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Demography of the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Illinois

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EXECUTIVE SUMMARY

- We have searched suitable Eastern Massasauga habitat in the Carlyle Lake region for 1,919 hours since 1999 and recorded 784 Eastern Massasauga captures.
- We have made 483 captures at South Shore State Park, 231 at Eldon Hazlet State Park, and 70 on U.S. Army Corps of Engineers properties.
- The Carlyle Lake region maintains a large number of Eastern Massasauga hibernacula and remains the only region in Illinois where the species can be readily captured in large numbers.
- Our population estimates for South Shore State Park revealed the population is comprised of a few individuals but the estimate does increase when including the breeding season.
- We detected no increasing or decreasing trend in the population size of the South Shore State Park and Field #3 hibernacula.
- Across all years only one year had a bias in operational sex ratios (2001 at South Shore State Park) but the percent of adult females varied from 22.2% to 69.6%.
- We found that 61.4% of the variation in operational sex ratios was due to demographic factors, whereas 38.6% was due to environmental factors. These results were similar region-wide.
- We observed no temporal linear trend in sex ratios.
- We found the average annual percentage of gravid females at South Shore State Park was low at 19.1% of the adult females captured. The results for the pooled remainder of the region were higher at 30.8%.
- Our data suggests a cyclical trend representing a biennial or triennial female breeding cycle.
- We estimated that 26.8% of the annual variation in the proportion of gravid females was due to demographic factors, whereas 73.2% was due to environmental factors at South Shore State Park and these numbers were similar for the data pooled for the remainder of the region.
- Since 1999, we have obtained litter size data for 19 females and have recorded 133 live young with 54 of those being female and 75 being male offspring.
- Litter size averaged 7 offspring with no overall bias in the sex ratio of offspring.
- We estimated that 52.4% of the variation in the proportion of female offspring was due to demographic factors and 47.6% was due to environmental factors.
- We obtained survival estimates for both sexes and all three stage classes but they varied greatly depending on the model chosen. Across models neonates (age 0) had the lowest survival rates, juveniles (age 1) had intermediate survival rates, and adults (age 2+) had the highest survival rates.
- Using overlap in core home range area coupled with population estimates we suspect the carrying capacity of South Shore State Park should fall between 116 – 233 individuals.

INTRODUCTION

Detailed study of declining populations is vital for proper management and conservation. In particular, demographic information such as birth rates, death rates, immigration and emigration, are invaluable for conservation efforts. Although the acquisition of detailed demographic data is expensive and requires long-term commitments, the benefits of the data collected far outweighs the costs of obtaining it. Detailed demographic data allows more precision in conservation strategies, focusing on areas which will have the maximum conservation benefit. The importance of long-term ecological studies is exemplified when attempting to understand how a species interacts with its environment. Data gathered under such a framework documents variation in life history and ecological parameters, both of which are necessary when guiding conservation of rare or declining species. Typically of interest are the basic life history traits of 1) age at maturity, 2) number, size, and sex ratio of offspring, 3) age- or size-specific reproductive investment, and 4) age- or size-specific mortality schedules. However, organismal populations are far from deterministic and are subject to stochasticity both from the environment and inherent in their demography, thus long-term studies are a necessity to capture the variation in life history traits. In addition, coupling the aforementioned life history traits and their respective variation with ecological parameters such as population size, sex ratios, carrying capacity, and density dependence, provides the foundation for population viability analysis (PVA). Using 12 years of demographic data collected on the Eastern Massasauga (*Sistrurus catenatus catenatus*) at Carlyle Lake, we estimated the parameters and their variation necessary to conduct a baseline PVA.

OBJECTIVES

The objectives of this study were to summarize the existing data collected on the Eastern Massasauga at Carlyle Lake, Illinois from 1999-2010 to estimate vital rates necessary for a subsequent PVA. Specifically our objectives were to:

1. Determine population size and estimate if a temporal trend exists.
2. Calculate the overall and operational sex ratios, determine if there were biases, partition the variation into demographic and environmental components, and determine if there was a temporal trend.
3. Calculate the proportion of reproductive females, determine if there were biases, partition the variation into demographic and environmental components, and determine if there was a temporal trend.
4. Calculate mean litter size, determine if offspring sex ratios were biased and the proportion of variation in offspring sex ratios due to demographic and environmental factors.
5. Estimate the annual survival rates for males and females.
6. Derive a method to determine carrying capacity for the South Shore population.

