Best Management Practices for Identifying, Managing and Creating Habitat for Ontario's Species at Risk Snakes

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Blue Racer and Blue Racer habitat. © J. Crowley

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1. Introduction

1.1 Purpose

The purpose of this best management practices (BMP) document is to assist in the protection and recovery of Ontario's species at risk snakes by providing guidance on species at risk (SAR) snake habitat identification, avoiding or minimizing adverse effects to snake habitat, enhancing and creating snake habitat, and monitoring the success of these actions. The document is also intended to provide the necessary information for individuals undertaking activities within or adjacent to snake SAR habitat to be able to comply with the Endangered Species Act, 2007 ("ESA") and its associated regulations. The intended audience includes planning authorities (e.g., municipal or provincial governments, conservation authorities), individuals, businesses, and conservation organizations who are undertaking activities within or adjacent to SAR snake habitat.

The recommendations in this document are based on the best available information from peer-reviewed literature, existing policy direction, unpublished reports, academic theses, and personal communication with individuals with expertise in SAR snake biology, ecology and conservation. However, as discussed throughout the document, there is still a lack of information on the effectiveness of many the recommended approaches for creating and managing SAR snake habitat. Thus, these approaches should be applied in an experimental framework, whenever possible, with a strong emphasis on effectiveness monitoring (see section 6). This experimental approach is essential to improve our understanding of snake habitat creation and management techniques. Consequently, this BMP document will be updated to reflect new information as our understanding of these habitat creation and management approaches changes. In order facilitate this process, individuals are encouraged to submit any new information pertaining to the effectiveness of snake habitat creation and management techniques to the Ontario Ministry of Natural Resources and Forestry (OMNRF) for consideration in future iterations of this BMP document. Please send any such information to esapermits@ontario.ca.

The recommendations discussed in this BMP may require authorizations under the ESA (see section 1.2), the Fish and Wildlife Conservation Act (FWCA) or other legislation. For example, surveys or monitoring that involves the capture and handling of threatened or endangered species generally requires an authorization under the ESA. Any activities that have the potential to contravene the ESA, FWCA or other legislation should be discussed with the local OMNRF district office prior to commencement.

1.2 The Endangered Species Act

The ESA provides the legislative framework for the protection and recovery of SAR in Ontario. Section 9 of the ESA includes the prohibition of activities such as killing, harming, harassing, capturing, or taking a living member of a species listed as extirpated, endangered or threatened on the Species at Risk in Ontario (SARO) List (Ontario Regulation 230/08). Section 10 of the ESA includes the prohibition of damage or destruction of the habitat of an endangered or threatened species.

The ESA contains provisions that enable the Minister of Natural Resources and Forestry to issue permits and enter into agreements authorizing activities that would otherwise be prohibited. Ontario Regulation 242/08 (General) under the ESA also sets out conditional exemptions from prohibitions under the Act for certain activities. For additional information, visit the Government of Ontario website (www.ontario.ca) or read the full text of the legislation and regulations using the links provided below.

- How species at risk are protected
- Endangered Species Act, 2007
- Ontario Regulation 230/08 (SARO List)
- Ontario Regulation 242/08 (General)

Rock outcrop overlooking a forested landscape in eastern Ontario, which provides habitat for a variety of SAR snakes, including the Gray Ratsnake. © J Crowley

1.3 Habitat Protection and Categorization under the ESA

The ESA generally defines habitat as “an area on which a species depends, directly or indirectly, to carry out its life processes” or, in cases where a habitat regulation exists for a species, as the area prescribed by the regulation. Regulated habitat may include areas currently unoccupied by the species, such as areas where the species formerly occurred or areas where there is the potential for the species to become re-established.

Section 10(1) of the ESA prohibits the damage or destruction of the habitat of threatened and endangered species. An activity is considered to damage or destroy habitat if it impairs or eliminates the function of the habitat for supporting one or more of the species’ life processes. Not all activities that alter habitat will damage or destroy that habitat. Therefore, an approach for categorizing habitat according to a species’ anticipated level of tolerance to alteration of that habitat has been developed, which is outlined in the Categorizing and Protecting Habitat under the Endangered Species Act policy (OMNR 2012a). Category 1 habitat identifies highly sensitive habitat areas that are anticipated to have the lowest tolerance to alteration. Category 2 habitat is considered to have moderate tolerance to alteration. Category 3 habitat is considered to have the highest tolerance to alteration. The application of this habitat categorization policy to SAR snake habitat is discussed in further detail in section 3.2

Habitat regulations may have an accompanying habitat protection summary that provides guidance on interpreting and applying the habitat regulation (e.g. OMNR 2012b, c and d, OMNR 2014). Government-endorsed habitat descriptions (e.g. general habitat descriptions; GHD), which provide greater clarity on the area of habitat protected for a species, may be available for SAR receiving general habitat protection (e.g. OMNR 2013a). Habitat protection summaries and general habitat descriptions will indicate how the species’ habitat is categorized.

2. Ontario's Species at Risk Snakes and their Habitat

Eastern Hog-nosed Snake. © J. Crowley

2.1 Species, Status and Distribution

There are 15 extant snake species native to Ontario, and one species, the Timber Rattlesnake (Crotalus horridus), which has been extirpated from Ontario. As of January, 2018, nine snake species/subspecies are listed as endangered, threatened, or special concern on the SARO List. Table 1 lists Ontario's SAR snakes, as well as their status and distribution. The Ontario Reptile and Amphibian Atlas provides detailed information on species distribution, including up-to-date range maps (www.ontarionature.org/atlas).

Table 1: Ontario's snake species/subspecies that are on the SARO List, their status and their distribution. The information below is current as of January, 2018.

Common name (Scientific name)	SARO List Status	Distribution
Blue Racer *(Coluber constrictor foxii)*	Endangered	Pelee Island
Butler's Gartersnake *(Thamnophis butleri)*	Endangered	Southwestern Ontario in Essex, Lambton, Dufferin and Wellington Counties
Eastern Foxsnake *(Pantherophis gloydi)* Carolinian population	Endangered	Southwestern Ontario
Eastern Foxsnake *(Pantherophis gloydi)* Georgian Bay population	Threatened	Eastern Georgian Bay
Eastern Hog-nosed Snake *(Heterodon platirhinos)*	Threatened	Throughout portions of southern and central Ontario
Eastern Ribbonsnake *(Thamnophis sauritus)*	Special Concern	Throughout southern and central Ontario as far north as Sudbury and Pembroke
Gray Ratsnake *(Pantherophis spiloides)* Carolinian population	Endangered	A small, disjunct area north of Lake Erie
Gray Ratsnake *(Pantherophis spiloides)* Frontenac Axis population	Threatened	Throughout the Frontenac Arch north of Kingston
Lake Erie Watersnake *(Nerodia sipedon insularum)*	Special Concern	Pelee, Middle, East Sister, and Hen Islands in western Lake Erie
Massasauga *(Sistrurus catenatus)* Carolinian population	Endangered	Two small, isolated populations in southern Ontario; one in Wainfleet Bog on the northeast shore of Lake Erie and a second in the Town of LaSalle and City of Windsor
Massasauga *(Sistrurus catenatus)* Great Lakes-St. Lawrence population	Threatened	Throughout the northern Bruce Peninsula and eastern Georgian Bay
Queensnake *(Regina septemvittata)*	Endangered	Small, disjunct populations associated with large rivers and lakes in southwestern Ontario
Timber Rattlesnake *(Crotalus horridus)*	Extirpated	Previously found along portions of the Niagara escarpment, particularly in the Niagara gorge; no longer found in the wild in Ontario

2.2 Snake Habitat

2.2.1 Hibernation Habitat

Snakes spend the winter in underground retreats, known as hibernacula (singular hibernaculum), that allow them to get below the frost line and avoid freezing. Snakes generally require access to the water table to avoid desiccation during hibernation (Costanzo 1986, 1989, Todd et al. 2009, Shoemaker et al 2009, Smith 2009, Yagi and Planck 2012). The area between the frost line and water table that provides the necessary conditions for overwintering, including sufficient oxygen, has been termed the "life zone" (Yagi and Planck 2012, Figure 1). The size of the life zone can vary significantly across the landscape, including over fine spatial scales, based on topography, soil type, drainage, vegetation cover, and other variables (A. Yagi pers. comm.). Snake hibernacula often have southern exposure, which is likely an important habitat characteristic for many species (Prior and Weatherhead 1996, Harvey and Weatherhead 2006a). Due to the very specific microhabitat conditions that are necessary for overwintering, hibernation habitat is often limiting on the landscape (Harvey and Weatherhead 2006a, Burger et al. 2012). Therefore, snakes often demonstrate high fidelity to hibernacula and these habitats are often used communally (Porchuk 1996, Blouin-Demers et al. 2000, King 2003, Lawson 2005, Harvey and Weatherhead 2006a, WEIS unpublished data).

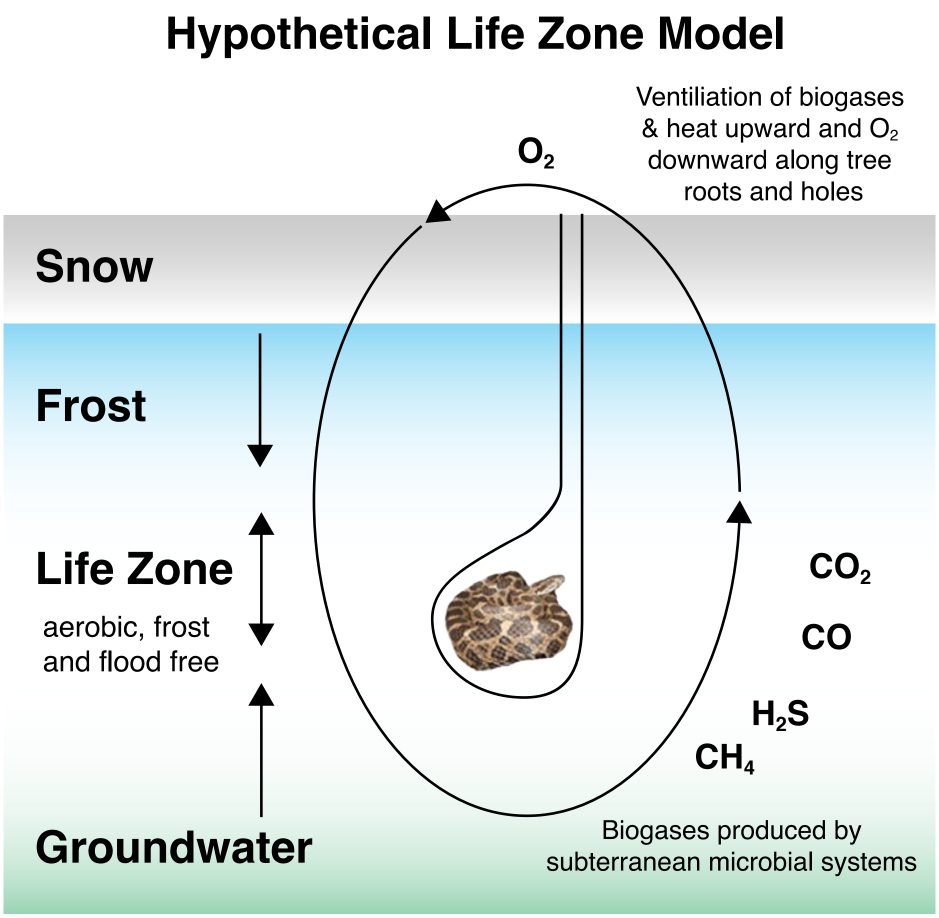

Figure 1. A hypothetical subterranean feature that has a suitable life zone for snake hibernation between the frost line and the water table (from Yagi and Planck 2012).

A variety of habitat features can provide suitable hibernation habitat for snakes, including fissures and crevices in rock, animal burrows, underground spaces associated with large tree roots and stumps, foundations (e.g., buildings, bridges, culvert embankments), crayfish burrows, ant mounds, old cobble-lined wells and cisterns, and other features that allow subterranean access (M'Closkey et al. 1995, Ernst and Ernst 2003, Harvey and Weatherhead 2006a, Jellen and Kowalski 2007, Gillingwater 2008, Rowell 2012, WEIS unpublished data). The type of habitat that hibernacula are located in (e.g. forest, wetland, early successional), as well as the microhabitat characteristics of the hibernacula (e.g. rock crevice, mammal burrow) vary considerably across species and geographic location.

The following paragraphs provide a description of the typical hibernation habitat that each of Ontario's SAR snakes have been documented to use, based on the best available information as of 2017. However, this information is not intended to be a comprehensive description of hibernation habitat, since our knowledge of SAR snake hibernation habitat is constantly evolving.

Rocky slope that is typical of some hibernation habitat for SAR snakes. © J. Crowley

Blue Racer

- In Ontario, Blue Racers hibernate primarily in underground cavities in limestone plains, which are accessed through cracks in the bedrock (Porchuk 1996). However, the species has also been documented to hibernate in rock piles and anthropogenic structures (e.g. bridge foundations; Porchuk 1996). Hibernation sites are typically located in open habitat (e.g., field, savannah and rocky areas; Porchuk 1996).

Butler's Gartersnake

- In one region in southwestern Ontario, Butler's Gartersnakes predominantly hibernate in crayfish burrows in wet meadows (WEIS unpublished data). However, in areas where crayfish habitat is lacking, Butler's Gartersnakes have been documented to hibernate in other features, such as ant mounts, mammal burrow and anthropogenic features (e.g. rubble piles, old foundations; COSEWIC 2010, Environment Canada 2016).

Eastern Foxsnake

- Eastern Foxsnakes hibernate in a wide range of habitats and microhabitats based on what is locally available. Individuals of this species hibernate in animal burrows (e.g. mammal burrows), root hollows, cavities in bedrock accessed through cracks and crevices, anthropogenic features (e.g. old foundations) and other underground cavities (Eastern Foxsnake Recovery Team 2010, WEIS unpublished data). Hibernation sites can occur in many habitat types, including forest, open habitat and wetlands (Eastern Foxsnake Recovery Team 2010, WEIS unpublished data).

Eastern Hog-nosed Snake

- Eastern Hog-nosed Snakes hibernate in burrows that they excavate in sandy soils or in mammal burrows (Plummer 2002, Ernst and Ernst 2003). Aside from a preference for sandy soils, there is little information about hibernation habitat selection of Eastern Hog-nosed Snakes in Ontario.

Eastern Ribbonsnake

- Little is known about the hibernation sites used by Eastern Ribbonsnake, but the species appears to utilize a variety of features, such as rock crevices, talus slopes, animal burrows, ant mounds, root hollows, and other underground cavities (COSEWIC 2012a). Hibernation sites may be located in a variety of habitats, including wetlands, upland forest, and open habitat (Carpenter 1953, Imlay 2009, COSEWIC 2012a), and they are typically located within a few hundred metres of summer wetland habitat (COSEWIC 2012a).

Gray Ratsnake

- Individuals in the Frontenac Axis population tend to hibernate in moderately sloped, rocky hillsides with a south-southeast aspect (Prior and Weatherhead 1996, S. Thompson pers. comm). Hibernation sites have been documented primarily in deciduous and mixed forest (Prior and Weatherhead 1996), but they can occur in a variety of habitat types, including open habitat (Prior and Weatherhead 1996). There is little information available on hibernation habitat use by the Carolinian population, but Gray Ratsnake hibernation habitat may be similar to, and as diverse as, Eastern Foxsnake hibernation habitat in that region.

Lake Erie Watersnake

- Lake Erie Watersnakes hibernate in underground cavities, which are accessed through fissures in the bedrock, mammal burrows and root hollows, as well as in anthropogenic structures (e.g. building foundations and shoreline walls; King 2003, Stanford et al. 2010, COSEWIC 2015). Hibernation sites may occur in a variety of habitats, including field, forest and shrub/scrub, and are typically within 100 metres of the Lake Erie shoreline, but they may be as much as 700 m inland (King 2003, Stanford et al. 2010, COSEWIC 2015).

Massasauga

- Massasaugas utilize different habitats and microhabitats for hibernation in different regions of the province. On the Bruce Peninsula, Massasaugas hibernate underground, typically in crevices in the bedrock, mammal burrows and root cavities (Harvey and Weatherhead 2006a). Hibernation sites occur in forested areas, and all forest within the distribution of this species on the Bruce Peninsula may be suitable for hibernation if appropriate microhabitat is present (Harvey and Weatherhead 2006a). Massasaugas along the eastern shore of Georgian Bay hibernate in wetlands with sparse tree or shrub communities, and hibernation sites are typically associated with moss or sedge hummocks (EMRT 2005; COSEWIC 2012b). In Wainfleet Bog, Massasaugas hibernate in root hollows, mammal burrows or other underground cavities in organic soils within shrub- or forest/shrub-dominated communities (Yagi pers. comm. 2012). In the Windsor/LaSalle area, Massasaugas have been documented to hibernate in mammal burrows, root hollows, crayfish burrows, and other underground cavities within early successional meadow and tallgrass prairie habitat (Prenny pers. comm. 2012).

