Movements of the Eastern Ribbonsnake (*Thamnophis sauritus*) in Nova Scotia

T. L. Imlay[1, 2], J. Saroli[1], T. B. Herman[1], and S. W. Mockford[1, 3]

[1]Department of Biology, Acadia University, Wolfville, Nova Scotia B4P 2R6 Canada
[2]Current address: Department of Biology, Dalhousie University, Halifax, Nova Scotia B3H 4R2 Canada
[3]Corresponding author: stephen.mockford@acadiau.ca

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The disjunct Eastern Ribbonsnake (*Thamnophis sauritus*) population in southwest Nova Scotia is listed as "threatened" by the Committee on the Status of Endangered Wildlife in Canada. A study of the movements of the species at two lakeshore locations known to support a high density of Eastern Ribbonsnakes was undertaken in 2007 and 2008. Average seasonal movements at both sites ranged from 17 m to 84 m for juvenile snakes and 21 m to 130 m for adults; one neonate was recaptured during the study after travelling 32 m. The maximum distance travelled by an individual snake was 391 m in one season. The best-fit model to explain differences in daily movement patterns included year ($P = 0.041$), indicating that there is annual variation in the movements of this species. Low recapture rates precluded accurate estimates of home-range size, which varied roughly from 0.16 ha to 0.78 ha. Both movements and home ranges were larger than previously documented in Nova Scotia, but maximum distances travelled were consistent with a previous study in Michigan. Most documented movements were along the lakeshore within contiguous, suitable habitat. More work is needed to understand the frequency of large movements and triggers that initiate movements, e.g., changes in water levels, habitat suitability, or prey availability.

Key Words: Eastern Ribbonsnake; *Thamnophis sauritus*; Nova Scotia; movements; home range; site fidelity; recapture

Introduction

Movement patterns of a species are one of the most commonly studied factors in relation to conservation efforts as they often reflect spatial and temporal changes associated with life history stage or resource availability and use (Gregory *et al.* 1987). For example, seasonal movements often reflect a shift from summer foraging locations to hibernacula or other overwintering habitat (Larsen 1987; Webb and Shine 1997; Whiting *et al.* 1997). Movements may also reflect differences in microhabitat use by gravid and non-gravid individuals, which have different thermoregulatory needs and face different risks of predation (Shine 1979; Reinert and Kodrick 1982; Madsen 1984; Macartney *et al*. 1988; Charland and Gregory 1995; Webb and Shine 1997; Whiting *et al*. 1997; Stephenson *et al*. 2003; Harvey and Weatherhead 2006). Graves and Duvall (1993) noted that gravid Prairie Rattlesnakes (*Crotalus viridis viridis*) used rookeries that were often at a considerable distance from habitat used by non-gravid female and male snakes. Gravid Broad-headed Snakes (*Hoplocephalus bungaroides*) remained at the wintering habitat (exposed cliffs) during gestation when non-gravid and male snakes used nearby wooded habitats (Webb and Shine 1997). During ecdysis, snakes may also become more sedentary as lack of visual acuity can increase predation risk (Madsen 1984). Food availability can also drive movement patterns as snakes move from areas of low to high prey density (Whitaker and Shine 2003).

Site fidelity is often regarded as advantageous, as increased familiarity with habitat features enables individuals to avoid predators, forage, and thermoregulate effectively (Madsen 1984). Site fidelity has been observed in a variety of species across various spatial scales (Carpenter 1952; Barbour *et al*. 1969; Larsen 1987; Ciofi and Chelazzi 1994; Webb and Shine 1997; Stephenson *et al*. 2003; Whitaker and Shine 2003). Less mobile species may use the same rock or burrow in consecutive years (Webb and Shine 1997; Stephenson *et al*. 2003; Whitaker and Shine 2003). More mobile species may make long daily movements, but also return to the same shelter every evening (Ciofi and Chelazzi 1994).

The Eastern Ribbonsnake (*Thamnophis sauritus*) occurs in eastern North America from Florida to southern Quebec, with a disjunct population in southwest Nova Scotia (Gilhen 1984; Conant and Collins 1991; Desroches and Lepare 2004). Basic ecological knowledge of this species, including life history, distribution, and abundance, is lacking for much of its range. In this study, we examined the movement patterns of Eastern Ribbonsnakes at two sites in southwest Nova Scotia known to support high ribbonsnake densities, comparing daily movements of different age classes, sexes, and sites over 2 years.