CONSERVATION STATUS

At the time of European settlement, the Eastern Massasauga *(Sistrurus catenatus catenatu*s) was found throughout the northern two-thirds of Illinois. There are accounts of early travelers and farmers encountering 20 or more in a single season (Hay, 1893). As early as 1866, however, the Eastern Massasauga was noted as declining (Atkinson and Netting, 1927). Through subsequent years, habitat destruction and outright persecution reduced the Illinois range of the Eastern Massasauga to a few widely scattered populations. Of the 24 localities Smith (1961) listed, only five may remain extant (Phillips *et al.,* 1999) and abundance estimates at all but one are less than 50 individuals (Anton, 1999; Wilson and Mauger, 1999). The exception is within the Carlyle Lake region. A cooperative effort between Illinois Department of Natural Resources (IDNR) and the U. S. Army Corps of Engineers (COE) resulted in approximately 30 reports of the Eastern Massasaugas between 1991 and 1998 (S. Ballard, pers. com.). Most of these reports were associated with mowing and a few were the result of road mortality or incidental encounters with park personnel and visitors. In 1994, the Eastern Massasauga was listed as endangered in Illinois, which resulted in increased interest in the conservation of the species. Currently fewer than 3 known populations may remain extant in Illinois and only some populations in the Carlyle Lake region may be viable in the long-term.

STUDY SITES

Carlyle Lake is the largest manmade reservoir in Illinois (26,000 acres) with 11,000 acres of public lands. The lake is an impoundment of the Kaskaskia River constructed by the (COE) in June 1967. The lake is bordered by state and federally managed lands, but public land is limited to less than a mile wide in some areas. Many of the surrounding parks and recreation areas provide camping, swimming, boat access, hunting, fishing, and hiking trails. The lake can be divided into four study sites based on the main recreation areas and surrounding property. Eldon Hazlet State Park (EHSP, ca. 3,000 acres) is located at the southern end of the west side of the lake and receives over 750,000 visitors annually with campsites, boat access, hiking trails, and lakefront cottages. South Shore State Park (SSSP, ca. three miles long) is located on the southeast side of the lake across from EHSP. The COE managed spillway areas of Dam East Recreation Area and Dam West Recreation Area. Over the years we have surveyed other COE sites including: Coles Creek Access Area, James Hawn Access Area, Carrigan Access Area, Massasauga Parking Lot, Point One, and Mourning Dove Parking Lot.

MATERIALS AND METHODS

GENERAL SURVEYS.– We captured snakes by conducting visual encounter surveys (VES) in appropriate habitat during the spring egress. We also took advantage of snakes encountered by COE or IDNR staff or the public. Most snakes were processed within a day of encounter, but in some instances, individuals were held longer. All snakes captured were released at their site of capture. Salvaged snakes were preserved in formalin and vouchered in the Illinois Natural History Survey Amphibian and Reptile Collection (see Appendix I).

DATA COLLECTION.– Live captures were divided into initial captures, within-year recaptures, and between-year recaptures. For initial captures and recaptures greater than 30 days since their previous capture, we recorded: sex (using cloacal probing), maturity (see below), snout-vent length (SVL) and tail length with a flexible tape (to the nearest mm), number of subcaudal scales (SSC), and mass with Pesola ® pull spring scales or an Ohaus ® electronic balance (to the nearest gram). We identified individuals by painting rattle segments, injecting a PIT tag subcutaneously, and photographing the body pattern. Rattle painting was not permanent, but allowed identification of individuals from a distance to minimize disturbance.

POPULATION ESTIMATION.– We estimated population size three ways using both closed and open population estimation methods. First, we used the Schumacher-Eschmeyer (Schumacher and Eschmeyer, 1943) and Schnabel (1938) closed population models for all spring surveys from 1999-2010. We tested the assumptions of equal catchability and population closure for each using the regression techniques outlines in Krebs (1989). We also calculated the 95% C.I. for each spring estimates and used percent relative precision (Greenwood, 1996) to determine which of the two models yielded the more precise estimate. Next, we calculated open population estimates using Jolly-Seber-Cormack models (Cooch and White, 2006) for captures during the spring census period and for the entire season combined. Again, we calculated confidence intervals of population estimates. All population estimates were then graphically represented and for each hibernacula and estimation we performed linear regression to determine the overall trend from 1999-2010. A positive slope indicates the population is growing, a negative indicates decline, and no significant difference in the slope indicates the population is stable.

