presence/absence of local populations at fine geographic scale.

4.3 Map habitat associated with local populations.

Quantify and map habitat availability associated with local populations in support of landscape ecology study.

4.4 Identify and map primary planning initiatives and arrangements.

Map ownership/stakeholder and planning authority initiatives where objectives may conflict or enhance recovery and population viability. Keep alert to all possible processes (landuse zoning, development scenarios, management practices) that may affect habitat suitability or availability.

4.5 Conduct stakeholder contact and stewardship program.

Conduct stakeholder contact program in all regions. Raise awareness and assist stakeholders with conservation measures on their own land to protect important natural areas harboring Massasaugas. Recognize and publicize participation by individuals in this program.

4.51 ***Solicit shelter promise from stakeholders.***

Devise stakeholder incentives for promise of protection or shelter of Massasauga populations on private/public lands. Publicize participation by stakeholders in recovery activities.

4.52 Promote adoption of sensitive landuse practices.

Actively participate with stakeholders in developing landuse practices that provide for long-term habitat availability and minimize disturbance of populations (e.g., road underpasses, closed access to essential habitat).

4.6 Protect habitat parcels where necessary.

In cases where essential habitat requires protection from development or other human activities appropriates steps including purchase, easements, regulations should be invoked to ensure their long-term security.

Improve communications & coordination.

5.1 ***Review and address legislation and regulation issues***.

Provide critical review and formal comment on developing legislation, policy, and regulations that may affect viability of Massasauga populations (e.g., Scientific Collectors Permit, Draft Fish and Wildlife Conservation Act).

5.2 ***Generate and distribute recovery contact list.***

Create contact/distribution list of recovery workers, experts, cooperators, landowners, etc. to facilitate comprehensive and timely communications and information sharing.

5.3 Establish internet-based communications system.

Develop internet-based communication system to facilitate open information flow among team members, working groups, and US counterparts. System to serve as a distributed network for use by all team members and interested parties. Link to US-based Massasauga Discussion Group (moderated by Gary Casper, E-mail = gsc@uwm.edu). Possibly establish public website to accommodate both team communications and public education/outreach.

5.4 Create recovery data repository and solicit input.

Establish internet accessible data archive to warehouse information of value to recovery team members. Information examples include, monitoring data, landowner survey results, reports, funding proposals, meeting minutes, resource & reference material, etc. Institute documentation (metadata) standards to ease future use of material.

5.5 ***Review progress and update recovery plan.***

Facilitate timely updates of the recovery plan in accordance with review of recovery actions and new information. Regard the plan as dynamic, modify plan as appropriate to reflect current knowledge and priorities. Conduct progress review every three years.

5.6 Collaborate with US on global recovery planning.

Establish memorandum of understanding with US counterparts to facilitate information exchange, expert consultation, cost-sharing, and conservation efficacy. Harmonize status assessment, management, and recovery planning in accordance with the Canada-US Framework for Cooperation on Recovery.

Section III

Implementation schedule

The implementation schedule (Table 1) outlines and sets priorities for recovery tasks over the recovery period. It will be used in the ongoing monitoring of all recovery tasks and will provide the basis for funding of recovery actions. Tasks are identified under general categories, and all headings are derived from *Section II*, as delineated in the Recovery Procedure. The schedule ranks objectives and tasks, identifies respective responsible agencies, sets target dates, and estimates costs in terms of financial resources and person-years for the recovery period. Tasks must be continually revised as plans move from implementation to completion as a result of monitoring results and updating information. Each revision will identify additional actions and studies that will be needed during the recovery period.

Recovery priorities are defined as follows:

Priority 1: An action that must be taken to prevent extinction or prevent the sub-species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in the sub-species' abundance or in habitat quality, or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for recovery of the sub-species.