Queensnake

- Very little is known about Queensnake hibernation habitat in Ontario, but it is suspected that hibernation sites occur within relatively close proximity (i.e. a few hundred metres) to the species' aquatic habitat.

Queensnake. © J. Crowley

Although surface habitat characteristics can be useful for identifying potential hibernation habitat (e.g. a south-facing rocky slope), occupied hibernacula cannot be differentiated from other potentially suitable but unused habitat features based on surface characteristics alone (Prior and Weatherhead 1996, Blouin-Demers et al. 2000, Harvey and Weatherhead 2006a, A. Yagi pers. comm.). Thus, the identification of snake hibernacula generally requires confirmation of use by the species, typically through targeted habitat surveys (see section 3.3.1 on hibernacula identification).

Hibernation periods vary among species, and within snake species at different latitudes. Warm spring temperatures can trigger early emergence, while cool autumn temperatures can induce snakes to enter hibernation earlier in cooler years. The hibernation period for Ontario's SAR snakes begins in September, October or early November and extends until April or early May, depending on species, seasonal weather variation, and latitude (Blouin-Demers et al. 2000, Rowell 2012, WEIS unpublished data). Snakes of many species thermoregulate at their hibernation sites (referred to as staging) for several weeks in the spring following emergence, as well as for a shorter period in the fall prior to entering hibernation (e.g. Marshall et al. 2006). This means that snakes may arrive at their hibernacula in late August or early September and leave as late as the end of May. Therefore, when determining appropriate timing windows for activities around hibernacula, it is important to consider that snakes will likely be present at hibernacula during both hibernation and staging periods.

2.2.2 Nesting Habitat

In Ontario, the Blue Racer, Eastern Foxsnake, Eastern Hog-nosed Snake and Gray Ratsnake are oviparous (they lay eggs). When selecting nesting sites, Ontario's snakes demonstrate a preference for open habitats (i.e. areas that lack tree and shrub cover, such as early successional habitat, forest clearings, forest edge, rock outcrops and shorelines), which receive full sun for most of the day and are warmer than the surrounding environment (Burger and Zappalorti 1986, Porchuk 1996, Robson 2011, Peet-Paré and Blouin-Demers 2012). The average temperature in the nest chamber is typically between 24-36°C (Blouin-Demers et al. 2004, Peet-Paré and Blouin-Demers 2012). High nest temperatures (e.g. at the high end of this range) result in shorter incubation periods for snake eggs (Blouin-Demers et al. 2004, Löwenborg et al. 2010) which, in turn, may increase hatchling survivorship by increasing the amount of time available for them to forage before their first hibernation. In addition, hatchling snakes incubated at higher temperatures tend to be larger, faster, more responsive to predatory stimuli, and have fewer abnormalities (Burger et al. 1987, Burger 1991, Burger 1998, Blouin-Demers et al. 2004, Löwenborg et al. 2010, Peet-Paré and Blouin-Demers 2012). However, extremely high nest temperatures, which can occur under scrap metal, for example, can result in egg mortality (Porchuk 1996). Naturally occurring nesting sites can include hollow trees, rotting logs, stumps, cavities under logs or rocks, piles of vegetation, and mammal burrows (Porchuk 1996, Blouin-Demers et al. 2004, Rowell 2012, COSEWIC 2014). Anthropogenic features, such as compost or brush piles, are also used.

Unlike other Ontario SAR snakes, Eastern Hog-nosed Snakes typically excavate nests in sand or loose, well-drained sandy soils (Cunnington and Cebek 2005, Peet-Paré and Blouin-Demers 2012), and the eggs are commonly laid 10-14 cm below the surface (Cunnington and Cebek 2005). As with other SAR snakes, Eastern Hog-nosed Snake nesting sites are located in open habitats (Cunnington and Cebek 2005, Peet-Paré and Blouin-Demers 2012), and nest sites also tend to be in areas with less than 5% herbaceous vegetation (Peet-Paré and Blouin-Demers 2012). These nesting habitats are sometimes limited on the landscape, resulting in communal use of, and high fidelity to, these features (Blouin-Demers et al. 2004, Cunnington and Cebek 2005, Robson 2011).

Open, sandy habitat suitable for Eastern Hog-nosed Snake nests. © J. Crowley

The timing of nesting and hatching varies with species, seasonal weather conditions, and latitude. In Ontario, SAR snakes nest between mid-June to late July (typically in late June and early July), but Gray Ratsnakes may also nest in early August (Frontenac Axis population) (COSEWIC 2007a, b, 2008, WEIS unpublished data). Hatching typically occurs from late August until mid-October (COSEWIC 2007a, b, 2008).

2.2.3 Gestation and Birthing Habitat

In Ontario, Butler's Gartersnake, Eastern Ribbonsnake, Lake Erie Watersnake, Massasauga, and Queensnake are ovoviviparous (eggs hatch within females, who embryos and give birth to live young). Gravid (i.e., pregnant) females use specialized habitats known as gestation sites, which typically occur in habitats that lack (or have very limited) canopy cover and receive high sun exposure (Harvey and Weatherhead 2006b, Foster et al. 2009), allowing them to maintain consistently high body temperatures to promote the development of the young (Foster et al. 2009, Harvey and Weatherhead 2010). Microhabitat features that allow snakes to regulate body temperature, and provide shelter from predation, are essential characteristics of gestation sites, and include rock piles, rock crevices, mammal burrows, brush piles, low-lying vegetation, and anthropogenic structures such as boards and scrap metal (Rouse 2006, Harvey and Weatherhead 2006b, Marshal et al. 2006, Shoemaker and Gibbs 2010, Gillingwater 2012, COSEWIC 2015). Like hibernation and nesting habitats, gestation and live-birthing sites have very specific microhabitat characteristics and may be limited on the landscape. Individuals demonstrate high fidelity to these sites, which are often used communally by multiple individuals "(Shoemaker and Gibbs 2010, Black 2016, Environment Canada 2016, WEIS unpublished data).

The characteristics of gestation sites vary among species, depending on species-specific habitat preferences. Female Butler's Gartersnakes utilize a variety of microhabitat features within open habitat for gestation, including cover objects such as rocks or debris, brush piles, patches of dense grass/herb cover, and areas with a heavy thatch layer of dead vegetation (COSEWIC 2010, WEIS unpublished data). Massasauga gestation sites are typically located in habitats with less than 25% canopy cover, such as forest clearings, forest edges, rock outcrops, early/mid-successional wetlands, shorelines, meadows, fields, and alvars (Harvey and Weatherhead 2006b, Marshal et al. 2006, Rouse 2006, Foster et al. 2009, Shoemaker and Gibbs 2010). Massasauga gestation sites in Ontario are typically characterized by large table rocks, rock piles, rock ridges, beaver lodges, dense, low-lying shrubs (e.g. cedar, juniper) or brush piles, and these features are usually associated with short vegetation such as shrubs or grasses (Harvey and Weatherhead 2006b, Rouse 2006, OMNR 2013a, Choquette 2015). Queensnakes, Lake Erie Watersnakes, and Eastern Ribbonsnakes are semi-aquatic and most summer activity, including gestation and birthing, occurs in open habitats along the shorelines of lakes, rivers and wetlands (King 2003, Gillingwater 2012, COSEWIC 2015). Microhabitat features typically used by these species include rocks, woody debris, dead vegetation and anthropogenic cover such as boards, sheet metal and geotextile material (Gillingwater 2012, COSEWIC 2015).

Gravid female Massasauga basking among vegetation and rocks (left) at a gestation site (right) in Eastern Georgian Bay. © J. Crowley

Most snake species give birth at or near gestation sites (Jellen and Kowalski 2007, Gillingwater 2012), and neonates make use of the same microhabitats that provided cover and retreat sites for the gravid females (Jellen and Kowalski 2007, Gillingwater 2012, Crowley pers. obs.). However, Butler's Gartersnake live-birthing sites can be a considerable distance (hundreds of metres) from gestation sites (Environment Canada 2016, Wood Environment & Infrastructure Solutions unpublished data). In Ontario, Butler's Gartersnake live-birthing sites tend to consist of grassy lowland areas or wet depressions in open areas, typically with some shrub or tree cover along the edges (Environment Canada 2016, Wood Environment & Infrastructure Solutions unpublished data). Newborn Butler's Gartersnakes have also been found using constructed birthing habitats in Ontario (WEIS unpublished data), which featured low-lying wet areas with scattered planted shrubs around the edges (WEIS unpublished data).

Gravid females move to gestation sites shortly after emerging from hibernation, and remain at these sites until giving birth in late summer (Marshall et al. 2006, Rouse et al. 2011). Depending on species, seasonal weather conditions and latitude, Ontario's SAR snakes arrive at gestation sites in mid-May to mid-June, and give birth between late July and late September (COSEWIC 2006, 2010, 2012a, b).

A female Massasauga and her newborn young (left) at a gestation and birthing site in a small forest clearing (right) on the Bruce Peninsula. © J. Crowley

2.2.4 Thermoregulation and Foraging Habitat

Unlike mammals and birds, which maintain a constant core body temperature, snakes are ectothermic and their body temperature fluctuates with the ambient environment. Therefore, snakes alter their behaviour and habitat use to regulate body temperature (behavioural thermoregulation). Ontario's snakes have optimal body temperatures within the range of 25-34°C, and they select habitats that allow them to maintain body temperatures as close to this preferred range as possible (Brown and Weatherhead 2000, Blouin-Demers and Weatherhead 2001a, b, Row and Blouin-Demers 2006b, Harvey and Weatherhead 2010, Plummer and Mills 2010, Harvey and Weatherhead 2011). Open and forest edge habitats are generally warmer than forest habitat, and Ontario's snakes primarily select these habitats for thermoregulation, foraging, reproduction, shedding and most other life processes during the active season (Blue Racer: Porchuck 1996; Gray Ratsnake: Blouin-Demers and Weatherhead 2001a, Carfagno and Weatherhead 2006; Massasuaga: Harvey and Weatherhead 2006b; Eastern Hog-nosed Snake: Lagory et al. 2009, Peet-Paré and Blouin-Demers 2012; Eastern Foxsnake: Row et al. 2012).

Snakes increase their body temperature by basking in sunny areas. Basking sites are located in open habitats, such as rock barrens, forest clearings, forest edge, fields, meadows, wetlands and shorelines that have warmer temperatures than the surrounding areas (Row and Blouin-Demers 2006c, Harvey and Weatherhead 2006b, Shoemaker and Gibbs 2010, Plummer and Mills 2010). Basking sites typically receive sunlight for most of the day (Webb and Shine 1998). Semi-aquatic species, such as the Eastern Ribbonsnake, Queensnake, and Lake Erie Watersnake, typically bask in open areas in wetlands and along the shorelines of lakes and rivers (Bell et al. 2007, COSEWIC 2006, OMNRF 2014). Snakes do not require large, open habitats for basking; small forest clearings and canopy gaps can be sufficient to provide basking opportunities (Harvey and Weatherhead 2010). However, habitats that become overgrown and develop closed canopies are unlikely to function as basking habitats (Jaggi and Baur 1999, Blouin-Demers and Weatherhead 2002, Johnson et al. 2016). Snakes may use basking sites throughout the active season, but individuals bask most often in the spring when air temperatures are cooler and snakes must actively bask to maintain their preferred body temperature (Brown and Weatherhead 2000, Row and Blouin-Demers 2006a, Harvey and Weatherhead 2010).

Wetlands are the primary thermoregulation and foraging habitat used by Eastern Ribbonsnake in Ontario, but the edges of these habitats are also readily used by a variety of other SAR snakes. © J. Crowley





Open and semi-open habitats that are used by various snake SAR in Ontario for thermoregulation and foraging. © J. Crowley

Open and semi-open habitats that are used by various snake SAR in Ontario for thermoregulation and foraging.(continued). © J. Crowley

Lake Erie Watersnake thermoregulation and foraging habitat on Pelee Island. © J. Crowley

Queensnake thermoregulation and foraging habitat in Southwestern Ontario. © J. Crowley

Snakes typically bask near retreat sites, which are microhabitat features that provide shelter from extreme temperatures and protection from predation, such as rock piles, vegetation (thatch, low-lying shrubs), brush piles, rock crevices, and mammal burrows. (Huey et al. 1989, Nilson et al. 1999, Row and Blouin-Demers 2006a, Harvey and Weatherhead 2006b, Shoemaker and Gibbs 2010, Sperry and Weatherhead 2010, Johnson et al. 2016). In most cases, microhabitat features used for basking also function as retreat sites. For example, a snake basking on top of a rock pile, beaver lodge, brush pile, etc. can seek refuge within that feature to hide from predators or avoid inhospitable temperatures. Semi-aquatic snakes will also bask on emergent or shoreline vegetation, floating logs, hummocks and other structure in aquatic habitats, particularly in areas where they can quickly escape into the water. For example, Queensnakes in Ontario have been documented to regularly bask in canary reed grass and branches along the shorelines of the river and then drop into the water at the first sign of potential danger (Aarts et al. 2016; J. Crowley pers. obs, J. Urquhart pers. obs.). Snakes also use a variety of artificial structures for thermoregulation, such as riprap, gabion baskets, retaining walls, crib docks, barns, hedgerows, woodpiles, cement slabs, plywood and other discarded debris (Blouin-Demers and Weatherhead 2002, Gibbons and Dorcas 2004, Shoemaker et al. 2009, Lelièvre et al. 2010, Conelli et al. 2011, Row et al. 2012, WEIS unpublished data, S. Gillingwater pers. Comm., S. Marks pers. comm.). Individuals of many snake species thermoregulate while completely hidden within or under microhabitat features, particularly thin rocks, thatch, and boards (Johnson et al. 2016, WEIS unpublished data). Open habitats that lack sufficient cover and retreat sites (e.g. mowed residential lawns, the rock pavement portions of alvars and cropland) are generally avoided and unlikely to be used as thermoregulation habitat (Enge and Wood 2002, Durbian and Lenhoff 2004, Durbian 2006, Harvey and Weatherhead 2006b, Row et al. 2012, Thomasson and Blouin-Demers 2015). However, the edges of open habitats, including those that may otherwise lack sufficient cover, often provide the necessary structure and thermal gradients for thermoregulation, and several species show a strong preference for habitat edges (Blouin-Demers and Weatherhead 2001a, Carfango and Weatherhead 2006, Row and Blouin-Demers 2006c, Harvey and Weatherhead 2006b).

A Massasauga basking beside juniper shrubs along a rocky shoreline in eastern Georgian Bay. © J. Crowley

Snakes forage for food in a wide range of habitats, and the type of habitat used for foraging depends on prey preferences (Blouin-Demers and Weatherhead 2001a, b). Given the strong influence of thermal quality on snake habitat selection, many snake species tend to forage in open and edge habitats where they can also meet their thermoregulatory needs (Blouin-Demers and Weatherhead 2001a, Row and Blouin-Demers 2006a). However, Gray Ratsnakes forage in closed-canopy forest more than most other snake species, despite the trade-offs between thermoregulation and foraging opportunities (Blouin-Demers and Weatherhead 2001a, b, Blouin-Demers and Weatherhead 2002). Lake Erie Watersnakes forage exclusively for fish in Lake Erie, and they depend on shoreline habitat for basking between foraging excursions.

A Lake Erie Watersnake returning to shore to bask after foraging in Lake Erie. © J. Crowley

Snakes shed their entire outer layer of skin multiple times a year, and the shedding process can take several days. When shedding, snakes have restricted mobility and are vulnerable to predation (Seigel et al. 1987, Blouin-Demers and Weatherhead 2001a, Aubret and Bonnet 2005). During this period, snakes use specific habitats, referred to as shedding sites, which are microhabitat features that facilitate the shedding process and provide protection from predators. Shedding sites are typically located in open canopy or edge habitats that allow snakes to maintain elevated body temperatures (Gibson et al. 1989, Peterson et al. 1993, Blouin-Demers and Weatherhead 2001a). Since basking and shedding sites provide similar conditions with respect to being suitable for thermoregulation and safe from predators, many habitat features can serve as both effective basking sites and shedding sites (Zappalorti and Reinert 1994, Blouin-Demers and Weatherhead 2001a).

Some habitats, such as brush piles, can be a valuable source of prey for snakes (Sperry and Weatherhead 2010), as well as provide ideal conditions for thermoregulation and shedding (USFWS 2003, Zappalorti and Mitchell 2008, Choquette 2015, WEIS unpublished data). Microhabitat features that are capable of satisfying a range of habitat needs during the active season provide particularly important habitat for snakes and have disproportionately high use compared to other habitats (Sperry and Weatherhead 2010). High quality basking and shedding sites can be limited on the landscape and are sometimes used communally by multiple individuals of the same species and individuals of multiple species (Zappalorti and Reinert 1994, Blouin-Demers and Weatherhead 2001a, Shoemaker and Gibbs 2010).