Study Area

Grafton and Molega Lakes were chosen as study sites based on previous surveys that suggested a high density of Eastern Ribbonsnakes at these locations (Figure 1). Grafton Lake (44.3820°N, 65.2010°W), in Kejimkujik National Park and National Historic Site, is the site of an ongoing mark–recapture program to determine population size and structure that started in 2002. At Grafton Lake, the available ribbonsnake habitat was expanded

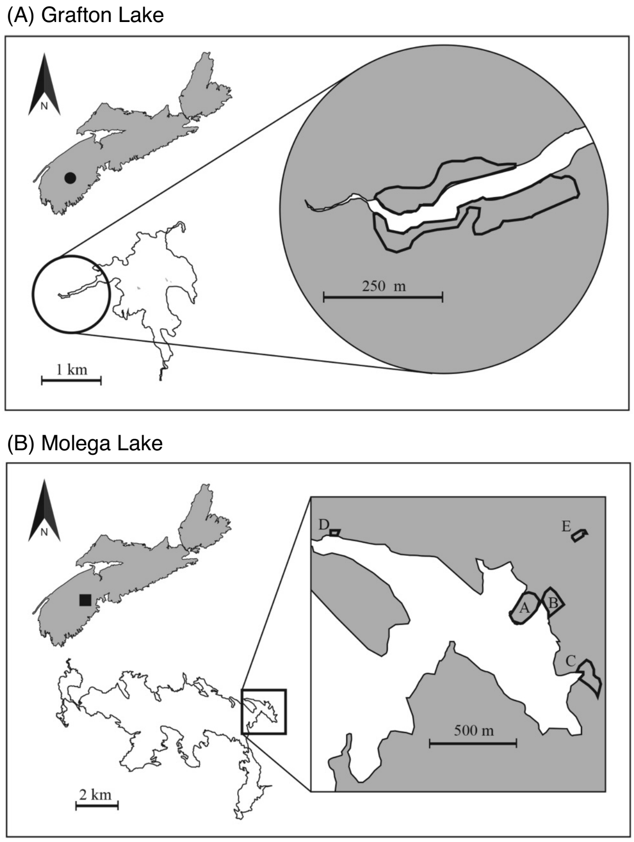

FIGURE 1. Location of Eastern Ribbonsnake (*Thamnophis sauritus*) study sites at (A) Grafton and (B) Molega Lakes, Nova Scotia. (A) In the detailed map, the study area at Grafton Lake is delineated by a bold line adjacent to the water. (B) Study sites are delineated by bold lines and labelled A to E.

in 1996 when a dam at Grafton Brook was removed. This resulted in a significant drop in water level in the lake and exposure of two large floodplains on either side of the brook. With the exception of several rapid stretches, water velocity in the brook is low. The floodplains support four distinct habitats (graminoid dominated areas, rocky areas, rocky areas with high density of woody shrubs, and areas with young conifers) and are surrounded by mixed deciduous and coniferous forest. In summer, pickerelweed (*Pontederia* spp.) and other aquatic vegetation (*Juncus* spp. and *Nuphar* spp.) are common along the edge of Grafton Brook. The current high density of ribbonsnakes at this site is attributed primarily to the large increase in suitable habitat resulting from dam removal.

At Molega Lake (44.3670°N, 64.7895°W) five distinct sampling zones were surveyed in an area known locally as Keddy's Cove (Figure 1B). The primary sampling zone (A) is a small peninsula, with shallow muddy banks along its base, leading to a small floodplain insulated from wind and waves by two conjoined eskers. A steeply banked causeway, apparently anthropogenic, along the peninsula is dominated by dense shrubs and bracken. A pair of small cottages on the peninsula are linked by a gravel driveway to the shoreline via the causeway. The central area of the peninsula surrounding the cottages consists of a well-tended yard, with dense shrubs and bracken lining the edges and shoreline. The floodplain of the esker is dominated by grasses; the vegetation on the eskers consists mainly of thick bracken and small trees.

Zone B, directly adjacent to and southeast of A, is a large muddy floodplain approximately 150 m across. When water level in the lake is high, the floodplain is mostly covered by water about 30–40 cm deep. Opposite the shoreline, a stream flows out to a section with permanently deeper water. Grasses and sedges line the shore close to the water, backed by taller shrubs, and finally trees marking the perimeter of the zone.

Zone C, approximately 500 m southeast of A, comprises a floodplain similar in structure to B but larger, approximately 250 m across. The flora is also similar to that of B, with grasses lining the muddy flooded shores and denser, larger sedges and bracken farther back from the waterline.