Table 1. Implementation schedule for the Eastern Massasauga recovery plan

Action	*Recovery Plan no.*	*Priority*	*Lead agency*	*Target date*	*Estimated cost(k)/p-y*
Resource materials	1.1	1	Toronto Zoo	On-going	$10/1.0
Awareness & skills workshops	1.2	1	Toronto Zoo	On-going	$5/0.1
Form partnerships	1.3	3	ONC & NPCA	On-going	-
Use media	1.4	3	Toronto Zoo	On-going	-
PVA & risk assessment	2.1	2	OMNR	2002	$30/0.5
Human & economic analyses	2.2	2	Parks Canada	2002	$20/0.5
Population distribution & status	2.3	2	Parks Canada	2000	$5/0.1
Evaluate global status	2.4	2	CWS	2004	$20/0.5
Define habitat requirements	2.5	1	OMNR	2001	$100/2.0
Maintain & restore habitat	2.6	1	OMNR	2002	$50/2.0
Life history & ecology	2.7	1	Parks Canada & OMNR	On-going	$100/3.0
Genetic population structure	2.8	2	Parks	On-going	$100/3.0
Coordinate with ecosystem management	3.1	1	OMNR	On-going	-
Monitoring programs	3.2	1	Parks Canada	2000	$30/0.25
Manage habitat	3.3	2	OMNR	2002	$5/0.1
Plan for extinctions	3.4	2	CWS	2004	$5/0.1
Survey potential habitat	4.1	3	OMNR	2004	$25/0.25
Document local populations	4.2	2	Parks Canada	2000	$10/0.25
Map habitat	4.3	2	Parks Canada	2000	$25/0.50
Map planning initiatives	4.4	2	Parks Canada	2004	$50/0.25
Stakeholder contact and stewardship	4.5	1	OMNR	On-going	$10/0.25
Protect habitat	4.6	1	OMNR & Parks Canada	2005	?
Address legislation & regulation issues	5.1	2	OMNR & CWS	2000	$5/0.1
Recovery contact list	5.2	2	OMNR	2000	$5/0.1
Internet communications	5.3	3	Parks Canada	2000	$2/0.1
Data repository	5.4	3	Parks Canada	2000	-
Review progress & update plan	5.5	1	OMNR	On-going	$5/0.1
Collaborate with US	5.6	1	CWS	On-going	$5/0.1

CWS = Canadian Wildlife Service, NPCA = Niagara Peninsula Conservation Authority,

OMNR = Ontario Ministry of Natural Resources, ONC = Ojibway Nature Centre

Section IV

Literature Cited

Bleakney, J. S. 1958. A zoogeographical study of the amphibians and reptiles of eastern Canada. National Museum Bull. 155:1-119.

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

Clark, T. W. and R. L. Wallace. 1998. Understanding the human factor in endangered species recovery: an introduction to human social process. Endangered Species Update. 15:2-9.

Clark, T. W., R. P. Reading, and A. L. Clarke [eds.]. 1994. Endangered species recovery: finding the lessons, improving the process. Island Press, Washington, D.C. 450 pp.

Cook, F. R. 1984. Introduction to the amphibians and reptiles of Canada. National Museums of Canada, Ottawa, Ontario.

Cook, F. R. 1993. After an ice age: zoogeography of the massasauga within a Canadian herpetofaunal perspective. Pp. 19-25 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Dalrymple, G. H. and N. G. Reichenbach. 1984. Management of an endangered snake in Ohio, USA. Biological Conservation 30:195-200.

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

Dunning, J. B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65:169-175.

Ernst, C. H. and R. W. Barbour. 1989. Snakes of eastern North America. George Mason University Press, Fairfax.

Erwin, W. J. and R. H. Stasiak. 1979. Vertebrate mortality during the burning of a re-established prairie in Nebraska. Am. Midl. Nat. 101:247-249.

Farrell, T. M., P. G. May, and M. A. Pilgrim. 1995. Reproduction in the rattlesnake, *Sistrurus miliarius barbouri*, in central Florida. J. Herpetol. 29:21-27.

Flanagan, J. P. 1992. Disease impact on Aruba Island rattlesnakes. Section 5 In R. A. Odum (ed.), International Symposium and Workshop on the Conservation and Research of the Aruba Island Rattlesnake: Population and Habitat Viability Assessment, IUCN CBSG, Apple Valley, Minnesota.

Greene, H. W. 1994. Systematics and natural history, foundations for understanding and conserving biodiversity. Amer. Zool. 34:48-56.

Greene, H. W. and J. A. Campbell. 1992. The future of pitvipers. Pp. 421-427 In J. A. Campbell and E. D. Brodie, JR. (eds.), Biology of the pitvipers. Selva, Tyler, Texas.

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

Hallock, L. A. 1991. Habitat utilization, diet and behavior of the eastern massasauga (*Sistrurus catenatus*) in southern Michigan. Unpublished M.Sc. Thesis, Michigan State University, Ann Arbor, Michigan. 40 pp.