SEX RATIOS.– We classified adults based on the following minimum sizes of known mature individuals: females $\geq$ 50.1 cm SVL and males $\geq$ 46.0 cm SVL. We then calculated the adult sex ratios per year per site where we had sufficient data. All sites that were lacking sufficient samples sizes were pooled. Next we performed χ^2 Goodness-of-fit tests to determine if sex ratios deviated from equality in any year at any site. We partitioned the variance into environmental and demographic components following Akçakaya (2002). Finally, we used linear regression to determine if a linear temporal trend existed in sex ratios.

PROPORTION OF REPRODUCTIVE FEMALES.– Do determine whether a female was gravid or not in spring censuses we used a combined method of manual palpation to feel for enlarge follicles and visual inspection of the girth of the rear third of the body. Although this method is not 100% accurate it is the best field method and has been used in numerous other studies. We then calculated the number of gravid females in the total sample of adult females per year and per site where we had sufficient data. All sites that were lacking sufficient samples sizes were pooled. We partitioned the variance into environmental and demographic components following Akçakaya (2002). Finally, to determine if there was a linear trend in proportion of gravid females, we used linear regression.

OFFPSRING NUMBER AND SEX RATIOS.– We captured gravid females late in the gestation period in July and brought them into captivity for parturition. Once females gave birth, we recorded the number of live offspring, stillborn, and unfertilized ova. We then calculated the mean and standard deviation for all litters. In addition, we determined the sex of offpsring to examine sex ratios at birth. To determine if there was a bias in offspring sex ratio we performed a χ^2

Goodness-of-fit test. Finally, we partitioned the variance into environmental and demographic components following Akçakaya (2002).

SURVIVAL.– We estimated survival based on the entire mark/recapture data set consisting of capture histories from 1999-2009 for *S. c. catenatus*. We constructed individual capture histories by only counting one capture of individuals during the annual census period. Because rattlesnake ecology varies by sex and stage, we included both in the data set as covariates. We modeled survival using three methods, Jolly-Seber-Cormack models, Pradel models, and a Bayesian missing data structure model with MCMC sampling. Jolly-Seber-Cormack and Pradel models were run in program Mark (Cooch and White 2006**)** whereas the Bayseian MCMC model was written and run in the R programming language. We ran all models to convergence with Markov Chains and once convergence was achieved, the burn-in period was discarded and sampling was initiated. MCMC monitors were used to determine appropriate thinning, and each chain was run for a sufficient length after burn-in to insure a suitably large sample from the posterior distribution.

CARRYING CAPACITY.– To estimate carrying capacity we used previously derived home range estimates and the area of grassland habitat present around the SSSP population. We chose the area of the 50% kernel density isopleths averaged over all individuals radio-tracked during a previous study (0.22 ha; Dreslik 2005). We then assumed that home ranges may overlap among individuals along a gradient from 0% - 99% overlap. We then calculated the number of individuals that could then occupy the SSSP site along this gradient given the amount of available grassland habitat present (25.2 ha).

RESULTS AND DISCUSSION

GENERAL SURVEYS.– Since beginning the study in 1999 we have searched sites around Carlyle Lake for 1,919 hours and made 784 Eastern Massasauga captures (Table 1). The bulk of the effort has been placed at the main hibernacula at SSSP which has resulted in 483 captures in 1,191 search hours (Table 1). The second most surveyed region was EHSP with 231 captures in 551 search hours (Table 1). Finally, we had surveyed COE properties and made 70 captures in 176 search hours (Table 1). Although search effort and the number of encounters are variable per year, the Carlyle Lake region maintains a large number of hibernacula for Eastern Massasaugas and remains the only area in the state where the species can be captured in large numbers.