2.2.5 Movement Habitat

Ontario SAR snakes can have home ranges that are up to several km in length, depending on the species (Lawson 2005, MacKinnon 2005, Rouse et al. 2011). During the active season, individuals move extensively throughout their home range to access habitats that are required for various life processes (Rouse et al. 2011, Martino et al. 2012, Gardiner et al. 2013). For example, Rouse et al. (2011) documented average monthly movement rates (during the active season) of about 1.5-7.5 km for Eastern Hog-nosed Snakes and 0.5-2 km for Massasaugas, and MacKinnon (2005) found that Eastern Foxsnakes in the Georgian Bay area moved, on average, about 20 km over the active season. Seasonal movements include spring and fall migration between hibernacula and summer habitat (Gardiner et al. 2013), long distance movements by males during the breeding period (Rouse et al. 2011), and movement among key habitat features such as reproduction sites, basking sites and shedding sites (Robson 2011). Snakes also move through various thermoregulation and foraging habitats over the course of a season (Rouse et al. 2011).

Ontario's SAR snakes move through a variety of habitats that they otherwise spend little time in, such as open water (e.g. lakes, rivers; Lawson 2005), closed-canopy forest (Porchuk 1996, Blouin-Demers and Weatherhead 2001a, Harvey and Weatherhead 2006b, Row et al. 2012, Thomasson and Blouin-Demers 2015), and open habitats lacking cover, such as sand dunes and rock barrens (Rouse et al. 2011, Crowley pers.obs.). In heavily developed landscapes that have little natural habitat, SAR snakes also use hedgerows, drains, ditches, and other vegetated linear features as movement corridors. However, snakes often avoid moving through large areas that do not provide sufficient cover. For example, Row et al. (2012) found that Eastern Foxsnakes avoided agricultural fields altogether, likely because these large areas are completely devoid of cover during most of the year.

Although closed canopy forest provides little in the way of basking opportunities, many SAR snakes will readily move through forest in order to access other habitats. © J. Crowley

3. Habitat Identification

The first step in identifying SAR snake habitat is determining which species depend on the site in question. Following this, habitats should be identified based on guidance under the ESA, such as habitat regulations, general habitat descriptions and other relevant OMNRF direction. In some cases, field surveys may be necessary to confirm the use of particular habitats or habitat features. The following sections describe the process for identifying SAR snake habitat in Ontario.

3.1 Determining Species' Presence

All existing species occurrence data for the area in question should be reviewed, including but not limited to OMNRF's provincially tracked species data (available through Land Information Ontario, the Natural Heritage Information Centre data, or OMNRF district data) and other relevant databases external to the Ministry (e.g., Ontario Reptile and Amphibian Atlas). This information can be useful in confirming species presence at the site in question. However, a lack of recent occurrence records in an area does not provide sufficient evidence of species absence. Much of Ontario's landscape has yet to be thoroughly surveyed for herpetofauna, and the lack of occurrence records in an area is often the result of insufficient survey effort, particularly in the case of cryptic snake species. Even in the absence of species occurrence records from the site in question, regulated or general habitat may be identified at the site based on nearby occurrences. Therefore, it is important to consider the species distribution in the surrounding landscape in addition to just within the boundary of the site in question.

When there is an absence of recent or historic SAR occurrence data at a site, field surveys should be carried out to assess presence/absence for each snake SAR that may be present (i.e. if the site is within the known distribution of a species and suitable habitat is present). However, if regulated or general habitat has already been identified at the site (e.g., based on the presence of nearby species occurrences), additional surveys/occurrence data may not be necessary.

If SAR occurrence data are absent from a site that has suitable SAR snake habitat, and regulated or general habitat has not already been identified at the site (e.g., based on the presence of nearby species occurrences), field surveys should be carried out to assess presence / absence of SAR snakes. Field surveys to assess presence / absence of Ontario's SAR snakes should follow the guidance and recommendations set out in the OMNRF *Survey Protocol for Ontario's Species at Risk Snakes (2016),* as well as the OMNRF *Survey Protocol for Queensnake (Regina septemvittata) in Ontario* (2015).

3.2 Applying ESA Habitat Direction to Identify SAR Snake Habitat

Depending on the type of habitat, general and regulated habitat for snakes is identified based on either a) the confirmed use of the habitat in question to carry out a specific life process, or b) the suitability of an area to provide for a specific life process and the proximity of that area to a species observation record (OMNR 2012b, c, 2013a, OMNRF 2014).

- a) The identification of some habitat types or features as regulated or general habitat under the ESA requires confirmation of their use by the species for the relevant life process. Habitat features that typically require confirmation of use by the species include hibernacula, nesting sites, gestation sites, communal basking sites and communal shedding sites (OMNR 2012b, c, 2013a, OMNRF 2014). Section 3.3 provides guidance for confirming the use these habitats by SAR snakes.

- b) Alternatively, some habitats for SAR snakes are identified based on the suitability of an area for a specific life process (e.g. thermoregulation and foraging) and its proximity to a verified observation of the species (OMNR 2012b, c, 2013a, OMNRF 2014). For example, regulated habitat for the Eastern Foxsnake (Carolinian population) includes specific habitat types that provide suitable foraging, thermoregulation, or hibernation conditions and that are within 1,500 metres of an observation of the species (O. Reg. 242/08). These habitats can be identified and categorized under the ESA based on an Eastern Foxsnake observation and basic habitat information (e.g. aerial imagery, Ecological Land Classification mapping, etc.); further surveys are not required to confirm the use of these habitats by the species.

It is important to note that even if the habitat types or features described in the first bullet above are determined not to be used by the species for that life process, the area may still be identified as general or regulated habitat for other life processes, as described under the second bullet (e.g. when the use of an area for gestation cannot be confirmed, that habitat would still be identified as thermoregulation habitat). Refer to section 2 for a description of the typical habitat characteristics that comprise suitable snake habitat.

An Eastern Foxsnake and typical forest-edge-shoreline habitat of this species in Eastern Georgian Bay. © J. Crowley

3.3 Confirming the Use of SAR Snake Habitat Features

Visual encounter surveys (VES) can be used to confirm the use of hibernation, nesting, gestation, birthing, communal basking and communal shedding sites by SAR snakes, as long as potentially suitable habitats are sufficiently surveyed at the right times of year. Shed skins may also be encountered during VES and can assist in confirming the use of a particular habitat features by SAR snakes, and the "Guide to the Identification of the Shed Skins of the Snakes of Canada" can assist with species identification. Although radio-telemetry can assist in locating these habitat features, a high proportion of a population must be tracked regularly for several years in order to effectively identify the majority of active hibernacula and other habitat features that are used by the population. This is extremely time- and cost-intensive, as well as intrusive and stressful for snakes. Thus, radio-telemetry is generally not recommended for the sole purpose of identifying habitat features.

Regardless of the methodology used, hibernation, nesting, gestation and birthing habitats can be very difficult to identify. This is due in part to the cryptic and often subterranean nature of some of these habitats, as well as the limited window of time during which snakes can be documented using these features. Further to this, habitat features may not be used every year. For example, most of Ontario's SAR snakes have biennial reproduction, and females of these species use gestation, nesting or live birthing sites only once every two years. Similarly, hibernacula may not be used every year (e.g. Burger et al. 2012). Consequently, two years of visual encounter surveys are necessary to determine with reasonable confidence that potential hibernation, gestation, nesting, and live-birthing habitats are not being used by the species. If it is not feasible to carry out two years of surveys, it is recommended that all potential hibernation, gestation, live birthing, and nesting habitats be treated as though they are depended on by the target species for the purposes of habitat protection and management. A single year of surveys is generally sufficient to assess use of potential communal basking and communal shedding sites because snakes tend to be more conspicuous when using these habitats.

Eastern Ribbonsnake. © J. Crowley

The following process is recommended to confirm the use of hibernation, gestation, birthing, nesting, communal basking and communal shedding habitat:

- Identify and map all potentially suitable hibernation habitats, as well as all open and edge habitats that may contain nesting, gestation, birthing, communal basking and communal shedding sites for the target species (refer to the habitat requirements discussed in Section 2.2 and the species-specific preferences outlined in Table 3). Ensure that aerial imagery and other habitat information that is consulted is of sufficient quality to accurately distinguish open habitats at a fine scale (e.g. ability to detect canopy gaps as small as 5 m in diameter) and at the broader landscape level.
- Inspect all potentially suitable hibernation habitats, as well as all open and edge habitats to refine the delineation of potential hibernation, nesting, gestation, birthing, communal basking and communal shedding sites.
- Conduct field surveys to assess the use of all potential hibernation, nesting, gestation, birthing, communal basking and communal shedding habitat by SAR snakes, following the methodology outlined in the following sections. All surveys for SAR snakes should adhere to the recommendations and methodology set out in the Ministry of Natural Resources and Forestry (OMNRF) *Survey Protocol for Ontario's Species at Risk Snakes (2016),* as well as the OMNRF *Survey Protocol for Queensnake (Regina septemvittata) in Ontario* (2015). When there is conflicting guidance (e.g. timing for surveys), the guidance provided in this document should be followed, as it is specific to the habitats being surveyed. For the purposes of this BMP, one survey is the effort required to thoroughly search all potential habitat in question; it is possible that one survey may require multiple days to complete, depending on the size of the site/habitat to be surveyed. Do not survey the same habitat more than once on the same day.

Treed alvars can provide high quality habitat for snakes, particularly along forest edges. © J. Crowley

3.3.1 Hibernation Habitat

It can be challenging to identify potential hibernacula for some species because these features cannot be reliably differentiated from the surrounding landscape based on surface habitat features (Prior and Weatherhead 1996, Harvey and Weatherhead 2006a, A. Yagi pers. comm.). In these cases, it is recommended that all areas that are potentially suitable, even if they encompass most of the site in question, be identified as potential hibernation habitat. For example, Harvey and Weatherhead (2006a) recommend that all forested areas on the Bruce Peninsula be identified as potential hibernation habitat for Massasauga. In most cases, the use of potential hibernation habitat by SAR snakes should be assessed using the visual encounter survey methodology outlined below. However, when it is possible to identify a limited number of finite features as potential hibernacula, the methods involving fencing and traps (see section 6.4.3) may be employed.

Visual Encounter Survey Methodology for Hibernation Habitat

- Visually scan for basking snakes while slowly walking through potential hibernation habitat.
- Scan any obvious potential hibernacula features (e.g. south-facing rocky slope) with binoculars, as this can allow for the detection of snakes before they retreat (Zappalorti and Reinert 1994).
- Survey potential hibernation habitat from mid-morning to mid-afternoon when the maximum daily air temperature is 10ºC or warmer, as most snakes will not emerge at cooler temperatures (Macartney et al. 1989, Blouin-Demers et al. 2000).
- Plan surveys according to daily weather conditions, and adjust the survey schedule as needed as weather changes. Staging periods in the spring and fall (when snakes are actively basking above ground) can be very short, ranging from a few days to a few weeks, depending on weather and species (e.g. Blouin-Demers et al. 2000, WEIS unpublished data). The emergence period can also be quite variable from year to year (Weatherhead 1989, Blouin-Demers et al. 2000, WEIS unpublished data).

Timing

- Conduct surveys during the spring emergence period (see section 2.2.1 for timing of the emergence period)
- Hibernation site surveys are most effective during the spring because the staging period tends to be longer during the spring than the fall, and snakes also bask more conspicuously during the spring (see section 2.2.4).
- Snakes may also be warier in fall than in spring (Shine and Mason 2004), making them more difficult to detect. Fall surveys can be effective but should be supplemental to the recommended minimum number of spring emergence surveys.

Search effort

- Ten visual encounter surveys of all potential hibernation habitat are recommended to determine if that habitat is used for hibernation. These surveys should be spread equally over two years.
- If, after completing 10 surveys, a feature or area is confirmed as a hibernaculum for any snake species (including non-SAR) other than the target SAR snake species, additional surveys are recommended to determine with reasonable confidence that the target species is not using the hibernaculum. This may be achieved by conducting five additional visual encounter surveys of the target area/feature during spring emergence or installing fencing and traps (see section 6.4.3).

3.3.2 Gestation Habitat

Conduct visual encounter surveys to assess the use of potential gestation habitat by SAR snakes.

Methodology

- Visually scan for basking snakes while slowly walking through potential gestation habitat (see section 2.2.3 for a description of gestation habitat).
- Occasionally scan ahead with binoculars, focusing on potential gestation microhabitat features (see section 2.2.3), as this can allow for the detection of snakes before they retreat (Zappalorti and Reinert 1994).
- After the initial scan, thoroughly search all potential gestation microhabitat features. This is important, because snakes sometimes thermoregulate under cover, and gestating females may retreat under cover once they have attained the desired body temperature (Shoemaker and Gibbs 2010).
    - Peer into all cavities; the use of a flashlight can assist with this.
    - Gently turn over any loose cover (rocks or logs) to search for snakes.
    - Do not damage structures during the search, and carefully replace cover objects or other structures exactly how they were found. Slight changes in the position of cover objects can significantly alter the microclimate beneath, potentially rendering it unsuitable for use by SAR snakes (Pike et al. 2011).
- When a snake is located within potential gestation habitat, identify the species and determine if it is a gravid female. This will require capturing the individual in most cases; when capturing and handling snakes, follow the guidance in the OMNRF SAR handling manual (OMNRF undated).
    - If the snake is gravid, consider the feature that the snake is basking on or near to be a gestation site. Additional surveys can help to identify the specific feature that is being used for gestation if it is not obvious during the first encounter.
    - If the sex or condition of the snake cannot be determined, it may be necessary to survey the area (all potential gestation/basking features within 30 m) repeatedly over several weeks to determine whether the snake is residing at the site for an extended period of time (i.e. weeks to months).

When surveying potential gestation habitat, it may be necessary to identify individual snakes to determine if the same snake is residing at the site.   Snakes can be marked using Passive Integrated Transponders (PIT tags) so that they can be easily identified during successive captures. PIT tags should only be implanted by a qualified professional (i.e. an individual with relevant biological expertise and training in the use of PIT tags on snakes). Alternatively, photographs can be used to differentiate between individuals of some species using the following characteristics:

- Massasaugas: a photograph clearly showing the dorsal patterning
- Eastern Foxsnake: photographs depicting both the dorsal patterning and part of the ventral (belly) pattern (ensure that the same portion of the ventral surface is photographed for all species).
- Eastern Hog-nosed Snake and Gray Ratsnake: photographs depicting both the dorsal patterning (when present) and part of the ventral (belly) pattern (ensure that the same portion of the ventral surface is photographed for all species).

Timing

- Conduct surveys during the core gestation period from mid-June until late July (or until mid-August in the case of Massasauga).

Search effort

- Ten visual encounter surveys of all potential gestation habitat are recommended to determine if that habitat is used for gestation by the target species. These surveys should be spread equally over two years.

3.3.3 Nesting Habitat

Figure 2. Eastern Hog-nosed Snake eggs. © G.Cunnington

Assess the use of potential nesting habitat by SAR snakes by searching potential nesting sites for eggs and/or egg shells. Snake eggs are small and elongate, typically 3-5 cm long and 1-2.5 cm wide (Figure 2). Unlike bird eggs, snake eggs are soft and pliable. They are usually beige or an off-white colour but may be more brownish from the nesting material. Female snakes lay a variable number of eggs, and a single clutch may range from two to more than 20 eggs.

Methodology

- Limit searches during the incubation period to cover objects or other structures that can be easily replaced as they were found.
- In late October or early November, thoroughly search any potential nesting structures, such as compost piles or rotten stumps, for eggshells and/or unhatched eggs.
- Sift through potential nest sites by hand, as using shovels or pitchforks can result in damage to unhatched eggs or overlooking eggshells.
- Consult with relevant snake experts and available resources, such as the Toronto Zoo snake egg ID guide, to identify any unhatched eggs or egg shells to species.
- Unhatched eggs should be left in place.
- Take care not to break apart potential nesting features during surveys, as this may result in the damage or destruction of these habitats.

Timing

- Conduct non-intrusive surveys for nests (e.g. searching under cover that can be replaced) from early July to early September.
- Conduct more invasive searches (e.g. searching through compost piles) for hatched eggs after mid-October.

Search effort

- One survey of all potential nesting habitat each year for at least two years is recommended to determine if the habitat is being used for nesting by the target species.

3.3.4 Birthing Habitat

Conduct visual encounter surveys to assess the use of potential Birthing habitat.

Methodology

- Search potential birthing habitat, including under cover, for gravid females and/or newborn snakes. Exercise caution during surveys to avoid stepping on snakes, as newborn snakes can be difficult to see in grass and other vegetation.
- Artificial cover objects can assist with the detection of newborn snakes in areas of potential birthing habitat. Newborn Butler's Gartersnakes (WEIS unpublished data) and Queensnakes (Gillingwater 2012) have been found under cover objects placed in gestation areas in Ontario. To use artificial cover objects:
  - Place cover objects throughout potential birthing habitat
  - Set cover objects out as early as possible in the spring to increase the probability of use by the target species.
  - Consult the OMNRF snake survey protocol for guidance on using cover objects for snake surveys (OMNRF 2016).