Zone D, approximately 1.3 km northwest of A, is a small inlet prone to flooding in low areas and mainly vegetated by tall shrubs and ferns. It has a rocky shoreline and heterogeneous relief. Small pools of still water, some up to a metre deep, dot the zone.

Zone E is approximately 500 m northeast of A. Unlike the other zones, it is inland and at a higher elevation. It is both spatially and structurally distinct from the other zones and comprises largely open woodland, with denser thickets of young Balsam Firs and pines. The substrate is primarily friable soil covered with conifer needles and coarse woody debris. A steeply banked stream, lined with exposed rocks, forms the southeast boundary of the zone, but was not included in visual surveys. No other open water occurred in the zone, and at no point did it become flooded.

Methods

Field Methods

We conducted visual surveys from April to November in 2007 and from May to August in 2008. At Molega Lake, zones A and B were both surveyed in 2007 and 2008; zones C, D, and E were added in 2008 when examination of the 2007 data suggested that zones A and B did not encompass the entirety of individual ribbonsnake movements. Grafton Lake was surveyed only in 2007 to allow more time for surveying at Molega Lake in 2008 and because additional data had been previously collected at the Grafton site. Over the 2 years, 965.2 h of observer effort was expended in visual surveys.

Visual surveys involved one or more researchers walking along transects running parallel to the water's edge. Typically, a distance of 5–10 m was maintained between researchers, although this varied with the habitat to be surveyed. Attempts were made to hand capture all ribbonsnakes that were observed. Locations of ribbonsnakes were recorded as UTM in NAD 83 using a handheld Garmin GPS 72 (Garmin Ltd., Schaffhausen, Switzerland); date and time were recorded for each observation. Snout-to-vent length (SVL) was measured for all captured snakes using a flexible, plastic measuring tape. Snakes were assigned to one of three age classes: neonate (born in August or September), juvenile, adult (SVL ≥ 37 cm). The smallest gravid female previously recorded in Nova Scotia had an SVL of 37 cm (Eastern Ribbonsnake (Atlantic Population) Recovery Team, unpublished data); this is consistent with other studies (e.g., Langford *et al*. 2011). The sex of adult snakes was assigned by examining the width of the tail posterior to the cloaca. Those with tails that tapered directly behind the cloaca were assigned as females. Those lacking an immediate taper behind the cloaca, because of the presumed presence of a hemipenis and those in which a hemipenis was observed during handling were assigned as males. Seven adults that were not consistently assigned to the same sex were noted as unknown sex during the analysis; in addition, all juvenile snakes were identified as unknown sex.

All captured snakes were given individual-specific marks. Adult and large juvenile snakes (SVL > 20 cm) were marked by clipping ventral scales in a unique code (Blanchard and Finster 1933). Small juvenile and neonate snakes were marked using a non-toxic permanent marker by drawing a series of circles posterior to the head and cloaca, and anterior to the cloaca. As clip codes were previously observed to regenerate during the active season (McNeil 2005) and marker codes fade, scale deformities and scars were also recorded and photographed to assist in identifying individual snakes. Shed ribbonsnake skins were also recorded as a ribbonsnake observation. Occasionally the individual could be identified from the skin if the ventral surface above the cloaca was intact, as the clip code was apparent.

Statistical Analysis

The mean and maximum number of captures, time between captures, straight-line distance between captures, and daily distance travelled between captures were calculated for each class from the recapture histories at both sites. A general linear model was used to examine the relation between daily distance travelled and the following variables: SVL, sex (male, female, or unknown), site (Grafton and Molega Lakes), and year (2007 and 2008). Daily distance travelled was determined by dividing the distance travelled between recaptures by the days between recaptures; a logarithmic transformation was used to normalize the data. Gravid female snakes are known to be less mobile than non-gravid females (e.g., Reinert and Kodrick 1982; Charland and Gregory 1995; Webb and Shine 1997); however, because it was not possible to determine the reproductive status of all females, this was not included as a variable in the model. A reverse step-wise regression procedure was used to select the best-fit model by comparing the small sample size correction for Akaike information criterion (AICc) and the AICc weight (Burnham and Anderson 2002).

ArcMap 9.2 (Environmental Sciences Research Institute, Redlands, California, USA) was used to calculate the distance between recaptures and the size of the home range of individual snakes with a minimum of five captures using a minimum convex polygon (Hawth's Analysis Tool version 3.27; Beyer, 2004). For snakes captured multiple times, home range size was calculated from the initial five captures and then additively with each additional capture. Increases in home range size with additional captures were used to determine the accuracy of the home range estimates for ribbonsnakes. Linear regression was used to determine whether there was a relation between the number of days between captures and the increase in home range size for snakes captured more than five times.