POPULATION ESTIMATION.– We validated the assumptions of equal catchability and population closure for all spring censuses (Table 2; Figure 1). We did not have sufficient recaptures to calculate closed population estimates for the majority of the hibernacula and for SSSP in 2004 and 2007 (Table 3). In all instances, the Schumacher-Eschmeyer estimator gave more precise estimates for each year compared to the Schnabel estimator (Table 3), thus for closed population estimators we will use the Schumacher-Eschmeyer. When using open population estimators we were able to calculate population size for EHSP Field #3 and for 2004 and 2007 at SSSP (Table 4; Figure 2). Results for spring captures only at SSSP were much lower than population size estimated derived from captures throughout the season (Table 4). This is most likely because conducting population estimation at spring emergence does not account for the additional influx of reproduction as does happen when data from the entire year are used. However, the spring estimates are more accurate, in that, they reflect annual survival and represent the number of individuals the population begins each annual cycle with. Regardless of the method used the trend for the SSSP population show peaks and troughs (Table 4; Figure 2). Population sizes for EHSP Field #3 are disconcertingly low and seemed to have peaked in 2007 (Table 4; Figure 2). The final step for determining population size will be to analyze the data using robust models (closed population estimates within years and open population estimates between years).

We detected no linear trend in the long-term population estimates for SSSP using the closed estimates during the spring censuses (Figure 3; $r^2 = 0.193$, $p = 0.204$), open estimates during emergence (Figure 3; $r^2 = 0.003$, $p = 0.860$), or open estimates for the full active season (Figure 3; $r^2 = 0.115$, $p = 0.307$). Thus the population at SSSP has remained stable during the last 12 years, albeit small. We also did not detect a trend in population size for EHSP Field #3 (Figure 3; $r^2 = 0.211$, $p = 0.214$) and it has also remained stable but small.

SEX RATIOS.– Across all years at SSSP we detected one year where the operational sex ratio was biased, 2001 (Table 5). Otherwise, both the overall and operational sex ratios were in equality (Table 5). Since 1999, we recorded 253 adult Eastern Massasaugas at SSSP and of those, 129 were females (Table 6). On an annual basis the percent of adult females in the population ranged from 27.3% to 69.6% but averaged 51.0% (Table 6). We found that 61.4% of the variation in operational sex ratios was demographic, whereas 38.6% was environmental (Table 6). Finally, across years the percentage of females in the population fluctuated but there was no linear trend over time (Figure 4; $r^2 = 0.01$, $p = 0.823$).

Because we lacked the robust numbers for other sites we pooled those data to determine if trends for all other sites were similar to what we observed at SSSP. We recorded no bias in either the overall or operational sex ratios across years for all other sites (Table 5). Since 1999, we recorded 280 adult Eastern Massasaugas at all other sites and of those, 145 were females (Table 6). On an annual basis the proportion of adult females in the population ranged from 22.2% - 68.2% but averaged 52.0% (Table 6). Similar to SSSP, we found that 61.0% of the variation in operational sex ratios was demographic, whereas 39.0% was environmental (Table 6). Although the percentage of adult females varied across years similar to SSSP, this fluctuation was more cyclical than linear (Table 6; $r^2 = 0.02$, $p = 0.691$).

Thus, the patterns in sex ratio fluctuations and the amount of variation due to demographic and environmental factors appear to be region-wide. Additionally, the populations within the region appear to have equal sex ratios, however, caution must be observed when interpreting this result. It is possible that smaller populations could show a bias in sex ratios, but that bias is masked by pooling the data for analysis. Our results do show that the largest population at SSSP at least has equal overall and operational sex ratios.

PROPORTION OF REPRODUCTIVE FEMALES.– Similar to the sex ratio data we were able to compile and analyze the number of reproductive females for SSSP but we had to pool the data for the remainder of sites. At SSSP, of the 215 times females were assessed for their reproductive condition we recorded them gravid 41 times (Table 7). This resulted in 19.1% of the females being gravid per year with a range from 0% - 61.1% (Table 7). We found that 26.8%

of variation in the proportion of gravid females was demographic, whereas 73.2% was environmental (Table 7). The annual pattern of the proportion of gravid females in the populations was cyclical with peaks every 2-3 years suggesting a reproductive cycle of biennial to triennial (Figure 5).

When we pooled all other sites, of the 210 times females were assessed for their reproductive condition we recorded them gravid 61 times (Table 7). This resulted in 30.8% of the females being gravid per year with a range of 0% - 54.6% (Table 7). Similar to the data for SSSP, we found most of the variation was environmental (61.9%) rather than demographic (38.1%). Finally, we observed a similar trend in the proportion of gravid females at all other sites, with periods resulting in either a biennial or triennial breeding cycle (Figure 5).