Timing

- Conduct surveys during the birthing period (see section 2.2.3 for timing).

Search effort

- Ten visual encounter surveys of all potential birthing habitat are recommended to determine if that habitat is used for birthing by the target species. These surveys should be spread equally over two years.

Detecting newborn snakes can be difficult because of their small size and tendency to remain hidden. An alternative approach to surveys for newborn snakes is to use the general location of the gestation habitat as a proxy for birthing habitat, since most of Ontario's SAR snakes tend to give birth at or very near their gestating sites (see section 2.2.3); Butler's Gartersnakes are an exception, and individuals of this species can make large movements (i.e. hundreds of metres) between gestation and birthing areas (WEIS unpublished data).

Female Massasauga with newborns at a birthing site on the Bruce Peninsula. © J. Crowley

3.3.5 Communal Basking/Shedding Habitat

Conduct visual encounter surveys to assess the use of potential communal basking/shedding habitat by SAR snakes. Basking and shedding sites are considered to be communal if two or more snakes are found to be using the site at any time (i.e. the snakes do not have to be present at the same time). Differences in pattern and size of shed skins can also be used to determine whether a basking or shedding site is used by more than one individual.

Methodology

- Visually scan for basking snakes while slowly walking through potential basking and shedding habitat (see section 2.2.4 for a description of basking/shedding habitat).
- Occasionally scan ahead with binoculars, focusing on potential basking and shedding microhabitat structures (see section 2.2.4), as this can allow for the detection of snakes before they retreat (Zappalorti and Reinert 1994).
- Use a digital camera with a zoom lens to photograph any basking snakes for identification purposes.
- After the initial scan, thoroughly search all potential basking and shedding structures for snakes and shed snake skins.
    - Peer into all cavities; the use of a flashlight can assist with this.
    - Gently turn over any loose cover (rocks or logs) to search for snakes.
    - Do not damage structures during the search, and carefully replace cover objects or other structures exactly how they were found. Slight changes in the position of cover objects can significantly alter the microclimate beneath, potentially rendering it unsuitable for use by SAR snakes (Pike et al. 2011).

Timing

- Survey potential communal basking habitat between May 15 and June 15, as snakes bask more often in the spring and detectability is highest at that time of year (see section 2.2.4).
- Survey potential communal shedding habitat between June 1 and September 15. Shed snake skins accumulate at shedding sites over the active season, but they often degrade by the following year; thus, detectability is highest during the late summer (J. Urquhart pers. obs.).

Search effort

- Five visual encounter surveys of all potential communal basking habitat are recommended to determine if that habitat is used for communal basking by the target species.
- Five visual encounter surveys of all potential communal shedding habitat are recommended to determine if that habitat is used for communal shedding by the target species.

4. Avoiding and Minimizing Adverse Effects to SAR Snake Habitat

Adverse effects to the habitat of a species result from activities that damage or destroy it, thus impairing or eliminating, respectively, the function of the habitat for supporting one or more of the species' life processes. Adverse effects can often be avoided or minimized through thoughtful project planning, particularly when a professional with species expertise is engaged in the planning process. Activities that are likely to have adverse effects on SAR snakes and their habitats may require ESA authorization (see section 1.3). The recommendations provided in this document are intended to help to identify suitable avoidance and mitigation options and to assist in the planning process. However, any activities that have the potential to damage or destroy SAR snake habitat (or negatively affect individuals of the species), as well as any avoidance or mitigation measures, should be discussed with the local OMNRF district office prior to their commencement.

This document provides recommendations that will assist in avoiding and minimizing adverse effects to SAR snake habitat (section 10 of the ESA), but adverse effects to the species (e.g. harm, harassment, or killing) are not addressed in this document. Thus, potential adverse effects of an activity on the species, as well as actions to minimize or avoid adverse effects on the species, must be considered in addition to the recommendations provided in this document.

4.1 Snake Habitat Sensitivity

As noted in section 1.3, species have varying levels of tolerance to the alteration of different types of habitat. The habitat categorization policy developed under the ESA, 2007 (OMNR 2012a) has been applied to several SAR snakes in Ontario and the habitat regulation summaries and government-endorsed habitat descriptions for these species provide guidance on the anticipated level of sensitivity to alteration of the different habitats used by these snakes.

Category 1 habitats are highly sensitive and are anticipated to have the lowest tolerance to alteration. In the case of snakes, hibernacula, gestation sites, oviposition sites, communal basking sites, and communal shedding sites are typically identified as category 1 habitats (O. Reg. 242/08, OMNR 2012b, c and d, OMNR 2013a, OMNRF 2014). These habitats are often limited on the landscape and, consequently, there is a high level of dependence on them (see section 2). They provide very specific microhabitat conditions, and even minor alterations can impair the function of the habitat for supporting the species' life processes. Snakes likely have the lowest tolerance to the alteration or loss of hibernacula. Many species of snakes demonstrate very high fidelity to hibernacula (see section 2). When a hibernaculum is destroyed, the individuals that depended on it will return to the same area and may continue to search for the feature until they perish due to winter temperatures, even if other potentially suitable hibernacula are available in the area (Black 2016). Further to this, suitable habitat features for hibernation can be extremely rare and, consequently, a single hibernaculum may be used by a large proportion of the population. Thus, the destruction of a hibernaculum could have a significant effect on a local population (Johnson et al. 2000, Black 2016), in some cases even resulting in extirpation of the local population.

Category 2 habitat for Ontario's SAR snakes typically includes the areas used for thermoregulation and foraging, which makes up the majority of the species' active season habitat (O. Reg. 242/08, OMNR 2012b, c and d, OMNR 2013a, OMNRF 2014). These habitats are typically less sensitive to alteration, more abundant on the landscape, and easier to re-create than category 1 habitat.

Open, rocky shoreline with shrubs and ground vegetation is an ideal thermoregulation and foraging habitat for SAR snakes. © J. Crowley

Habitats that are used primarily as movement corridors by SAR snakes are generally classified as category 3 habitat (O. Reg. 242/08, OMNR 2012b,c and d, OMNR 2013a, OMNRF 2014). These habitats are considered to have the highest tolerance to alteration because snakes are able to move through a wide variety of habitat types. Therefore, many alterations / activities within category 3 habitat are unlikely to impair the function of this habitat as a movement corridor.

4.2 Avoiding Adverse Effects to SAR Snake Habitat

4.2.1 Avoiding Adverse Effects through Project Planning

Whenever possible, projects should be planned to avoid all adverse effects to SAR and their habitat (OMNR 2012e). Adverse effects to SAR habitat can generally be avoided by excluding activities from the species' regulated or general habitat, or ensuring that activities carried out in these areas do not eliminate or impair their function for the specific life process(es) they are used for. Although avoidance alternatives must be considered on a case-by-case bases, the following are generally effective methods for avoiding adverse effects to SAR snake habitat:

- Re-locate the project to an area where SAR snakes will not be affected; this is the most effective way to ensure complete avoidance of adverse effects
- If working in an area where SAR snakes occur, identify areas that are unlikely to provide suitable SAR snake habitat and limit activities that have the potential to damage or destroy habitat to these areas. For example, choosing an old parking lot or a field used for row crops as the site of a proposed development would likely avoid adverse effects to SAR snake habitat, even if SAR snakes occur in the general area. Consider any indirect effects that the activity may have on nearby SAR snake habitat, as any such indirect effects would also constitute damage or destruction of the habitat. For example, constructing a tall structure adjacent to SAR snake thermoregulation habitat that shades the habitat may constitute damage, even though the footprint of the building is not within the habitat.

- In the case of activities that only have a short-term effect on the habitat, conduct these activities during a time of year when the habitat is not being used. For example, conduct activities that may have a short-term effect on the water table during the summer when snakes are not overwintering (as long as the water table returns to pre-activity conditions by the time snakes enter hibernation)

- Consider the sensitivity of the habitat to the proposed activity (e.g. how will the activity affect the function of the habitat), and carry out the activity in an area where it will not impair the function of the habitat. For example, activities that may constitute damage or destruction to hibernation or gestation habitat may not adversely affect movement habitat (e.g. if the snakes are still capable of moving through the area).

4.2.2 Avoiding Adverse Effects to Hibernacula

Hibernacula are particularly sensitive to a wide range of alterations (e.g. changes to vegetation composition, subterranean characteristics or the water table), and activities that occur a considerable distance from identified hibernacula (e.g. changes to the water table) have the potential to damage or destroy these habitats. The following recommendations can assist in avoiding adverse effects when working within or near snake hibernacula:

- Avoid activities that will affect the subterranean structure of the area (e.g., excavation, blasting), including the use of heavy machinery (car-sized or larger), which can result in soil compaction and the collapse of underground chambers.

- Avoid activities that will change the surface structure (e.g., plowing, scarification, etc.).

- Refrain from conducting any activities that would alter the habitat composition of the area (e.g. changes to vegetation type/structure or Ecological Land Classification type). However, in some cases it may be appropriate to selectively remove trees to reduce shading and improve habitat quality around staging/basking areas (see section 5).

- Avoid activities that will result in the alteration of the water table or surface/subsurface drainage (e.g., installing tile beds, ditching, dewatering, etc.) between September 15 and May 15 (Kraus et al. 2010, Parks Canada Agency 2012), including activities that occur outside of this period but that have lasting effects. Note that some activities, such as clear-cutting, may affect the water table in the surrounding area for prolonged periods (Marcotte et al. 2008).

- Avoid any changes to the habitat that would make it more prone to human disturbance, such as the construction of public hiking trails or ATV trails, particularly during the staging periods (see section 2.2.1 for details on timing).

- Avoid constructing roads of any type within these habitats, including small access roads and cottage roads. Ensure that any new roads are located far enough away from hibernacula so as to avoid chemical, sound, or light pollution originating from the road, traffic or associated maintenance activities.

4.2.3 Avoiding Adverse Effects to Gestation, Nesting, Live Birthing, Communal Shedding and Communal Basking Habitats

Gestation, nesting, live-birthing, communal shedding and communal basking habitats are particularly sensitive to disturbance (see section 4.1) and the best way to avoid adverse effects is to refrain from conducting any activities within or in close proximity to these habitats. These habitats typically have a very limited distribution on the landscape and with careful project planning it is often feasible to avoid them. When it is necessary to work within these habitats, the following recommendations can assist in avoiding adverse effects:

- Refrain from planting trees and shrubs or from making any other changes that would reduce sun exposure.
- Maintain or replace all naturally-occurring structure, including cover objects (e.g. rocks, rock piles, and logs).
- Refrain from mowing, using herbicide or otherwise removing ground vegetation or low-lying shrubs, which provide important cover for snakes as they move throughout the habitat.
- Avoid building any structures within these habitats, and ensure that the construction of structures in adjacent areas will not shade the habitat.
- In the case of nesting habitat, avoid disturbing the nesting material during the nesting period, and ensure that the structure is not permanently altered or removed until the species no longer depends on it (see O. Reg. 242/08 for information on when certain species are considered to be dependent on these structures).
- Avoid any changes to the habitat that would make it more prone to human disturbance. This includes activities such as the construction of public hiking trails or ATV trails.
- Avoid constructing roads within these habitats, including small access roads and cottage roads. Ensure that any new roads that are constructed in the general area are located far enough away from these habitats that chemical, sound, or light pollution originating from the road, traffic or associated maintenance activities will not affect the habitat.
- Avoid creating barriers that would prevent snakes from accessing or moving throughout the habitat.

4.2.4 Avoiding Adverse Effects to Thermoregulation and Foraging Habitat

SAR snakes typically have a moderate tolerance to the disturbance of basking, foraging and shedding habitat (see section 4.1), and it may be possible to carry out activates within these habitats while avoiding adverse effects. The following recommendations can assist in avoiding adverse effects to these habitats:

- Avoid significantly increasing canopy closure, such as through large-scale tree or shrub planting.
- Maintain or replace all naturally-occurring structure, including cover objects (e.g. rocks, rock piles, and logs).
- Refrain from mowing, applying herbicide or otherwise removing ground vegetation or low-lying shrubs, which provide important cover for snakes as they move throughout the habitat.
- Avoid constructing large structures, such as houses, shopping malls, etc. Small-scale construction projects may not result in adverse effects to the habitat, but it will depend on the specifics of the project.
- Avoid constructing roads within these habitats, including small access roads and cottage roads. Ensure that any new roads that are constructed in the general area are located far enough away from these habitats that chemical, sound, or light pollution originating from the road, traffic or associated maintenance activities will not affect the habitat.
- Avoid constructing barriers to snake movement, such as retaining walls, sound barriers, concrete medians along roadways or solid fences; when these features are necessary, modify them to facilitate snake movement (e.g. elevate them 10-30 cm off the ground or design them with regular gaps along the bottom to allow for wildlife passage).

4.2.5 Avoiding Adverse Effects to Movement Habitat

Activities that will prevent or deter the movement of snakes are likely to impair the function of movement habitat, while most other activities can occur without resulting in adverse effects to the species. Even large-scale changes in land cover (e.g. forest harvest, reforesting old fields, low-density housing development, etc.) may be compatible with SAR snake movement habitat as long as the activity does not reduce the suitability of the area for movement. The following recommendations can assist in avoiding adverse effects to SAR snake movement habitat:

- Avoid constructing physical barriers to snake movement, such as walls or solid fences; when these features are necessary, modify them to facilitate snake movement (e.g. elevate them 10-30 cm off the ground or design them with regular gaps along the bottom to allow for wildlife passage).
- Avoid creating large open areas that are inhospitable to snake movement (see section 2.2.5), such as parking lots or tilled fields.
- Maintain or replace all naturally-occurring structure, including cover objects (e.g. rocks, rock piles, and logs).
- Refrain from mowing, applying herbicide or otherwise removing ground vegetation or low-lying shrubs, which provide important cover for snakes as they move throughout the habitat.
- Avoid constructing major roads (highways, concessions, etc.).

4.3 Minimizing Adverse Effects to SAR Snake Habitat

When it is not possible to avoid all adverse effects to SAR snake habitat, it is often possible to significantly reduce adverse effects through careful project planning. Four broad strategies for minimizing adverse effects to snake habitat include: limit the area that is negatively affected, prioritize the retention of the most sensitive habitats and key habitat features on the landscape, minimize fragmentation of SAR snake habitat, and take steps to retain as much of the habitat function as possible in affected areas. Since avoidance is not being achieved, an ESA authorization (e.g. permit) will generally be required to facilitate the approaches being proposed in this section. If conditions in an ESA authorization differ from those outlined in this document, the conditions in the authorization should always take precedence.

4.3.1 Limit the Amount of Habitat that is Negatively Affected

In cases where SAR snake habitat cannot be avoided altogether, plan the project footprint such that there is as little overlap as possible with SAR snake habitat. The following recommendations can assist with accomplishing this goal:

- Keep the project footprint as small as possible. This can be accomplished by building up rather than sprawling across the landscape; this also helps to minimize other negative effects to wildlife by reducing the overall length of roads and other service infrastructure that is required.
- Similarly to the point discussed above in the avoidance section, locate as much of the project footprint as possible in areas that are outside of SAR snake habitat.
- Maximize the use of existing natural features to provide ecosystem services rather than replacing them with alternatives that do no support wildlife habitat. For example, maintain wetland areas for natural storm water management rather than building artificial holding ponds.

4.3.2 Prioritize the Retention of Sensitive Habitats and Key Habitat Features

One of the most important considerations for minimizing adverse effects to SAR snake populations is the retention of core habitats and habitat features that individuals depend exclusively on. Due to high dependence by SAR snakes on hibernacula (section 2.2.1), the sensitivity of populations to the loss of these features (section 4.1), and the significant challenges associated with recreating these habitats (section 5.1), it is extremely important that hibernacula are identified during site assessments and that the steps are taken to avoid the damage or destruction of these habitats. Although nesting, gestation, birthing, communal basking and communal shedding sites are often easier to re-create than hibernacula, species demonstrate high fidelity to these features and their destruction can have negative repercussions for the population, even if alternate replacement habitats are created. Therefore, concerted efforts should also be made to avoid the damage or destruction of these habitats. Alternatively, thermoregulation habitat and movement habitat tend to be relatively abundant on the landscape, and individuals will typically have access to more area that supports these life functions than is necessary; thus, if some of these habitats are lost, individuals can typically shift their habitat use to other areas within their home range that will provide the same function.

Although it is a good general rule to prioritize the protection of sensitive habitat types, such as hibernacula and gestation sties, it is also important to consider the local availability of all habitat types and strive to maintain a diversity of habitats on the landscape. Whenever possible, avoid damaging or destroying habitats that are limited at the home range or population scale, even if they are not typically considered to be particularly sensitive or rare habitat types. For example, in a highly forested area, open habitat that is suitable for thermoregulation may be limited on the landscape, and the open habitat that does exist may be disproportionately important to the local population. In this case, avoid activities in those open habitats and/or offset their loss by creating additional open habitat for the population.