R version 1.7.2 (R Development Core Team 2012) was used for all statistical tests and to calculate summary statistics; means are presented with the standard deviation.

Results

In total, 136 ribbonsnakes were captured at least once at Grafton (54 in 2007) and Molega (50 in 2007 and 32 in 2008) Lakes during this study. Annual adult recapture rates did not exceed 60% (53–56% at Molega Lake and 48% at Grafton Lake) and juvenile rates ranged from 14–42% at Molega and 20% at Grafton Lakes (Table 1). Only a few individuals were captured in both years at Molega Lake. Of the 22 neonates marked, only one was recaptured during the study. An analysis of the time between recaptures revealed that 50% of recaptures at Grafton Lake and 70–82% of recaptures at Molega Lake occurred within 3 weeks of the previous capture (Figure 2).

Ribbonsnake movements varied with year, age class, and site. Throughout the season, movements of up to 136 m and 391 m were documented for juvenile and adult snakes, respectively (Table 2). However, average movements for juveniles (17.2–84.0 m) and adults (21.3–129.5 m) were typically less extensive. The only recaptured neonate snake moved 32 m between captures. The best-fit model to explain daily distance travelled included only year as a significant variable (P = 0.041) (Table 3). There was also strong support for the second best-fit model that included year and site (ΔAICc = 2.1) and some support for the inclusion of SVL (ΔAICc = 4.4). Ribbonsnake movements were

TABLE 1. Total number of recaptured Eastern Ribbonsnakes (*Thamnophis sauritus*), recapture rates, and time between recaptures for all age classes at Molega and Grafton Lakes, Nova Scotia.

Site	Year	Age	No. marked	No. recaptured (%)	Mean no. of captures (SD)	Max. no. of captures	Mean time between captures, days (SD)	Maximum time between captures, days
Molega	2007	Neonate	12	0	—	—	—	—
		Juvenile	21	3 (14)	2.3 (0.6)	3	15.8 (6.0)	33
		Adult	17	9 (53)	4.4 (2.4)	8	15.9 (17.4)	74
	2008	Neonate	3	0	—	—	—	—
		Juvenile	11	5 (42)	2.0 (0.0)	2	29.2 (39.6)	98
		Adult	18	10 (56)	2.7 (1.9)	8	22.1 (32.6)	112
	2007–2008*	Juvenile	21	3 (14)	2.0 (0.0)	3	—	292
		Adult	17	4 (24)	3.5 (3.1)	9	—	346
Grafton	2007	Neonate	7	1 (14)	—	2	—	1
		Juvenile	20	4 (20)	2.8 (1.0)	4	19.9 (16.6)	42
		Adult	27	13 (48)	2.8 (1.1)	5	43.9 (52.8)	190

*Includes only snakes marked in 2007 that were recaptured at least once in 2008.
Note: SD = standard deviation.

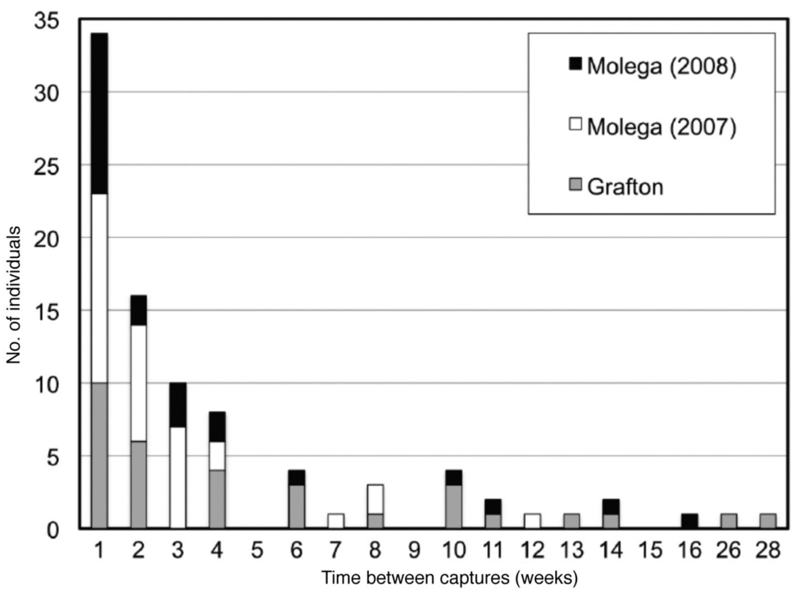

FIGURE 2. Time between captures of Eastern Ribbonsnakes (*Thamnophis sauritus*) at Grafton and Molega Lakes, Nova Scotia, in 2007 and 2008. Most recaptured snakes were caught within 3 weeks of the previous capture.