Region-wide the annual proportion of gravid females is low, with some years showing minimal or no detectable potential for recruitment. With much of the variation being environmental this is possibly a life history characteristic that can be targeted for management by improving resources, specifically managing the primary prey base (small mammals). This could offer additional energetic resources per individual that could be directed toward reproduction.

OFFSPRING NUMBER AND SEX RATIOS.– Because gravid females are difficult to detect and capture during gestation, we had to pool all of our litter size data across all years and sites. We have litter size data for 19 females that birthed in captivity since 1999 (Table 8). Across those 19 females, we documented 133 live young with 54 of those being female and 75 being male offspring (Table 8). On average females gave birth to 7 offspring (Std.Dev. = 4.16) with a range of 1-15 (Table 8). Although there are apparent biases in offspring sex ratios within broods, the overall sex ratio of offspring produced was not biased ($\chi^2 = 3.42$, $p = 0.064$). When we examine the variation in the proportion of female offspring we found that 52.4% of the variation was demographic and 47.6% was environmental (Table 9).

SURVIVAL.– We obtained survival estimates for both sexes and all three stage classes. In essence the neonate stage class represent the transition between age 0-1, the juvenile from 1-2, and the adult 2+. Depending on the assumptions of the model chosen the values for annual survival probabilities vary greatly (Table 10). This is most likely due to different assumptions on how the fate of the terminal census is handled. Jolly-Seber-Cormack models are the strictest and assume the animal is dead at the terminal census if it is not captured (Cooch and White, 2006). Pradel models are somewhat different, in that, the terminal census is based on the probability the individual is present given the total capture history (Cooch and White, 2006). Finally, the Bayseian MCMC computes the probability an animal is alive during the terminal census based on detection probabilities.

With such variation in annual survival probabilities (e.g. male neonates range from 0.100 – 0.588) it is difficult to reach a consensus as to which one is accurate. Even when we take the harmonic mean of the three methods annual adult survival is still higher than expected from direct field observations. Thus we do not consider these estimates finalized. In the future we will continue to explore additional models and examine the specific assumptions of each model to determine which model best fits observation from the last 12 years of censuses.

CARRYING CAPACITY.– Depending on what we declare as the overlap in core home range area (50% kernel density isopleths) dictates how large the carrying capacity of a particular area of suitable habitat could be (Table 11). When we used SSSP as an example if we assumed core home range areas were spatio-temporally distinct, we would estimate carry capacity at 116 individuals (Table 11). Given the estimated population sizes for the site, we believe that carrying capacity would be near the lower end with values of no more that 50% overlap of the core home ranges. Such a range of overlap provides an estimated carrying capacity at SSSP between 116 – 233 individuals.

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TABLE 1: Survey effort for Eastern Massasaugas (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010 including the annual number of encounters (Enc.) and search effort at South Shore State Park (SSSP), Eldon Hazlet State Park (EHSP), and U. S. Army Corps of Engineers properties (COE).

	SSSP		**EHSP**		**COE**		**Total**	
Year	**Enc.**	**Hours**	**Enc.**	**Hours**	**Enc.**	**Hours**	**Enc.**	**Hours**
1999	56	113.75	----	------	----	------	56	113.75
2000	32	92.75	11	49.75	----	------	43	142.50
2001	47	95.81	35	75.79	14	55.91	96	227.51
2002	18	23.52	25	42.00	6	16.64	49	82.16
2003	56	110.67	0	0.42	0	7.12	56	118.21
2004	16	66.00	6	28.92	1	10.63	23	105.55
2005	38	83.37	22	39.02	0	0.57	60	122.96
2006	32	156.90	8	57.12	----	------	40	214.02
2007	22	94.88	30	130.12	34	42.8	86	267.80
2008	34	206.55	23	36.80	3	8.36	60	251.71
2009	86	103.78	60	70.70	2	7.5	148	181.98
2010	46	43.23	11	21.13	10	27.01	67	91.37
Totals	**483**	**1,191.21**	**231**	**551.77**	**70**	**176.54**	**784**	**1,919.52**

TABLE 2: Annual regression analyses testing the assumptions of equal catchability and population closure in Spring census for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010.