4.3.3 Minimize Fragmentation of SAR Snake Habitat

Activities that destroy snake habitat (i.e. complete removal of the habitat) or that damage the habitat to the point where it no longer supports movement can result in habitat fragmentation. Habitat fragmentation can result in small, isolated populations that are at higher risk of local extirpation. At a finer scale, habitat fragmentation can prevent snakes from moving throughout their home range and may restrict access to important habitats, such as hibernacula or gestation sites. Thus, in addition to maintaining a mosaic of suitable habitat within an area, it is important that those habitats are adjacent to each other or are connected through suitable movement corridors. Following are general recommendations for maintaining habitat connectivity for SAR snakes:

- Consider the landscape context, the spatial configuration of SAR snake habitat and the activity to determine how best to avoid fragmentation. In some cases, limiting activities to one large contiguous area that occurs along the edge of a habitat patch will minimize fragmentation of the remaining habitat. In other cases, the destruction of a large area that bisects high quality habitat may fragment those remaining habitats, whereas the removal of smaller patches of habitat will maintain movement habitat in the intervening areas.
- Maintain or create SAR snake thermoregulation and foraging or movement habitat across as much of the landscape as possible to avoid creating isolated habitat patches.
- When activities are likely to fragment habitat, maintain or create movement corridors between habitat patches. This is particularly important to ensure that important habitat features, such as hibernacula, are not isolated from other habitats. Movement corridors should have a minimum width of 25 m (Knoot and Best 2011), when possible.
- Maintain natural drainage systems and associated riparian zones, as these habitats can act as movement corridors for a diversity of wildlife, including snakes.
- In highly developed landscapes, maintain and create linear features that can facilitate movement, such as hedgerows and vegetated margins of drains (i.e. drainage ditches).

- Avoid the creation of movement habitat along roads; creating habitat in close proximity to roads exposes snakes to a high risk of road mortality.
- Avoid constructing barriers to snake movement, such as retaining walls, sound barriers, concrete medians along roadways or solid fences; when these features are necessary, modify them to facilitate snake movement (e.g. elevate them 10-30 cm off the ground or design them with regular gaps along the bottom to allow for wildlife passage).
- Avoid creating habitat patches that are less than 10 ha in size, as snake diversity and abundance tends to be greater in larger habitat patches (Kjoss and Litvaitis 2001).

4.3.4 Maintain Functionality in Degraded Habitats

When activities damage but do not outright remove SAR snake habitat, it may be possible to retain some of the functionality of the habitat, depending on the magnitude and scope of the activity. It may also be possible for habitat that has been adversely affected to serve an alternative function, even if the original functionality is lost. For example, areas that previously functioned as high quality thermoregulation and foraging habitat but are no longer suitable for those life processes may still provide suitable movement corridors if managed appropriately. See section 4.2 for information on avoiding adverse effects SAR snake habitat, and implement these practices throughout as much of the affected area as possible.

Old fields and savannah can provide high quality thermoregulation and foraging habitat for SAR snakes. These habitats should be maintained on the landscape whenever possible. © J. Crowley

5. Habitat Creation, Restoration and Maintenance

Although the creation, restoration and maintenance of snake habitat (referred to collectively as habitat management) is ongoing in Ontario and globally, there is little published information on the effectiveness of these efforts or on the long-term implications for local populations (Shoemaker et al. 2009). For example, Shoemaker et al. (2009) found that few projects based their designs on the environmental or physical characteristics of naturally occurring snake habitat, nor did they assess the effectiveness or use of the restored or created habitat. This study also concluded that “few (if any) studies have demonstrated that habitat manipulation has resulted in improved conservation status for a snake taxon or population” (Shoemaker et al. 2009). The general lack of knowledge regarding the effectiveness of habitat management techniques makes it difficult to replace these habitats when they are destroyed. Therefore, maintaining naturally occurring snake habitat should always be prioritized over options to offset the damage or destruction of habitat through the restoration and creation of new habitat.

Despite the uncertainties and challenges associated with the management of snake habitat, these activities may none-the-less be necessary to offset adverse effects in cases where it is not possible to avoid the damage or destruction of the existing habitat. The creation, restoration and maintenance of habitat is also identified as an important recovery action for most SAR snakes in Ontario (e.g. Eastern Foxsnake Recovery Team 2010, Gillingwater 2011, Environment Canada 2016), and these activities are being undertaken regularly throughout Ontario to contribute to the recovery of these species (e.g. Long Point Basin Land Trust, St. Clair Region Conservation Authority 2017).

When creating, restoring and maintaining snake habitat, consider the landscape context and the distribution of available habitat and microhabitat features. The creation, restoration and maintenance of specific habitats (or habitat features) should be focused on areas of the landscape where those habitats are limited. For example, in addition to the project site that is being managed, consider other nearby properties or other populations within the province where habitat creation efforts may produce a larger benefit to the species. Additionally, consider the connectivity among existing habitat and the location of habitat management activities; avoid creating habitat in areas that will encourage snakes to move through high risk areas, such as road corridors.

Given the uncertainty regarding the effectiveness of many habitat creation techniques for SAR snakes, several habitat structures/features should be created at a site to increase the likelihood that at least one will be used by the target species. When possible, vary the characteristics and/or location of the features to some extent to give snakes a range of conditions to choose from. For example, create several basking structures at the project site in locations that span a range of environmental conditions (such as varying distances from the forest edge). This variation in design and placement, combined with effectiveness monitoring and research, can also help to improve our knowledge of habitat creation techniques.

Caution: avoid using mesh erosion control materials during any work within SAR snake habitat. Snakes can become entangled in these materials, resulting in injury and mortality (Kapfer and Paloski 2011).

The following sections provide detailed guidance regarding the creation, restoration and maintenance of specific habitat types.

5.1 Hibernation Habitat Creation

There has been growing interest in the construction of artificial hibernacula in Ontario over the past decade (e.g., Eastern Foxsnake Recovery Team 2010, Blanchard and Beck 2014, Toronto Zoo 2015). Although a number of artificial hibernacula have been constructed in Ontario, there are few data on their effectiveness as viable alternatives to natural hibernacula. Eastern Foxsnakes have been documented to have successfully hibernated in artificial/created hibernacula at Point Pelee, Ontario in 2015 (T. Dobbie pers. comm.) and over multiple years in Windsor, Ontario (WEIS unpublished data). Preliminary results from post-construction monitoring of artificially created hibernacula in Norfolk County, Ontario, suggest that these structures can successfully mimic natural hibernacula conditions (G. Beck unpublished data). Eastern Foxsnakes have been observed entering these artificial hibernacula and Milksnakes and Eastern Hog-nosed Snakes have been observed in the immediate vicinity of these features, suggesting that the hibernacula may be used by multiple species (Blanchard and Beck 2014, G. Beck unpublished data). Effectiveness monitoring of artificially created hibernation habitat (Section 6) is particularly important because these features have the potential to cause mortality, and become habitat sinks (i.e., cause more harm than good), if conditions do not support successful overwintering.

The methodology for hibernacula creation presented in this BMP is not appropriate for populations of Massasauga in the eastern Georgian Bay region or Butler's Gartersnake. Massasaugas in eastern Georgian Bay overwinter in moss hummocks in wetland habitat, while Butler's Gartersnakes tend to overwinter in crayfish burrows in lowland, wet habitats (see section 2.2.1). Methodology for creating hibernacula for Massasaugas in eastern Georgian Bay and Butler's Gartersnakes are in the very early stages of development/testing, and they are not presented in this document.

5.1.1 Planning Considerations

Constructing a successful artificial hibernaculum requires choosing an appropriate location within occupied habitat (i.e., an area where the species is known to occur) where there is adequate sun exposure, sufficient basking and retreat sites, and a suitable life zone (Figure 1). Important steps to maximize the likelihood that SAR snakes will successfully overwinter in the artificial hibernaculum include:

- Determine the maximum depth of the frost line using a frost tube inserted 2-3 m into the ground. Monitor for multiple years until an exceptionally cold (i.e., colder than average) winter is experienced.
- Determine the depth of the water table by digging or drilling pilot holes and measuring the depth at which water enters the holes during the winter. Water tables can fluctuate significantly (sometimes by several metres) among and between years, and it is necessary to monitor water table levels for over multiple years prior to constructing the hibernaculum. The water table should reach the lower depths of the hibernaculum because snakes generally require access to the water table to avoid dehydration during hibernation (see section 2.2.1). Although some water within the hibernaculum appears to be beneficial, rapid flooding of hibernacula can cause significant mortality (Shine and Mason 2004). When data on the depth and fluctuations of the water table are not available, construction should occur in late fall or early winter (late November until the ground is frozen) so that the height of the winter water table can be assessed (Figure 3).
- Locate the hibernaculum in an area where there will always be a suitable life zone between the frost line and the water table, taking into account annual variation in frost line and water table depth.
- Choose sites with well-drained soils to reduce the risk of flooding in the hibernaculum; avoid constructing hibernacula in areas with drainage tile because they can become blocked and result in flooding.
- Monitor drainage patterns at potential sites for one or more years prior to construction, and select a site where surface water flows away from the site and does not pool. When possible, construct the hibernaculum into the side of a gently sloping, south-facing hill.
- Select a south-facing site that receives sunlight for the majority of the day during the spring and is protected from the wind.
- Ensure that suitable basking sites are available or constructed within 100 m of each hibernaculum.
- Locate the hibernaculum within suitable habitat that is occupied by the target species.
- Select a site that is as distant as possible from known threats, such as roads, active industrial or agricultural activities, urban areas, areas of intensive recreational activity, etc.

Once a suitable site is identified, it should be carefully surveyed (following the methodology set out in section 3.3.1) prior to construction to ensure that there are no existing hibernacula at the location.

Figure 3. Hibernacula can be constructed in late fall or early winter, as long as the ground is workable (i.e., not frozen deeply). © G. Beck

5.1.2. Recommended Methodology for Building Hibernacula

Materials and Equipment

- Excavator/backhoe
- Tractor or loader
- Concrete blocks
- Concrete slabs or other similar, often salvaged, materials
- Granular 'A' gravel (i.e. sand/gravel mix)
- Flexible 0.1 m (4") solid plastic piping (e.g., unperforated "Big O" tile)
- Stumps, roots, rotting logs
- River rock/field stone (medium to large size, 0.2 m to 0.5 m diameter)
- Landscape fabric
- Materials to create brush piles (see section 5.4)

Stage 1: Excavation and Dimensions

- Excavate a large pit at the chosen location, with a minimum depth of 2 m, and a surface diameter of at least 4 m (Figure 4).
- When excavating, remove soil to a depth below the frost line and approximately 1 m below the winter water table.
- The excavation should be "bowl-shaped" with gradually tapering sides. Avoid creating steep sides, which would allow cold air to reach the inner-most chambers of the hibernaculum.
- Install drainage features if there is the potential for rapid flooding at the site. In such cases, excavate two or more "overflow" drainage passages approximately 1 m above the bottom of the pit (ensuring that these are still below the frost line), and install drainage tile, cobblestone and/or broken concrete for drainage (Figure 5).

Figure 4. A large excavator digging in the early stages of hibernaculum construction. © G. Beck

Figure 5. An overflow drainage spillway during mid-construction, built to mitigate potential rapid flooding of the constructed hibernaculum. The spillway is built above the grade level of the deepest part of the excavated "bowl" to allow some water to remain within the hibernaculum. Field stone surrounds a Big 'O' pipe and will be covered with additional fill. © G. Beck

Stage 2: Laying the Groundwork

- Line the base of the pit with a 0.25 m-deep layer of Granular 'A' gravel or a sand/gravel mix (Figure 6). This layer can improve drainage and humidity.
- Position one segment of the unperforated 0.1 m diameter "Big O" plastic piping such that one end is at the bottom of the pit and the other extends up the side of the pit to the top. Repeat this with at least two more segments of the plastic piping (Figure 7).
- Drill roughly 6 cm diameter holes into the piping at 45 cm intervals; the holes can vary in their orientation, alternately facing up, down and to the side. These openings facilitate snake movements within the hibernaculum and promote the mixing of air, which moderates temperature gradients.
- Position the plastic piping so that there is at least one gentle "up" bend in the pipe before it descends fully to the bottom of the excavation. This bend in the pipe creates a simple "trap" for cold air flow. Do not drill holes into the trap section of the pipe. This bend, the perforations in the "Big O' pipe, and a partially-covered surface opening (see below), helps prevent freezing temperatures from reaching the innermost chambers of the hibernaculum.

Figure 6. Dumping a sand/gravel mix into the bottom of the excavated hibernaculum to promote drainage. © G. Beck

Figure 7. Early in the construction process, arrange "Big O" plastic pipe from the bottom of the excavation to the surface. Drill large diameter holes into the pipe to increase air circulation and to provide potential entry/exit spots for snakes.

Stage 3: Creating Underground Chambers

- Place irregularly shaped concrete blocks, concrete slabs, rock, and even a small amount of woody material into the excavation. Salvaged cement slabs and concrete blocks make good materials for hibernaculum construction (Figure 8).
- Use construction blocks to create chambers near the bottom of the hibernaculum and to keep concrete slabs from lying flat against the bottom or one another (Figure 9).
- Position materials at contrasting angles to create inter-connected chambers through which snakes can move vertically and laterally (Figures 10 and 11); do not layer materials flat against each other. An excavator bucket with a "thumb" makes it easier to control placement of materials (Figure 12).
- Woody material (e.g., stumps) should make up only a small portion of the material included in the hibernaculum to limit settling from decay over time (Figure 13). Larger logs can be placed towards the surface of the hibernaculum during construction but should not be placed too deep as they could cause collapse of the structure as they decompose. The use of untreated, rot-resistant wood, such as Eastern Red Cedar (Juniperus virginiana), may be beneficial in providing longer-term structural support (New Jersey Audubon 2013).

Figure 8. Salvaged materials, such as used concrete slabs and construction blocks, can be used for hibernaculum construction. Left: © G. Beck; Right: © WEIS

Figure 9. Use construction blocks to create chambers near the bottom of the hibernaculum and to keep concrete slabs from lying flat against the bottom or one another. © G. Beck

Figures 10 and 11. Position materials carefully to create inter-connected passageways and deep chambers. © G. Beck

Figure 12. An excavator bucket with a "thumb" has more control in placing materials within the hibernaculum. © G. Beck

Figure 13. Some woody material (e.g., roots and stumps) should be included in the hibernaculum construction but their quantities should be limited to guard against excessive settling over time. © G. Beck

Stage 4: Completing the Surface of the Hibernaculum

- Place a layer of landscape fabric over the centre of the hibernaculum at the surface or initial grade level (ensuring not to block the entrances) and cover the landscape cloth with cobblestones, topsoil, brush or other organic material to provide insulation (Figure 14).
- When covering the hibernaculum, create a low mound so that settling does not result in a depression over time, although the completed hibernaculum need not protrude much above the natural grade. Mounding above grade is not a suitable alternative to digging deep enough to establish an appropriate life zone.
- Pile additional materials, such as river rock, fieldstone and brush piles near the hibernaculum to provide cover and basking sites for snakes (Figure 15).
- As construction nears completion, ensure that a sufficient number of passageways reach the surface (in addition to the “Big O” piles) to allow snakes entry and exit, but not so many that cold air descends easily to the innermost chambers.
- Surround the entrances of the ”Big O” pipe with fieldstone, rock, or small construction rubble. The inter-connected spaces between the rocks and other material provide entry/exit points for snakes that are concealed from predators (Figure 16).
- Grade the remaining soil away from the openings to avoid flooding of the hibernaculum (Figure 17).
- If shed skins from the target species can be found near the site, place them at the entrances to the hibernaculum, as scent may be important in attracting snakes to hibernacula (Shine and Mason 2004).

Figure 14. Landscape fabric placed across parts of the top of the constructed hibernaculum and covered with rocks, logs and topsoil to form a mound provides additional insulation. © G. Beck

Figure 15. Field stone, brush and stumps near the surface provide hiding and basking sites for snakes and potential access points into the hibernaculum through inter-connected underground passageways. © G. Beck

Figure 16. Brush and field stone cover the entrances to the pipes at the surface, providing cover and insulation. © G. Beck

Figure 17. Final grading away from the openings ensures that surface drainage will not lead to potential flooding of the hibernaculum. © G. Becks

Construction Tips:

- Involve someone with expertise in snake ecology and habitat use, and ideally with experience in hibernacula construction, in all stages of the project: site selection, design and construction.
- Do not use old construction materials that contain glass, metal, wire or toxic residue (e.g., railway ties, pressure treated lumber, painted wood, etc.), as these materials can result in injury or mortality of snakes from cuts and associated infections.
- Install data loggers at hibernacula to monitor temperature.
- A detailed 16-minute, step-by-step video on snake hibernaculum construction is available online (Long Point Basin Land Trust 2013). Follow the instructions in this document where they differ from those in the video.

After one or two growing seasons there may be little evidence of the presence of the hibernaculum (Figure 18).