Hay, R. 1993. Summary report of management concerns and guidelines for the Eastern Massasauga Rattlesnake (*Sistrurus catenatus catenatus*). Pp. 107-108 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Hutchinson, B., C. Duchesne, and H. Schryver. 1993. GIS analysis of habitat use by Massasauga rattlesnakes in Bruce Peninsula National Park. Pp. 45-47 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Jaworski, T. 1993. The management of a 4.04 hectare field for the Massasauga Rattlesnake, *Sistrurus catenatus*, at Cedar Bog, Champaign County, Ohio. Pp.

60-63 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Johnson, B. 1988. Combat and courtship of the eastern massasauga rattlesnake - comparison of field and captive behaviour. In M. J. Rosenberg (ed.), Proceedings of the 12th International Herpetological Symposium on Captive Propagation and Husbandry.

Johnson, B. 1993. Eastern massasauga rattlesnake conservation education program at the Metro Toronto Zoo. Pp. 89-93 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Johnson, B. and V. Menzies [eds.] 1993. International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario 141 pp.

Johnson, G. 1995. Spatial ecology, habitat preferences, and habitat management of the eastern massasauga, *Sistrurus c. catenatus*, in a New York transition peatland. Ph.D. dissertation, SUNY, College of Environmental Science and Forestry. 205 pp.

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

Johnson, G. and A. R. Breisch. 1993. The eastern massasauga rattlesnake in New York: occurrence and habitat management. Pp. 48-54 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Jonsson-Ninniss, S. and J. Middleton. 1991. Effect of peat extraction on the vegetation in Wainfleet Bog, Ontario. Canadian Field Naturalist 105:505-511.

Keenlyne, K. D. 1978. Reproductive cycles of two species of rattlesnakes. Am. Midl. Nat. 100:368-375.

Keenlyne, K. D. and J. R. Beer. 1973. Food habits of *Sistrurus catenatus catenatus*. J. Herpetol. 7:382-384.

LeRay, W. J. 1930. The rattlesnake (*Sistrurus catenatus catenatus*) in Ontario. Canadian Field Naturalist 44:201-203.

Lumsden, H. G. 1966. The prairie chicken in southwesten Ontario. Canadian Field Naturalist. 80:33-45.

Madsen, T., B. Stille, and R. Shine. 1996. Inbreeding depression in an isolated population of adders, Vipera berus. Biological Conservation 75:113-118.

Middleton, J. 1993. The massasauga rattlesnake, *Sistrurus catenatus*, in Wainfleet Bog. Pp. 43-44 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Mierzwa, K. 1993. Habitat utilization and status of the Eastern Massasauga Rattlesnake, *Sistrurus catenatus*, in the Chicago region. Pp. 66-70 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Minton, S. A. JR. 1983. *Sistrurus catenatus*. Catalog. Amer. Amphib. Rept. 332:1-2.

Morgan, J. M. and J. H. Gramann. 1989. Predicting effectiveness of wildlife education programs: a study of students' attitudes and knowledge toward snakes. Wildl. Soc. Bull. 17:501-509.

Mortiz, C. 1994. Defining "evolutionarily significant units" for conservation. Trends in Ecology and Evolution 9:373-375.

Niagara Peninsula Conservation Authority. 1997. Wainfleet Bog Management Plan. Wainfleet,Ontario. NPCA: Allanburg.

Parker W. S. and M. V. Plummer. 1987. Population ecology. Pp. 253-301 In R. A. Seigel, J. T. Collins, and S. S. Novak (eds.), Snakes: ecology and evolutionary biology. Macmillan Publishing Company, Toronto, Ontario.

Parent, C. 1998. Effects of human disturbance on the behavioural ecology of eastern massasaugas. MSc. Thesis, Biology, Carleton University. 68 pp.

Pielou, E. C. 1991. After the ice age: the return of life to glaciated North America. University of Chicago Press, Chicago, Illinois. 366 pp.

Pratt, P. D., K. Cedar, and J. Barten. 1993. A remnant population of the eastern massasauga rattlesnake at Ojibway Prairie, Windsor, Ontario. Pp. 40-41 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

Prior, K. A. and P. J. Weatherhead. 1992. Response of free-ranging Eastern Massasauga Rattlesnakes to human disturbance. J. Herpetol. 28:255-257.

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

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. and L. M. Bushar. 1993. The status of the Massasauga in Pennsylvania: A story of continuing habitat loss and population isolation. Pp. 55-59 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto, Ontario.

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

Rodda, G. H., T. H. Fritts, and D. Chizar. 1997. The disappearance of Guam's wildlife: new insights for herpetology, evolutionary ecology, and conservation. Bioscience 47:565-574.