Year	r^2	Slope	*p*	*df*
1999	0.676	0.027	<0.001	11
2000	0.421	0.017	0.007	15
2001	0.673	0.031	0.001	10
2002	0.592	0.019	<0.001	32
2003	0.845	0.023	<0.001	17
2005	0.519	0.02	0.006	11
2006	0.619	0.044	0.001	12
2008	0.548	0.02	<0.001	19
2009	0.813	0.026	<0.001	20
2010	0.923	0.031	<0.001	9

TABLE 3: Annual closed population estimates using the Schnabel and Schumacher-Eschmeyer methods, 95% confidence intervals (95% C.I.), and percent relative precision of confidence intervals (PRP) for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010.

	Schnabel			Schumacher-Eschmeyer		
Year	**N**	**95% C.I.**	**PRP**	**N**	**95% C.I.**	**PRP**
1999	70	46, 150	74.66	69	46, 137	65.94
2000	60	32, 478	375.29	60	35, 195	133.3
2001	41	24, 124	122.44	34	24, 62	54.94
2002	66	45, 127	62.39	61	46, 90	35.45
2003	55	39, 95	44.92	51	39, 75	34.87
2004	-----	---------	-----	-----	----------	-----
2005	70	38, 416	270.14	60	36, 177	115.97
2006	29	16, 164	255.89	26	18, 50	62.64
2007	-----	---------	-----	-----	----------	-----
2008	74	42, 284	163.57	61	39, 132	76.02
2009	42	32, 62	35.91	43	35, 57	25.96
2010	35	24, 66	60.67	37	31, 46	19.86

TABLE 4: Annual open population estimates using Jolly-Seber-Cormack models for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Estimates are provided for South Shore State Park using spring census and all year captures and for Field #3 at Eldon Hazlet State Park using spring census captures.

	South Shore - Spring			South Shore - All			Field #3 - All		
Year	**N**	**95% C.I.**	**PRP**	**N**	**95% C.I.**	**PRP**	**N**	**95% C.I.**	**PRP**
2000	30	22, 37	23.99	156	124, 189	20.72	-----	----------	-----
2001	33	25, 41	24.03	330	274, 386	17.05	-----	----------	-----
2002	26	19, 33	26.53	309	259, 360	16.34	6	2, 11	72.65
2003	20	15, 25	24.58	116	93, 139	19.66	3	1, 4	62.55
2004	23	17, 30	27.77	64	47, 80	26.34	9	1, 17	86.98
2005	23	17, 30	27.79	113	88, 139	22.33	12	4, 20	69.91
2006	24	17, 30	28.52	66	49, 84	25.93	13	5, 22	64.04
2007	18	12, 23	30.84	181	146, 217	19.80	21	10, 33	55.50
2008	25	18, 32	27.82	162	131, 194	19.45	17	9, 26	49.33
2009	34	25, 43	25.20	211	172, 251	18.72	16	8, 25	52.52
2010	32	23, 42	29.33	114	88, 140	23.13	5	1, 11	118.55

TABLE 5: Annual results from χ^2 analyses of overall and operational sex ratios for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Significant deviations from equality are bolded.

		Year											
		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
South Shore													
Overall	χ^2	0.38	1.00	1.09	0.30	0.30	0.09	2.46	0.00	4.17	0.13	0.89	0.14
	p	0.537	0.317	0.297	0.586	0.586	0.763	0.117	1.000	0.041	0.724	0.345	0.705
Operational	χ^2	0.33	**6.82**	0.04	0.62	1.92	0.67	2.91	0.00	3.52	1.00	0.36	0.05
	p	0.564	**0.009**	0.847	0.433	0.166	0.414	0.088	1.000	0.061	0.317	0.549	0.819
All Other Sites													
Overall	χ^2	0.00	4.24	0.04	0.91	0.08	4.45	1.38	0.50	0.60	1.29	0.22	2.13
	p	1.000	0.040	0.846	0.339	0.782	0.035	0.239	0.480	0.439	0.257	0.639	0.144
Operational	χ^2	-------	2.79	3.07	2.50	0.11	2.78	1.19	0.50	0.61	0.00	0.57	2.91
	p	-------	0.095	0.080	0.114	0.739	0.096	0.275	0.480	0.435	1.000	0.450	0.088
All Sites													
Overall	χ^2	0.36	4.35	0.17	0.13	0.37	1.64	0.08	0.15	3.05	0.27	0.17	1.59
	p	0.546	0.037	0.684	0.719	0.541	0.201	0.782	0.695	0.081	0.606	0.683	0.208
Operational	χ^2	0.33	**9.29**	1.76	2.97	0.73	3.27	0.21	0.17	3.06	0.47	0.92	1.98
	p	0.564	**0.002**	0.185	0.085	0.394	0.071	0.647	0.683	0.080	0.493	0.336	0.160

TABLE 6: Annual variation in the operational sex ratios represented as the percent of females in the population for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Results are categorized using data from South Shore State Park and all other sites combined to provide the variance due to demographics and the environment.