Figure 18. A completed hibernaculum constructed in a sunny gap on sandy soils, adjacent to a natural wooded area in known SAR snake habitat. © G. Beck

5.1.3 Additional Recommendations when Replacing a Hibernacula

When hibernacula are being created in an effort to replace one that will be destroyed, the following additional steps are recommended:

- Monitor the existing hibernaculum for at least two winters, ideally until an exceptionally long or cold winter is encountered. Monitoring should assess the number of SAR snake species and individuals using the hibernaculum, water level, depth of the frost line, depth of the hibernating snakes, air temperature, and relative humidity levels at various points inside the hibernaculum throughout the winter.
- Use the monitoring data to design a hibernaculum that will mimic these conditions.
- Construct a minimum of 3 hibernacula in suitable habitat and as close as possible to the original hibernaculum. Constructing multiple hibernacula will increase the probability that at least one will be used by the target species.

Since the conditions that make a hibernaculum suitable for SAR snakes are not fully understood and are difficult to recreate, it can take many years of detailed monitoring and habitat management to effectively create an artificial hibernaculum to replace one that is destroyed (A. Yagi pers. comm.). As discussed in section 4.1, the destruction of a hibernacula may result in significant mortality, even if additional hibernacula are successfully created on the landscape. Therefore, the destruction of hibernacula should always be a last resort, even if the proposed project includes the creation of new potential hibernation habitat.

5.2 Nesting Habitat Creation

5.2.1 Nest Boxes and Cages

Artificial nesting structures for the Eastern Foxsnake, Gray Ratsnake and Blue Racer should be constructed using either a nest box or nest cage design (nesting habitat for the Eastern Hog-nosed Snake is addressed in the following section). As with other snake habitat, there are limited data on the use and effectiveness of artificial nest structures for snakes. However, there has been some documented success (i.e. eggs being laid and hatching) with the use of artificial nest structures for snakes in Ontario, including Eastern Foxsnakes in southwestern Ontario (St. Clair Region Conservation Authority 2014, 2015) and Gray Ratsnakes in eastern Ontario (Thompson 2005, Norlock 2006, Desy and Norlock 2007). Additional research is required to assess the use and success of these structures, particularly for the Blue Racer. Monitoring artificially created nesting habitat (Section 6) is particularly important because these features have the potential to be sink habitats if conditions do not support embryo development and hatching.

Recommendations regarding site location and nesting material are the same for both nest boxes and nest cages, but their construction methods and materials differ (discussed in the following sections). To date, there is no evidence that boxes or cages differ significantly in their usage by snakes. Small differences in the size of the structure, the nesting material used, and the location of the structure probably have more effect on usage than whether the structure is a cage or box. Use either a nest cage or nest box depending upon your resources and personal preferences.

Nest structures should be built as early in the spring as possible to increase the probability of use that year. Nest structures require annual maintenance, and long-term maintenance plans for nest structures are necessary, particularly if the intent is for the structures to replace natural nesting habitat.

Nest Box Construction

Nest boxes are cubic wooden-framed boxes with mesh fencing to keep out egg predators.

Materials

- 24 feet of 12-16 gauge wire fencing that is 48 inches wide with mesh openings between 2 inch x 2 inch and 2 inch x 4 inch
- 10 pieces 2 inch x 2 inch x 8 foot lengths of cedar lumber (for box frame)
- 2 pieces of 2 inch x 2 inch x 8 foot lengths of cedar lumber, or short pieces of cedar may be used (for braces)
- 1-2 lb of 3½ inch wood screws and screwdriver
- 1-2 lb of 7/8 to 1 inch fence staples and staple gun

Methods

- Begin by cutting the 10 pieces of lumber for the frame into 4-foot lengths.
- Assemble two 4 foot x 4 foot squares.
- Join the two squares together with other frame pieces to form a 4 foot cube.
- Pre-drill holes and fasten all parts with 3½ inch wood screws.
- Brace corners with 10-inch pieces cut from the other lumber. Cut the corners of the brace pieces at a 45º angle and attach with screws (Figure 20).
- Attach wire fencing to the back, bottom and two sides with staples. Ensure there are no gaps between the frame and the fencing large enough for a Raccoon to get through.
- Assemble two more 4 foot square sections and cover with wire fencing to form the removable front and top. It is not necessary to brace the corners of these two sections, but they should be securely fastened to the structure (e.g. with zip ties or screws) once the nest box has been filled with nesting material (this is important to avoid vandalism).
- Anchor the nest box to the ground using T-bars or stakes so it is not prone to being tipped over.
- The finished boxes are 4 foot x 4 foot (Figures 19 and 20).

Figure 19. Assembling a nest box for Gray Ratsnakes. Corner braces are visible in two of the corners. © B. Barkley

Figure 20. Fully assembled nest box. The box is more than 75% full of nesting material and located in a sunny location in appropriate snake habitat. © G. Beck

Nest Cage Construction

Nest cages are similar to nest boxes but are constructed from wire mesh fencing without a wooden frame.

Materials

- 12-16 gauge wire fencing 48 inches wide with mesh openings between 2 inch x 2 inch and 2 inch x 4 inch.
- One piece of fencing 13 feet long (for the cage) and one piece 50 inch x 50 inch (for the top). Ensure the top is large enough to completely seal the nest cage.
- 3-4 T-bar fence posts, 48 inches long
- 15-20 zip ties

Methods

- Shape the long piece of fencing into a cylinder with the ends overlapping by at least two links (Figures 21 and 22), and fasten the length of the two ends of the cage fencing together with zip ties at intervals of approximately 6 inches.
- At the desired location for the nest cage, pound the T-bar fence posts into the ground. Ensure that the fence posts are equally spaced and set just inside the diameter of the cage.
- Place the cage over the fence posts and fill with nesting material.
- Place the 50 inch x 50 inch piece of fencing on top of the cage and fasten using the remaining zip ties, ensuring that there are no gaps through which predators can enter.

Figure 21. A nest cage created for Eastern Foxsnakes. The top of the cage has not been attached yet. © St. Clair Region Conservation Authority

Figure 22. Nest cage created for Eastern Foxsnakes with the lid attached. © St. Clair Region Conservation Authority

Site Location (nest boxes and nest cages):

- Place nest structures in areas with suitable habitat and that are known to be occupied by the target species.
- Place nest structures away from potential hazards (e.g., roads).
- Place nest structures in open or edge habitats, such as in old fields near forest edges, where they will receive full sun for at least half the day.
- Place nest structures in areas with ground vegetation or other structures (e.g., rocks, brush piles, etc.); avoid placing them in areas that lack basking and retreat sites (e.g., mowed residential lawns, barren rock clearings, etc.).
- Nest structures can be placed near compost or wood chip piles if they are in appropriate habitat and receive adequate sunlight.
- Avoid placing nest structures in locations frequently used by people. Nest structures created in areas near buildings such as barns and sheds can be effective as long as those areas have minimal human traffic (e.g. not along a trail or pathway; K. Brown pers. comm.).
- Create several nest structures at the project site in locations that span a range of environments (e.g., varying distances from the forest edge).

Nesting Material (nest boxes and nest cages):

- Use approximately 1/3 coarse mulch or peat moss (wood chips can be used as a substitute), 1/3 straw and 1/3 dry leaves as nesting material (Row 2009, G. Beck unpublished data) (Figure 23). Mix these components together before filling the nest structure.
- Fill nest structures until they are 75-100% full, as the material will settle with time. Including partially composted material in the nest structure can help maintain higher temperatures. Fill the nest structure with new nesting material each spring, and include at least some of the previous year's nesting material with the new material. Include shed snake skins and eggshells from previous years to help attract snakes (Brown and Shine 2005).

Figure 23. A snake nest box being filled with a mixture of mulch, straw and leaves early in the spring. © G. Beck

5.2.2 Nesting Habitat for the Eastern Hog-nosed Snake

The Eastern Hog-nosed Snake typically nests underground in burrows that are excavated by the female (see Section 2.2.2). Creating nesting habitat for this species is largely experimental, but research on Eastern Hog-nosed Snake nest site selection in Ontario (see Section 2.2.2) provides insight that can help to inform nesting habitat creation for this species. The goal is to create a matrix of open, sandy areas interspersed with herbaceous and shrub cover, as these vegetated areas will provide important cover and thermoregulation sites for the nesting females. To create experimental nesting sites, identify sandy areas or areas with well-drained, sandy soils, open the canopy, and remove all vegetation (including roots) in small (e.g. 2 x 2 m) plots. If areas with suitable substrates are not available at the site/property in question, create sandy areas (by bringing sand into the site) in existing open habitat. Regardless of which method is used, ensure that there is plenty of cover, such as dead wood, shrubs and brush piles throughout the site. Efforts to create nest sites for Eastern Hog-nosed Snakes in Ontario should be part of a hypothesis-driven, experimental research study.

Figure 24. Eastern Hog-nosed Snake (© Joe Crowley) and typical open, sandy, nesting habitat of this species." (© G. Cunnington)

5.3 Gestation and Birthing Habitat Creation

5.3.1 Gestation Habitat

With the exception of the Massasauga, there has been little research into the creation of gestation habitat for Ontario's SAR snakes. However, since gestation sites are essentially basking sites that are used for a specialized life function, the creation of high quality basking sites will typically provide suitable gestation habitat for most species. For example, forest openings created to provide basking sites for Massasaugas were readily used by gravid females for gestation (Johnson 2013). Thus, to create gestation habitat for Ontario's SAR snakes, follow the guidance for creating basking sites in section 5.4 (but see additional methodology for Queensnake in section 5.3.3).

5.3.2. Birthing Habitat

Most of Ontario's SAR snakes give birth at or near gestation sites, and the same habitat features are often used by both gestating females and newborn snakes (see section 2.2.3). To create birthing habitat for all Ontario's SAR snakes except for Butler's Gartersnake, follow the guidance for creating basking sites in section 5.4 (but see additional methodology for Queensnake in section 5.3.3). Guidance for creating birthing habitat for Butler's Gartersnake is provided below.

Unlike Ontario's other SAR snakes, Butler's Gartersnake birthing habitats are often independent of gestation sites (Section 2.2.3). Butler's Gartersnakes typically give birth in areas with dense grasses associated with lowland areas or wet depressions (Section 2.2.3). To create Butler's Gartersnake birthing habitat:

- Create small depressions (2-3 m in diameter and about 0.5 m deep) in lowland areas, such that they remain wet or moist throughout the summer.
- Plant native sedges, rushes and grasses in the created depressions.
- Plant a few patches of native shrubs along an edge to provide some cover. Ensure the shrubs do not cast too much shade on the site.
- Install brush piles (see section 5.4) or vegetation piles (small mounds of dead vegetation, such as leaf litter, thatch or mowed grass) that can be used as retreat sites for females or neonates near new or existing depressions (Figures 25 and 26).
- Note that it may take multiple seasons for the planted vegetation to become established and make the site suitable for gestating females.

Figure 25. Gestation and birthing site for Butler's Gartersnake. © WEIS

Figure 26. Vegetation thatch installed to create a gestation and birthing site for Butler's Gartersnake. © WEIS

5.3.3 Use of Erosion Control Material for Queensnake Gestation and Birthing Sites

Queensnakes have been documented to use geotextile erosion control material as gestation and birthing sites in Ontario (Gillingwater 2012). To create gestation and live-birthing habitat for Queensnakes using erosion control materials:

- Install erosion control material in areas known to have Queensnakes and a lack of suitable basking/retreat sites (do not use mesh erosion control material – see note in section 5 introduction).
- Install material in sunny locations within approximately 3 m of the low (summer) water level, such that they will be close to the water yet not submerged during the gestation period.
- Anchor the material at the edge farthest from the water and partially cover with a thin layer of soil (Figure 27).
- The optimal size of erosion control material patches is not known but Queensnakes have made use of patches measuring 1.2 m x 1.2 m and 1.2 m x 1.8 m.
- Install fencing around the erosion control material to keep people from walking on it and potentially crushing Queensnakes. Fencing options include just a few horizontal strands of wire at different heights, or a large mesh fence (with a mesh size of at least 5 cm x 5 cm) that snakes can pass through.
- The use of the material by Queensnakes may be rare in the first year but should increase over time (Gillingwater 2012).
- The erosion control material can last for more than a decade, but routine annual maintenance is required to remove plants that root through the material or any sediment that covers it.

Figure 27. Creating a Queensnake gestation site using erosion control cloth. © S. Gillingwater

Queensnake observed at one of the small populations in southwestern Ontario. © J. Crowley

5.4 Thermoregulation and Foraging Habitat: Microhabitat (Basking Site) Creation

This section describes how to create microhabitat features that will function as basking, retreat and shedding sites for SAR snakes. As noted in section 5.3.1, these features can also function as gestation habitat. These microhabitat features provide protection from predators, as well as a range of thermal conditions that facilitate thermoregulation and shedding (see Section 2.2.4). For simplicity, these features are referred to as "basking sites" throughout this section.

The placement of basking sites is extremely important, and they must be located in open habitats that receive sunlight for the majority of the day (see Section 2). If there is no suitable open habitat at the site in question, follow guidance in Section 5.5 to create open habitat, and then construct basking sites in the newly created habitats.

Following are general guidelines for creating basking sites for SAR snakes:

- Create these structures in areas where the target species has been confirmed to occur.
- Ensure that structures are located in suitable thermoregulation and foraging habitat (see section 2.2.4) that will receive full sun for most of the day, such as large canopy gaps in forests, old fields near forest edges, and along shorelines,.
- Create structures in natural or unmaintained areas with cover (herbaceous or shrub), or along vegetated edges (e.g. forest edge, hedgerow, etc.); avoid building structures in areas that are lacking structural complexity and cover, such as mowed lawns, which snakes tend to avoid (see section 2.2.4).
- Place additional cover objects (e.g., logs, wood or flat rocks) around structures to provide additional retreat sites for snakes, if no natural cover objects are nearby. Avoid placing cover boards around basking structures as they are prone to vandalism.
- Plant a few low-growing native shrubs (e.g. Common Juniper; Juniperus communis) around basking structures to provide additional retreat sites. Do not plant shrubs in areas that will shade the structure when they reach maturity.
- Place structures away from features that may pose a threat to snakes, such as roads.
- Inspect the structures at least once a year to determine whether they receive adequate sunlight. If sites are being shaded for half the day or more, consider moving the structure or removing the vegetation that is shading the structure.

Eastern Foxsnake basking on rocks. © J. Crowley

5.4.1 Rock Piles

Rock piles can function as suitable basking sites for all of Ontario's SAR snakes. To be most effective, rock piles should be created with different sized rocks or cement blocks, using the following methods:

A rock pile created along the edge of shrubs in an old field habitat can provide an excellent basking site for snakes. © J Crowley

- Create rock piles that are at least 2 m in diameter and 0.5 m in height.
- Use flat rocks; flat rocks have a higher surface-area to volume ratio and heat up faster, and snakes demonstrate a preference for thin, flat rocks (Fitch and Fleet 1970, Blouin-Demers and Weatherhead 2002).
- Use a wide range of rock thicknesses so that the structure will provide a range of temperatures. Most rocks should be less than 20 cm thick, and rocks should generally not exceed 40 cm thickness.
- The majority of the rocks should be 15-75 cm in diameter, with at least one large, flat rock that is greater than 60 cm in diameter; large rocks hold heat for longer periods and help to moderate temperature fluctuations.
- Arrange rocks to create cavities for retreat sites. Small rocks or mortar can be used to stabilize larger rocks.
- Limit the size of cavity entrances to a maximum of 5 cm x 5 cm to minimize predator access. Small rocks or mortar can be used to reduce cavity entrance size (Willson and Porchuk 2001).
- Rocks should be relatively stable if stepped on. Rocks that wobble or shift when stepped on may result in the injury or mortality of snakes.

5.4.2 Gabion Baskets

Gabion baskets are wire-mesh filled with large rocks that are typically constructed for erosion control purposes, but can also be used to create snake habitat (Figure 28). Although gabion baskets do not look natural, they are relatively resistant to vandalism, compared to rock piles which can be taken apart, either maliciously or for personal use of the rocks (Schlesinger and Shine 1994). The wire exterior may also reduce some forms of snake predation and provide a secure location for shedding. Consider the use of gabion baskets in areas where rock removal or the stacking of rocks (e.g., inukshuks) is common, such as along major trails and roadsides. Although gabion baskets are known to provide excellent basking sites for many common snake species, such as the Eastern Gartersnake, Northern Watersnake and Red-bellied Snake (Crowley pers. obs., D. Seburn pers. obs., J. Urquhart pers. obs.), it is unknown whether they will function in this capacity for many of Ontario's SAR snakes. For this reason, gabion baskets should be constructed with other basking structures (e.g. rock piles, brush piles) as part of an experimental study, and their use should be carefully monitored and reported.

The following are recommendations for the construction of gabion baskets for snake basking sites:

- The optimal size of a gabion basket for SAR snakes is not known. Creating baskets of various shapes and sizes (e.g. 2 m x 2 m, or 4 m x 4 m and at least 0.5 m tall) will provide snakes with more options.
- As with rock piles, use rocks of different sizes and shapes, with the majority of rocks being 15-75 cm in diameter.
- Use a heavy wire mesh for the gabion basket with openings 5 cm x 5 cm or larger to reduce the risk of snake entanglement.