TABLE 2. Average and maximum movements of neonate, juvenile, and adult Eastern Ribbonsnakes (*Thamnophis sauritus*), at Molega and Grafton Lakes, Nova Scotia.

			Total distance travelled		Daily distance travelled	
Site	Age and year	No.	Mean, m (SD)	Maximum, m	Mean, m (SD)	Maximum, m
Molega	Juvenile 2007	4	47.2 (47.9)	130.0	14.6 (14.5)	36.0
	Juvenile 2008	5	84.0 (47.2)	136.1	3.3 (3.9)	9.2
	Adult 2007	30	62.7 (53.8)	196.4	10.2 (18.3)	94.3
	Adult 2008	18	21.3 (47.0)	112.1	4.8 (6.2)	18.0
Grafton	Neonate 2007	1	—	32.2	—	32.2
	Juvenile 2007	7	73.1 (16.6)	133.0	8.6 (9.2)	26.0
	Adult 2007	24	129.5 (114.8)	391.0	17.4 (54.9)	273.0

Note: SD = standard deviation.

TABLE 3. Best-fit model for Eastern Ribbonsnake (*Thamnophis sauritus*), movements at Grafton and Molega Lakes, Nova Scotia.

Model	AICc	k	ΔAICc	AICc weight
year	164.2	2	0.0	0.681
site* + year	166.3	4	2.1	0.234
site* + SVL* + year*	168.6	6	4.4	0.076
sex* + site* + SVL* + year*	172.8	7	8.7	0.009

*Not significant ($P < 0.05$).
Note: AICc = correction for Akaike information criterion, k = number of parameters, SVL = snout-to-vent length.

longer in 2007 than in 2008 for snakes at either Grafton or Molega Lakes (Figure 3).

The average home range size for snakes that were caught five or more times in a year was 0.43 ha (SD 0.27) (Table 4). With each successive capture of these snakes, home range size increased by 0.001–0.49 ha, suggesting that additional captures are still required to gain a more precise estimate of true home range size. For snakes captured more than five times, there was no significant relation between time between captures and increases in home range size ($R^2 = -0.125$, $P = 0.988$).

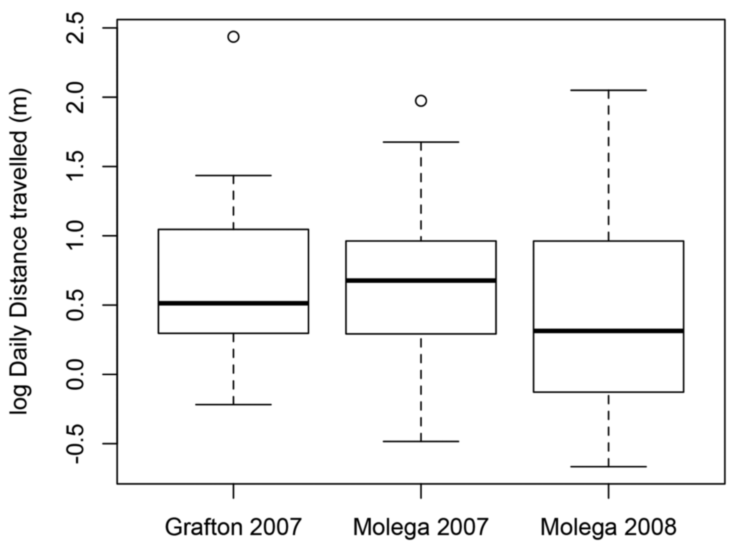

FIGURE 3. Distance travelled daily by Eastern Ribbonsnakes (*Thamnophis sauritus*) at Grafton and Molega Lakes, Nova Scotia, in 2007 and 2008. Daily distance travelled was greater in 2007 than 2008.

TABLE 4. Minimum convex polygon estimates of home range size of individual adult Eastern Ribbonsnakes (*Thamnophis sauritus*) that were recaptured five or more times in a year, ordered by snout-to-vent length (SVL), at Grafton and Molega Lakes, Nova Scotia.