Rodger, L. 1998. Tallgrass communities of southern Ontario: a recovery plan. Report prepared for World Wildlife Fund Canada and the Ontario Ministry of Natural Resources.

Runtz, M. W. P. 1995. Wild things: the hidden world of animals. Stoddard, Toronto, Ontario

Schmidt, K. P. 1938. Herpetological evidence for the post-glacial extension of the steppe in North America. Ecology 19:396-407.

Sealy, J. B. 1995. Movements and management of nuisance rattlesnakes in a state park in North Carolina. SSAR Annual Meeting. Abstract only.

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

Seigel, R. A. and N. B. Ford. 1987. Reproductive ecology. Pp. 210-252 In R. A. Seigel, J. T. Collins, and S. S. Novak (eds.), Snakes: ecology and evolutionary biology, Macmillan Publishing Company, Toronto, Ontario.

Seigel, R. A. and C. A. Sheil 1995. Final Report: Satus and long-term changes in populations of Massasauga Rattlesnakes (Sistrurus catenatus) at the Squaw Creek National Wildlife Refuge.

Seigel, R. A., C. A. Sheil, and J. S. Doody. 1998. Long-term changes in a population of an endangered rattlesnake Sistrurus catenatus subjected to a severe flood. Biol. Cons. 83:127-131.

Snell, E. A. 1987. Wetland distribution and conversion in southern Ontario. Working Paper No. 48 Inland Waters and Lands Directorate, Environment Canada. Canada Land Use Monitoring Program. 53 pp.

Sutton, K. 1992. Mouse bites snake. In: Georgian Bay Today p. 5.

Tear, T. H., J. M. Scott, P. H. Hayward, and B. Griffith. 1995. Recovery plans and the endangered species act: are criticisms supported by the data? Conservation Biology 9:182-195.

Weatherhead, P. J. 1984. Resource management study of the Massasauga rattlesnake in Georgian Bay Islands National Park: data analysis and interpretation. Prepared for Parks Canada, Contract GB84-14. Unpubl. typescript. 20 pp.

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: 447-452.

Weller, W. F. and H. J. Parsons. 1991. Status of the Eastern Massasauga, Sistrurus catenatus, in Canada. Prepared for COSEWIC. Unpubl. typescript. 38 pp.

Weller, W. F. and M. J. Oldham, eds. 1988. Ontario Herpetofaunal Summary 1986. Ontario Field Herpetologists, Cambridge, Ontario.

Weller, W. F. and M. J. Oldham. 1993. Historic and current distribution and status of the Eastern Massasauga (*Sistrurus catenatus*) in Ontario, Canada. Pp. 35-39 In B. Johnson and V. Menzies (eds.), International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake, Metro Toronto Zoo, Toronto Ontario.

APPENDIX 1

Recovery Team members

Kent Prior, (Chair)
Canadian Wildlife Service
E-mail kent.prior@ec.gc.ca
Tel 819.994.2338

Ron Black,
Ontario Ministry of Natural Resources
E-mail blackr@gov.on.ca
Tel 705.746.4201

Karen Cedar,
Ojibway Nature Centre
E-mail kcedar@city.windsor.on.ca
Tel 519.966.5852

Kim Frohlich
Niagara Peninsula Conservation Authority
E-mail frohlich@chardonnay.niagara.com
Tel 905.788.3135 x 241

Bob Gray
Ontario Ministry of Natural Resources
E-mail grayro@epo.gov.on.ca
Tel 519.371.8467

Bob Johnson
Toronto Zoo
E-mail bjohnson@zoo.metrotor.on.ca
Tel 416.392.5968

John Middleton
Brock University
E-mail jmiddlet@spartan.ac.brocku.ca
Tel 416.688.5550 x 3128

Chris Parent
Killbear Provincial Park
E-mail cparent@ epo.gov.on.ca
Tel 705.342.5492

Frank Burrows
Parks Canada
E-mail frank_burrows@pch.gc.ca
Tel 519.596.2444 x 310

Paul Pratt
Ojibway Nature Centre
E-mail ppratt@city.windsor.on.ca
Tel 519.966.5852

Darelene Upton
Parks Canada
E-mail darlene_upton@pch.gc.ca
Tel 705.756.2415

Anne Yagi
Ontario Ministry of Natural Resources
E-mail yagian@epo.gov.on.ca
Tel 905.562.1196

Paul Zorn
Parks Canada
E-mail paul_zorn@pch.gc.ca
Tel 613.938.5933