Figure 28. Eastern Gartersnakes basking on a gabion basket. © D. Seburn

5.4.3 Rock or Cement Slabs

If constructed correctly, rock or cement slabs should be suitable as basking sites for all of Ontario's SAR snakes (Figure 28). Following are instructions, based on work with Butler's Gartersnake and Eastern Foxsnake in southwestern Ontario (WEIS unpublished data), for creating basking sites for snakes using rock or cement slabs:

- Use slabs that are at least 1 m x 1 m and no more than 10 cm thick.
- Construct the slab on level ground to minimize the risk of it sliding, and ensure that the slab is stable once completed.

- Elevate the slab 5-7 cm above the ground using a minimum of six brick or cement supports at the corners and in the middle of the slab. Alternatively, elevate the slab 5-7 cm above the ground along one side only, using brick or cement supports along the elevated side.
- Use additional bricks, rocks or cement to limit the number and size of openings under the slab to reduce openness and limit access by predators.

Figure 29. SAR snake basking site created using a cement slab. © WEIS

5.4.4 Brush Piles

Brush piles are heaped mounds of woody debris, consisting primarily of branches (Figures 30). Brush piles can provide suitable basking habitat for all of Ontario's SAR snakes when constructed according to the following recommendations:

- Create piles at least 1 m high and 2 m in diameter.
- Materials can include small to large branches, small logs, and some (less than 25%) dead vegetation (e.g. leaf litter), but at least a few branches or small logs greater than 5-10 cm in diameter should be used. These larger objects will last longer and create more cavities for retreat and may deter predators from gaining access to the centre of the brush pile.
- Avoid using small woody debris (such as wood chips), as it tends to create a dense mound rather than a cavity-filled structure.
- Rocks of various sizes can be added to brush piles to provide additional retreat/shedding sites for snakes.
- Brush piles that are constructed near existing rock piles may provide a wider range of thermoregulation opportunities; however, they should never be constructed over top of existing rock piles because this will not create a new basking site but may instead reduce the thermal quality of the rock pile.
- Brush piles will settle over time and will need to be replenished with new materials every few years.

Figure 30 a. Timber Rattlesnake basking at the edge of a created brush pile. © D. Blodgett

Figure 30 b. Butler's Gartersnake basking on a created brush pile. © WEIS

5.5 Thermoregulation and Foraging Habitat: Creation, Restoration, and Maintenance of Open Habitat

In Ontario, SAR snakes require primarily open and edge habitat for thermoregulation and foraging throughout the active season (see section 2.2.4). Thus, creating and maintaining open habitat, such as grassland, field, savannah and forest clearings, can provide thermoregulation and foraging habitat for SAR snake populations. For example, the removal of forest canopy cover and/or creation of forest clearings can provide thermoregulation opportunities for snakes and result in increased use of management areas by snakes (Johnson 1995, Ross et al. 2000, Webb et al. 2005, Todd and Andrews 2008, Vermont Fish and Wildlife 2015), particularly if open habitats are otherwise limited in the immediate area (Figures 31 and 32). Even the removal of trees and shrubs from small areas can create suitable snake thermoregulation habitat (Pike et al. 2011, Johnson 1995, Johnson et al. 2016). Similarly, shrub and vegetation removal within early successional habitats can significantly improve their quality for supporting thermoregulation (Johnson et al. 2016). Although the creation of open habitats can benefit SAR snakes, such habitats with little-to-no vegetative structure or complexity (e.g. cover, basking structures) will generally be avoided by snakes. Thus, the addition of microhabitat features (section 5.4) and vegetative structure is an extremely important component of the habitat creation process.

Several different techniques can be used to create and maintain open habitat for snakes, including restoration of anthropogenic or degraded areas to create early successional habitat, opening the canopy in forested or shrub-dominated areas using selective logging or manual shrub removal, and maintaining early successional habitats through mowing, prescribed burns or herbicide treatment. Each of these methods poses some risk to snakes but has the potential to achieve significant benefits, if implemented correctly. These methods are discussed in greater detail in the following subsections.

Habitat management activities that pose a potential risk to SAR snakes or their habitat may require authorization under the ESA, 2007, even if the outcome of the project is expected to be beneficial. This is particularly true of management activities that have the potential to result in SAR snake mortality, such as mowing and prescribed burns. When creating or restoring open habitat for SAR snakes, consider if any other SAR may be in the area and how the management activities may affect those species; authorization under the ESA may be required if the activities post a risk to other SAR species or their habitat.

Maintaining old field habitats in an early successional state is an easy way to manage the landscape for SAR snakes. © J Crowley

The following are general guidelines for creating, restoring and/or maintaining foraging and thermoregulation habitat for SAR snakes:

- Create a mosaic of open habitats and forested areas that maximizes the ratio of forest edge habitat to other habitat types (e.g. open, closed canopy; Blouin-Demers and Weatherhead 2001a, Edgar et al 2010, Bonnet et al. 2016). Several small (i.e., < 1 ha) canopy openings will provide more edge habitat than a single larger clearing (Blouin-Demers and Weatherhead 2001a, Todd and Andrews 2008). Ideally, at least 25% of the landscape should consist of open habitat (Johnson et al. 2000, Shoemaker 2007).

- When possible, focus habitat creation initiatives on areas that recently had an open canopy or are still partially unshaded (e.g., recent woody plant growth has shaded the area) as these areas are most likely to still be occupied by SAR snakes.

- Rotate management activities (e.g., burns, vegetation removal, etc.) such that in any given year only a small portion of the site is being actively managed and a diversity of early and late successional habitats exist on the landscape.

- After habitat management activities (e.g. prescribed burns) are complete, and no longer pose a risk to snakes, add microhabitat structure, including basking sites, to the newly created area. Concentrate these structures along edges, particularly south-facing edges, to encourage dispersal into the new habitat.

- Carry out habitat maintenance activities that involve heavy equipment and prescribed burns while snakes are hibernating in order to avoid injury to or mortality of snakes.

- Maintenance of most early successional ecosystems is required every 3-5 years because the re-growth of shrubs can reduce habitat quality in as little as 3 years (Johnson et al. 2016). Open habitats that are generally devoid of shrubs can be improved for snakes by planting patches of native shrubs or other thick vegetation such as brambles. Guidelines include:

    - Plant patches of shrubs near basking structures to expand the range of thermal conditions and cover available to the snakes, provide a variety of basking options.

    - Avoid planting shrubs in areas where they will cast shadows on basking habitats when they have reached their full height.

    - Select appropriate shrub species based on habitat suitability for the species, but some possibilities include dense deciduous shrubs such as alders (*Alnus* spp.) and willows (*Salix* spp.), , or low-lying evergreens such as Common Juniper.

    - Limit total shrub cover to less than 50% of the site.

5.5.1 Restoration of Anthropogenic or Degraded Areas

The restoration of agricultural fields, cultural meadows, manicured lawns and other areas with human land-use to early successional habitat can benefit not only SAR snakes but also a wide range of biodiversity. Considerable literature exists in the field of restoration ecology, and this literature should be consulted when undertaking restoration activities to create early successional habitat for SAR snakes. In addition to following general ecological restoration practices, the guidance in the introduction to section 5.4 should be followed to promote the use of restored areas by SAR snakes.

5.5.2 Manual Vegetation Removal

Selective logging and manual shrub removal can be used to create small to medium-sized canopy openings for snakes. Removing even a small number of trees and shrubs can be very effective for opening the canopy (Pike et al. 2011), and this activity poses very low risk to individual snakes. The following recommendations will assist in creating and maintaining open habitat for snakes:

- Create open habitats in or near areas that are known to be used by the target species.
- Create openings of at least 100-500 m^2 in forested areas (Blodgettt pers. comm.), and 25-100 m^2 in shrub-dominated areas (Johnson 2013, Johnson et al. 2016), such that the majority of the clearing receives sun exposure for most of the day.
- Reduce forest canopy closure to as little as 10-15%, and shrub cover to less than 50%, in treated areas.
- Cut shrubs as close to the ground as possible (Johnson et al. 2016); however, shrubs and other ground cover should be maintained throughout parts of the site to provide a range of thermal conditions and protection from extreme temperatures.
- In areas of thick shrub cover, completely remove some shrubs and create brush piles from this material.
- Leave the stumps of all cut trees in place because they provide cover for snakes, and rotting root systems may be used as hibernation sites (Smith 2009).
- Use fallen trees and branches to create brush piles within, or along the edges of, clearings.
- Follow-up pruning will likely be required as dormant-season cutting often results in significant re-growth in spring.
- In forested landscapes, prioritize the retention of trees with abundant seeds, cones, or nuts (e.g., oaks, pines, etc.), which can be a beneficial food source for snake prey.

Figure 31. A recently-thinned pine plantation to restore oak-savannah habitat with gaps, suitable for Eastern Hog-nosed Snake. Shrub re-growth can result in significant shading after only a few years. © G. Beck

Figure 32. Two Massasaugas basking in a recently-cut shrubby area. © N. Rayman, USFWS

5.5.3 Prescribed Burns

Prescribed burns are an effective ecosystem management tool when used to create, restore and maintain ecosystems that are adapted to periodic fire events that have been suppressed by humans (Figure 33). This management tool can benefit SAR snakes and other species that depend on early successional habitat by preventing these ecosystems from succeeding into more mature habitats like shrub thickets and forest (Steen et al. 2015). Prescribed burns can also be an efficient and cost effective method for creating SAR snake habitat at the landscape scale (Cross et al. 2015, Durbian 2006). However, prescribed burns can result in direct and indirect snake mortality (Durbian 2006, Cross et al. 2015, WEIS unpublished data). Consequently, great care must be taken when conducting prescribed burns to avoid or minimize their adverse effects to SAR snakes.

Figure 33. Prescribed burns can be used to create and maintain open habitat for some at-risk snake species. Left: © G. Beck; Right: © WEIS

Snake mortality from controlled burns can be reduced or avoided by conducting burns during the hibernation period (Durbian 2006, Johnson et al. 2000, Kingsbury and Gibson 2012, Mifsud 2014). However, exact timing depends on the project location as well as seasonal weather conditions.

When conducting a burn during the hibernation period:

- Follow all government rules and regulations. (https://www.ontario.ca/page/outdoor-fire-rules-and-permits).
- Do not burn the area immediately surrounding hibernacula, gestation sites, nesting sites, or live birthing sites; use manual vegetation removal around these sensitive habitats (Mifsud 2014).
- In order to ensure the maintenance of some mature habitats and maintain habitat complexity and diversity, divide the site into burn and non-burn units, and burn only a subset of the burn units in any given year (Fuhlendorf and Engle 2004, Wilgers and Horne 2006).
- Burn small areas every 3-7 years (Mifsud 2014).

When it is not possible to conduct the burn during the hibernation period, consider other vegetation control options such as mechanical cutting and herbicides. When it is necessary to conduct prescribed burns during the active season for logistical reasons, due to weather, or to achieve additional goals (e.g., controlling invasive species), limit active season burns in SAR snake habitat to areas where populations are large enough to be able to withstand some mortality without a reduction in population viability (and only if authorized under the ESA). Several steps can be taken to reduce the risk to SAR snakes and other species when prescribed burns need to be conducted during the active season:

- Protect refuge areas (e.g., brush, leaf, log, or rock piles) near, but outside, burn units by creating firebreaks (Mifsud 2014).
- Create refuge areas near, but outside, burn areas for retreating snakes and other wildlife.
- Remove any brush piles, log piles, rocks, and other potential retreat sites that can reasonably be moved from burn areas at least 10 days prior to the burn (Mifsud 2014). Return these features to the burned area (or re-create them) immediately following the burn.
- Qualified professionals (i.e. individuals with expertise in SAR snake surveys) should carefully search the area immediately prior to burning and manually remove any snakes found; when capturing and relocating snakes, follow the guidance in the OMNRF SAR handling manual (OMNRF undated). Note that it can require significant effort (e.g. multiple staff constantly searching the site prior to the burn) to minimize risk to snakes (WEIS unpublished data).
- Undertake burning when snakes are likely to be inactive: before 9 am and after 5 pm in the spring and fall, and 12-3 pm from July 1 – August 31 (Cross et al. 2015, Johnson et al. 2000, Kingsbury 2002, Mifsud 2014).
- Replace or create microhabitat structures (e.g. brush piles, rock piles) after the burn is complete and all embers have gone out (Steen et al. 2015).
- Conduct prescribed burns on days with high surface moisture or air humidity to avoid high heat conditions that burn uniformly. This will leave small patches of habitat that are beneficial to SAR snakes (Kingsbury 2002).

5.5.4 Mowing

Mowing can be effective for controlling the growth of woody vegetation, and delaying the natural succession of meadows and fields into forest, especially in areas where prescribed burns are unsafe (Durbian 2006, Johnson et al. 2000). Early studies of mowing suggest that much of the direct snake mortality may be avoided by cutting vegetation at a height of 10-15 cm above the ground (Johnson et al. 2000). However, recent research involving radio-tracked snakes documented an unexpectedly high mortality of Massasaugas (43%) during mowing, even with mower blades at a height of 20 cm (Durbian 2006); two of seven radio-tracked Massasaugas known to be in the mowed area were killed by the mower blade, while a third was killed by the tractor (mower) tire. Due to the significant risk posed by mowing within SAR snake habitat, this activity should be restricted to the hibernation period whenever possible. If mowing cannot be avoided within SAR snake habitat during the active season, the following recommendations can help to minimize SAR snake mortality:

- Use a hand mower (i.e. avoid large tractors that can crush snakes)
- Raise the mower blade as high as possible, with a minimum height of 20 cm.
- Mow on rainy days, cold and overcast days or during other weather conditions when snakes are likely to be under cover.
- Move slowly through the habitat with the mower and, when possible, have someone walk a safe distance in front of the mower to watch for snakes and move them out of harm's way.
- Do not mow within the immediate area around habitat features that are known to be occupied at that time of year (e.g. hibernacula in the spring, gestation site during the summer); rather, use manual removal for woody plants in these areas.

5.5.5 Herbicide Use

Although herbicides can be effective in controlling vegetative growth and maintaining a site in an early successional state, they have been shown to negatively affect many reptile species (Bishop et al 1998, Campbell and Campbell 2002, de Solla et al 2007, 2014), as well as many snake prey species. Biomagnification of contaminants in snakes is a significant risk because snakes are upper-trophic-level carnivores (Campbell and Campbell 2002, Drewett et al. 2013). Given these drawbacks of herbicide use alternative techniques for maintaining early successional habitat should take priority whenever feasible. However, the selective application of herbicides, applied directly to cut stems, may be appropriate in some cases. The broad-scale use of herbicides, such as aerial or machine-based application, is not recommended. Herbicide application should be conducted only by a licensed applicator, following all appropriate health and safety measures, and federal and provincial regulations.

6. Effectiveness Monitoring of Habitat Management Activities

There is very little information on the effectiveness of various habitat creation techniques for snakes, both in terms of the likelihood that created habitats will be used by the species, as well as the long-term effects (beneficial or negative) on local populations. Uncertainty regarding the effectiveness of habitat structures created for snakes is further confounded by the fact that colonization and use of “successful” structures can take many years in some cases. For example, Eastern Foxsnakes were not observed basking at a hibernaculum created in Norfolk County until five years after its construction (Blanchard and Beck 2014, G. Beck unpublished data). Similarly, there is also considerable lack of information on the effectiveness or mitigation and avoidance techniques (see section 4). Thus, long-term monitoring of habitat creation, restoration, and maintenance activities is essential to determine whether these activities have their intended consequences. Effectiveness monitoring can also help to identify, and find solutions for, any problems that may exist with ongoing management activities. For example, if an artificial nest structure was installed according to the methods in section 5.2.1 but a temperature data logger indicated that the temperature in the structure was too low for egg development, modifications to the structure could be made to increase the temperature (e.g. additional material could be added or overhanging branches pruned to increase sun exposure). Finally, effectiveness monitoring and research are critical to reducing uncertainty, improving existing techniques, and informing future habitat management activities.

6.1 Measuring Success

To assess the effectiveness of habitat management activities, it is necessary to determine whether the habitat is successfully used for the intended life process (e.g. hibernation, gestation) and, in some cases, how the habitat affects the fitness and/or survival of the individuals using it. For most habitat types, effectiveness monitoring cannot rely solely on observations of individuals “using” the habitat, as that information is not sufficient to determine if the habitat is functioning as intended. For example, observations of snakes entering and “using” an artificially created hibernaculum are not sufficient to assess the effectiveness of the habitat creation efforts because snakes that use the feature may not survive the winter. Isolated observations of snakes exiting an artificially created hibernaculum are also insufficient to assess effectiveness because the overall survival rate of the snakes using the structure would remain unknown; despite some observations of successful hibernation, survival rates in created hibernacula may be considerably lower than those in natural hibernacula, and the feature may be acting as a long-term mortality sink. Therefore, a well-developed effectiveness monitoring study for created hibernacula should include an assessment of the survival of the snakes that use the hibernacula over several years, and a comparison of those survival rates to typical survival rates for the local population (or the species, if data on the local population are lacking). If the survival rate of the snakes using the artificially constructed hibernacula is consistent with typical survival rates for the population/species, then the habitat creation efforts can be considered successful. However, if the survival rate is unacceptably low, the habitat should be modified in an attempt to increase survival, or it should be removed if it is likely to negatively affect the population.