Site	Year	Sex	SVL, cm	No. of captures	Home range, ha
Molega	2007	F	38	8	0.78
		M	39	7	0.64
		F	40	8	0.21
		F	44	5	0.18
	2008	F	39	8	0.16
Grafton	2007	M	39	5	0.23
		F	43	5	0.76
		F	51	5	0.49

Discussion

Both juvenile and adult snakes were documented travelling up to 100 m in 24 h; one adult at Grafton travelled nearly 400 m. In Michigan, the maximum daily distance travelled was 278 m (Carpenter 1952), consistent with our observations. In contrast, a study in Alabama documented daily movements up to 1 km for one male snake (Langford *et al*. 2011). The results of these studies also contrast with Bell *et al*. (2007), who reported more limited mobility in Eastern Ribbonsnakes in southwest Nova Scotia. However, movement data for this study were drawn primarily from gravid females, whose movements might have been reduced by both their reproductive status and the implanted radio-transmitters used to track them. Juvenile movements were within the range of adult movements, which is consistent with observations of juveniles or sub-adults in other species (Webb and Shine 1997; Bonnet *et al*. 1999).

Only one neonate was recaptured during the study at Grafton Lake; it travelled 32 m from the initial capture site in 1 day. In 2006, a neonate was recaptured at Molega Lake; it travelled 25.5 m in 4 days, similar to the Grafton observation (Eastern Ribbonsnake (Atlantic Population) Recovery Team, unpublished data). The lack of neonate recaptures at these sites is likely a result of the non-permanent marking technique and low detectability of snakes in this age class. More recaptures are needed to improve understanding of the movements and site fidelity of this age class, especially as high mortality from anthropogenic causes has been documented for neonates of other species (Bonnet *et al*. 1999).

Given the low recapture rates, it was difficult to estimate accurate home range size of adults. However, home range sizes were larger than the typical 50 m^2 noted by Bell *et al*. (2007). Although the home range estimates for adult males and females overlapped, females were recaptured more frequently than males, suggesting a sex-biased recapture rate. Gravid female snakes typically have smaller home ranges and reduced activity levels (Shine 1979; Reinert and Kodrick 1982; Madsen 1984; Macartney *et al*. 1988; Charland and Gregory 1995; Webb and Shine 1997; Whiting *et al*. 1997; Stephenson *et al*. 2003; Harvey and Weatherhead 2006); therefore, they may be encountered more frequently. Movements of male snakes may have extended beyond the sampling area in 2007 given that most recaptures occurred within 3 weeks of the initial capture, thus reducing the likelihood of recapture. Additional work is needed to determine the true extent of home ranges and whether area differs between the sexes and life-cycle stages (i.e., gestation).

Recapture rates during this study were low at both sites in 2007 and at Molega in 2008, with most recaptures occurring within 3 weeks of the previous capture. In 2008, additional wetlands and an upland area around zones A and B at Molega Lake were frequently surveyed in an attempt to document movements outside these zones. It should be noted that the low recapture rates might have reduced the likelihood of capturing marked snakes in these peripheral areas. Only four ribbonsnakes, and no marked individuals, were observed in these other survey areas, suggesting that although ribbonsnakes were capable of travelling long distances in a short period (as observed in 2007), they were not choosing to disperse long distances in that year.

Movements of the Concho Water Snake (*Nerodia harteri paucimaculata*) were largely driven by fluctuations in water levels that altered the availability of suitable habitat (Whiting *et al*. 1997). Whitaker and Shine (2003) noted that movements of Eastern Brown Snakes (*Pseudonaja textilis*) were likely driven by prey availability. Mean distances travelled by adults at Molega Lake in 2008 were considerably lower than in 2007, indicating annual variation in movements. Because the lakeshore wetland environment of ribbonsnakes is highly dynamic, it is possible that the extent of movements changes with changing water levels and availability of suitable habitat or prey (e.g., small amphibians and minnows; Carpenter 1952; Bell *et al.* 2007).

The cryptic behaviour of Eastern Ribbonsnakes and the densely vegetated wetland habitats with which the species is associated make the species difficult to study. Although large movements have been documented, it is unknown how frequently these movements occur and what changes in the environment trigger them. Given the species' current conservation status as threatened in Nova Scotia, special concern in Ontario, and declining in several states in the United States (Harding 1997; COSEWIC 2002), we recommend that future work determine the frequency and trigger for large movements and assess the risk of mortality of individuals undertaking these movements to aid recovery planning.

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