The following are recommended indicators of success for a variety of management actions, and properly designed effectiveness monitoring studies should allow for the assessment of these indicators:

Hibernacula

- Survival rate of snakes that use the artificially created hibernaculum is similar to, or higher than, survival rates at other naturally occurring hibernacula (typically within the same region, if the data exist). When possible, annual survival (not just overwinter survival) should be assessed, as the quality of the hibernacula may also affect survival post-emergence (snakes may survive hibernation but experience higher mortality during the early active season due to stress/problems encountered during hibernation).

Gestation sites

- Evidence of gravid females using the site for gestation. See section 3.3.2 for a discussion on how to determine if a site is being used for gestation.

Nesting sites

- Use of the artificial nesting site by the target species and successful hatching of at least some of the eggs.

Birthing sites

- Evidence that neonates have been born at the created birthing site. The observation of two or more neonates at the site indicate that they were likely born in the immediate area; the observation of only a single neonate does not provide conclusive evidence of use of the site for birthing, as the observed individual may have moved to the area from a nearby location.

Communal basking and communal shedding sites

- Use of the structure for the intended life process (basking or shedding) by two or more of the target species within the same active season.

Thermoregulation and foraging habitat

- Increased use of the area by the target species after management actions have been completed. Increased use may be indicated by an increase in the number of individuals using the habitat, or by the same number of individuals spending more time in the habitat than they did prior to the management actions.

6.2 Study Design

The study design should allow for a clear determination of whether habitat management activities have been effective. To do this, indicators of success (see section 6.1) must be clearly identified and the study designed so as to specifically assess them. For example, if an indicator of success is increased abundance of the target species in the managed habitat, then the monitoring study should be designed to collect and compare pre- and post-management relative abundance information. Sections 6.4-6.7 provide guidance for monitoring the use of habitat by SAR snakes, but McDiarmid et al. (2012) should also be consulted for detailed guidance on the design of ecological monitoring studies for snakes. Visual encounter surveys used for monitoring should adhere to the recommendations and methodology set out in the OMNRF snake survey protocol (OMNRF 2015, 2016). When there is conflicting guidance (e.g. timing for surveys), the guidance provided in this document, which is specific to the habitats being surveyed, should be followed. Authorizations under the FWCA and ESA may be required in the case of monitoring work that involves the capture and handling of individuals.

Snakes may use artificial basking structures within days or weeks of their creation (e.g., Sperry and Weatherhead 2010, Choquette 2015, WEIS unpublished data), but it can often take several years for snakes to begin using newly created habitat (Edgar et al. 2010, Gillingwater 2012, Blanchard and Beck 2014, G. Beck unpublished data, K. Brown pers. comm.). This is particularly true of hibernacula, gestation sites, nesting sites, and live-birthing sites because snakes show high fidelity to existing features. Consequently, it is generally necessary to conduct monitoring for a minimum of three years after habitat creation, restoration or maintenance activities have been completed in order to assess the effectiveness of these management activities. Consider extending monitoring efforts if the species has not been detected after three years, or if indicators of success cannot be adequately assessed during the initial timeframe.

6.3 Adaptive Management

Ecosystems and biological organisms, such as snakes, are complex and difficult to manage, and every project site is a unique situation with a complex combination of biotic and abiotic variables that can affect the success of habitat management activities. Further to this, there is still a great deal of uncertainty with respect to the optimal techniques for creating SAR snake habitat. Thus, habitat creation projects should be treated as experiments within an adaptive management framework. Adaptive management is a process that involves monitoring the outcome of management activities, and using that information to reduce uncertainty and improve management decisions over time (Holling 1978, McLain and Lee 1996). Effectiveness monitoring is an integral part of this process because the data that are generated are used to test hypotheses about the habitat creation techniques (i.e. answer questions about what works well and what does not). This information can then be used to inform future efforts, resulting in the improvement of habitat management techniques over time. Despite its utility, an adaptive management process should never be used as an excuse for rushed project design; habitat management activities should always be based on the best available information, including a thorough assessment of snake habitat use and spatial ecology at the site in question.

6.4 Monitoring Hibernacula

Monitoring of hibernacula should include assessments of the environmental characteristics of the features, as well as the use of the features by the target species (including the overall survival of the individuals using these features).

6.4.1 Monitoring Environmental Characteristics of the Hibernacula

During the winter months, collect hourly temperature profiles from a range of depths throughout the hibernaculum using temperature data loggers to determine the depth of the frost line. Daily (or at a minimum, weekly) measurements of water table depth should also be collected. This information will allow for a determination of whether a life zone was successfully created within the hibernaculum, and it will help to improve our understanding of how environmental conditions affect the suitability of hibernacula for SAR snakes (i.e., what conditions result in successful hibernation or mortality).

6.4.2 Monitoring the Use of Hibernacula

As discussed in section 6.1, effectiveness monitoring for hibernacula requires the determination of the hibernation survival rate in the created hibernacula and a comparison of this rate to the typical hibernation survival rate for the local population or species. Therefore, it is necessary to sample all snakes as they enter and exit the hibernaculum. The best methodology for achieving this is to set up perimeter fencing and traps surrounding the hibernacula to capture all snakes entering and existing the feature. A perimeter fence is a circular drift fence that surrounds the entrance(s) to a hibernaculum. Traps are installed at regular intervals along the fence. As snakes leave the hibernaculum, they are guided along the fence until they encounter a trap. This method is effective for capturing many species of snakes (Row and Blouin-Demers 2006b, Todd et al. 2007). Different kinds of traps can be used with the fences depending upon soil type, habitat and target species. Pitfall traps (Gibbons and Semlitsch 1981) buried in the ground can be suitable for small snakes whose lengths are less than the depth of the pit (Fitch 1987), but predation of trapped animals can be a drawback of this methodology (Ferguson et al. 2008). Funnel or box traps should be used for Ontario's SAR snakes because they have higher capture rates and lower risk of predation than pitfall traps (Enge 2001, Kjoss and Litvaitis 2001, Zappalorti and Torocco 2002). Funnel traps allow snakes to enter through the wide end of a funnel into a box. The narrow opening of the funnel, which extends into the box, keeps snakes from escaping as they search the edges of the box for exits.

To set up perimeter fencing and traps for the purpose of monitoring snake hibernacula:

- Install the fencing and traps before August 15th so it is in place prior to the arrival of snakes at the hibernaculum.
- Construct fencing from heavy duty plastic sheeting stapled to wooden posts surrounding the hibernaculum entrance(s).
- Build fences at least 0.6 m high for most snake species in Ontario, and at least 2.0 m high for climbing snakes, such as Gray Ratsnake and Eastern Foxsnake (OMNR 2013b).
- When working with Eastern Foxsnake and Gray Ratsnake, consider covering the top of the fenced area with galvanized steel mesh or screen to prevent any trapped snakes from escaping.
- Fold the bottom of the fencing in towards the hibernaculum and pile soil, rocks, and other material onto this 'lip' to keep snakes from escaping under the fence.
- Install one funnel trap for fenced areas with a diameter <5 m. For larger fenced areas, install one additional funnel trap (equally spaced around the fence) for every 5 m increase in fence diameter.
- Create shade over one end of each trap with a tarp or piece of wood securely fastened in place to prevent snakes from overheating.
- More detailed construction guidance, with drawings and photographs, can be found in Row and Blouin-Demers (2006b).

In the fall, traps should be checked daily once the fencing has been installed until all snakes have likely returned to their hibernation sites (e.g. night time temperatures below freezing). Daily trap checks should resume in the spring and be carried out for the entire duration of the emergence period (see section 2.2.1).

When snakes are captured, they should be individually marked using Passive Integrated Transponders (PIT tags) so that they can be easily identified during successive captures. PIT tags should only be implanted by a qualified professional (i.e. an individual with relevant biological expertise and training in the use of PIT tags on snakes). Alternatively, photographs can be used to differentiate between individuals of some species, using the following characteristics:

- Massasaugas: a photograph clearly showing the dorsal patterning
- Eastern Foxsnake: photographs depicting both the dorsal patterning and part of the ventral (belly) pattern (ensure that the same portion of the ventral surface is photographed for all species).
- Eastern Hog-nosed Snake and Gray Ratsnake: photographs depicting both the dorsal patterning (when present) and part of the ventral (belly) pattern (ensure that the same portion of the ventral surface is photographed for all species).

6.5 Monitoring Nesting Habitat

Monitoring should include an assessment of the environmental characteristics of the nest structure, as well as the use of the structures by target species (including assessments of hatching success).

6.5.1 Monitoring Environmental Characteristics of Nesting Structures

Monitor the temperature of the nesting material within created nest structures from the time the structure is installed until the end of the active season, using the following methodology:

- Use a small, battery-powered data logger (with a battery that will last for at least six months), with a temperature recording accuracy of at least +/- 0.5^{o} C.
- Install the data logger about 30 cm below the surface of the nesting material, and set it to record the temperature hourly.
- Retrieve the data logger after the nesting season, when checking for eggshells, to download temperature readings.
- Aim for an average summer temperature in the nesting material that is between 25-30^{o}C (see section 2.2.2).

6.5.2 Monitoring the Use of Created Nesting Structures

- Egg survival and hatching success in artificial nesting structures is similar to, or higher than, the average survival and hatching success rate of the local population / species.
- Monitor created nesting structures for use by snakes using the following methods:
- Open the structure and check for evidence of unhatched eggs or eggshells in late October or early November after eggs have hatched. Do not disturb nest structures during the nesting and incubation period (mid-June to mid-October).
- Sift through the nesting material by hand because using shovels or pitchforks can damage unhatched eggs or result in eggshells being overlooked. Also, search the nesting material for shed snake skins (nest structures may be used as shedding sites) and evidence of predation.
- See section 3.3.3 for a description of snake eggs.
- Leave unhatched eggs in place or, if it is unlikely that they will hatch due to the time of year, consider having them incubated and hatched in captivity.

Nest structures may not be used by SAR snakes for a variety of reasons, including low density of the species in the area, abundance of other nesting sites, fidelity to other nesting sites, or unsuitable conditions within the created nesting structure.

6.6 Monitoring Gestation and Birthing Habitat

Conduct visual encounter surveys to assess the use of created gestation and birthing habitat following the recommended methodology outlined in section 3.3.2 and section 3.3.4, with the following changes to survey effort and timing:

Gestation sites

- Conduct at least five surveys each year during the core gestation period from mid-June until late July (or until mid-August in the case of Massasauga).
- Spread surveys as evenly as possible throughout the gestation period; avoid surveys on consecutive days.

Birthing sites

- Conduct at least five surveys each year during and shortly after the live-birthing period (late July to early September, depending on the species).
- Spread surveys as evenly as possible throughout the live-birthing period; avoid surveys on consecutive days.

6.7 Monitoring Communal Basking / Shedding Structures

Conduct visual encounter surveys to assess the use of created basking and shedding structures following the methodology outlined in section 3.3.5.

Alternatively, monitor basking sites using trail cameras, as follows:

- Set up a trail camera a few meters from the basking site in the early spring, such that it is not facing the sun.
- Program the camera to take photographs at a fixed time interval (e.g., every 10 minutes) rather than relying on the motion sensors in the camera. Snakes, which are slow-moving and have body temperatures similar to that of the environment, do not always trigger the motion sensors of these cameras (Smith and van der Ree 2015).
- With an adequate memory card, a trail camera need only be checked approximately once a week (or less) to replace the memory card and batteries, if needed.
- Leave the trail camera in place for at least two months in spring to increase the probability of detecting the target species.
- Avoid placing trail cameras in areas with high public use, or in easily visible spots, as this is likely to increase the risk of theft or vandalism. Housing cameras in locked structures can also help to reduce theft.

6.8 Monitoring Thermoregulation and Foraging Habitat

Monitoring the effectiveness of efforts to create, restore and manage open open habitats for snakes poses unique challenges, especially if working at large scales. Considering that individuals of the target species may have been present prior to habitat creation, restoration or maintenance activities, it is necessary to design monitoring studies that will provide information on how the species' use of the habitat has changed in response to these activities (see section 6.1 for a discussion of indicators of success). It is very difficult to estimate the abundance of snake populations due to the cryptic nature of these species and extremely low recapture rates. Consequently, measures of relative abundance are often used to assess trends over time or differences across sites (e.g., Cavitt 2000, Dorcas and Willson 2009, McDiarmid et al. 2012). A mark-recapture study should be employed to determine if habitat management activities resulted in a change in relative abundance within the affected area. A mark recapture study entails conducting visual encounter surveys and/or cover board surveys, marking all captured individuals, and tracking total captures, new captures and re-captures over time.

When developing the monitoring program, a Before-After-Control-Impact (BACI) study design (see Smokorowski and Randall 2017) is highly recommended. This study design entails collecting relative abundance data for several years Before and After habitat management activities, as well as at Impact sites (i.e. sites where management occurs) and Control sites (unaffected sites). Annual variation in snake relative abundance can be very high (McDiarmid et al. 2012, WEIS unpublished data), and may be higher than changes in abundance resulting from management activities. Thus, using a BACI study design will make it possible to determine if observed changes in relative abundance at the impact site are the result of management activities as opposed to natural variation in other variables, such as different weather patterns in different years.

The following recommendations will assist in designing an effective mark-recapture monitoring program for assessing changes in relative abundance of Ontario's SAR snakes in response to habitat management activities. Consult See McDiarmid et al. (2012) for further information on designing mark-recapture studies for snakes and Smokorowski and Randall (2-17) for additional information about the BACI design methodology.

- Conduct visual encounter surveys and cover board surveys for SAR snakes according to the methodology and recommendations in the OMNRF SAR snake survey protocol (OMNRF 2016), and ensure that surveyors have appropriate expertise and experience conducting surveys for the target species.
- Begin monitoring a minimum of two to three years before undertaking the habitat management activity. Due to high natural variation in snake capture rates from year to year, a single year of data collection prior to the habitat management activity is insufficient to detect a change in abundance resulting from the activity.

Searching for snakes in meadow marsh-shoreline habitat. © J. Crowley

- Conduct monitoring at multiple Impact sites (i.e. sites where management occurs) and Control sites (unaffected sites), as per the BACI design.
- When snakes are captured, they should be individually marked using Passive Integrated Transponders (PIT tags) so that they can be easily identified during successive captures. PIT tags should only be implanted by a qualified professional (i.e. an individual with relevant biological expertise and training in the use of PIT tags on snakes). Alternatively, photographs can be used to differentiate between individuals of some species using the following characteristics:
    - Massasaugas: a photograph clearly showing the dorsal patterning
    - Eastern Foxsnake: photographs depicting both the dorsal patterning and part of the ventral (belly) pattern (ensure that the same portion of the ventral surface is photographed for all species).
    - Eastern Hog-nosed Snake and Gray Ratsnake: photographs depicting both the dorsal patterning (when present) and part of the ventral (belly) pattern (ensure that the same portion of the ventral surface is photographed for all species).
- Establish and follow standardized monitoring protocols for results that will be comparable between sites and years. For example, ensure that search effort, timing of surveys, and the range of weather conditions under which surveys are conducted are similar in surveys.
- Techniques for standardizing search effort will vary with the project goals and logistics, but may include:
    - Time-constrained surveys with the same number of observers (e.g. all surveys are one hour long and conducted by two surveyors).
    - Calculating the 'number of encounters/person hour' as the metric for comparison. For species that are primarily found under cover (e.g. Queensnake), the 'number of encounters/100 cover objects searched' can also provide a standard metric for comparison.
    - Constraining surveys to fixed number of randomly distributed plots of a specific size.
    - Deploying and searching the same number of cover boards at each site.
- Conduct a minimum of ten surveys at each treatment site and control site over the course of each active season. Even the accuracy of relative abundance estimates of snakes can be severely limited by low detection probabilities, but this challenge can be partially overcome with high sampling efforts (Steen 2010).

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9. Glossary

Active season: The portion of the year when snakes are active (e.g. basking, foraging, moving) and are not hibernating; typically from April or early May until late September, October or early November, depending on species, latitude and seasonal weather variation.

Ectothermic: An organism that has a variable body temperature that fluctuates with, and is largely determined by, the temperature of the surrounding environment.

Open habitat: Areas that have less 25% forest canopy and less than 50% shrub cover, such as early successional habitat, savannah, forest clearings, forest edge, fields, rock outcrops and shorelines.

Thermoregulation: The maintenance of a specific internal body temperature (or range of temperatures). In the case of snakes, which are ectothermic, thermoregulation is achieved through behaviors such as basking in the sun to elevate body temperature or seeking shelter to cool down, and this is referred to as behavioral thermoregulation.