	South Shore State Park						**All Other Sites**					
Year	**♀♀**	**♂♂**	**Total**	**%♀**	***p*(1-*p*)**		**♀♀**	**♂♂**	**Total**	**%♀**	***p*(1-*p*)**	
1999	15	12	27	55.6	0.2469	0.0563	----	----	----	--------	---------	---------
2000	9	24	33	27.3	0.1983	1.8560	10	19	29	34.5	0.2259	0.8682
2001	13	14	27	48.1	0.2497	0.0218	34	21	55	61.8	0.2360	0.5536
2002	15	11	26	57.7	0.2441	0.1169	25	15	40	62.5	0.2344	0.4592
2003	9	4	13	69.2	0.2130	0.4326	4	5	9	44.4	0.2469	0.0485
2004	2	4	6	33.3	0.2222	0.1870	2	7	9	22.2	0.1728	0.7866
2005	15	7	22	68.2	0.2169	0.6504	8	13	21	38.1	0.2358	0.3936
2006	8	8	16	50.0	0.2500	0.0016	3	5	8	37.5	0.2344	0.1633
2007	16	7	23	69.6	0.2117	0.7937	23	18	41	56.1	0.2463	0.0762
2008	6	10	16	37.5	0.2344	0.2911	9	9	18	50.0	0.2500	0.0057
2009	11	14	25	44.0	0.2464	0.1221	12	16	28	42.9	0.2449	0.2232
2010	10	9	19	52.6	0.2493	0.0051	15	7	22	68.2	0.2169	0.5914
Totals	**129**	**124**	**253**	**51.0**	**2.7830**	**4.5346**	**145**	**135**	**280**	**51.8**	**2.5444**	**4.1696**
Avg. Prop. of Females (Weighted)						**0.5099**					**0.5179**	
Total Var. of Prop. of Females (Weighted)						**0.0179**					**0.0149**	
Demographic Variance (Weighted)						**0.0110**					**0.0091**	
Environmental Variance						**0.0069**					**0.0058**	
% Demographic						**61.4%**					**61.0%**	
% Environmental						**38.6%**					**39.0%**	

TABLE 7: Annual variation in the number of gravid (G) and non-gravid (NG) females represented as the percent of reproductive (Gravid) females in the population for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Results are categorized using data from South Shore State Park and all other sites combined to provide the variance due to demographics and the environment.

	South Shore State Park						All Other Sites					
Year	**G**	**NG**	**Total**	**%G**	***p*(1-*p*)**		**G**	**NG**	**Total**	**%G**	***p*(1-*p*)**	
1999	1	19	20	5.0	0.0475	0.3959	0	1	1	0.0	0.0000	0.0929
2000	1	20	21	4.8	0.0454	0.4299	6	5	11	54.5	0.2479	0.6373
2001	6	13	19	31.6	0.2161	0.2973	23	31	54	42.6	0.2445	0.7928
2002	6	19	25	24.0	0.1824	0.0608	10	28	38	26.3	0.1939	0.0658
2003	3	16	19	15.8	0.1330	0.0204	0	6	6	0.0	0.0000	0.5573
2004	0	6	6	0.0	0.0000	0.2182	1	1	2	50.0	0.2500	0.0762
2005	11	7	18	61.1	0.2377	3.1815	2	7	9	22.2	0.1728	0.0613
2006	3	6	9	33.3	0.2222	0.1831	1	4	5	20.0	0.1600	0.0549
2007	4	13	17	23.5	0.1799	0.0338	7	26	33	21.2	0.1671	0.2832
2008	0	15	15	0.0	0.0000	0.5455	0	17	17	0.0	0.0000	1.5790
2009	3	28	31	9.7	0.0874	0.2735	6	13	19	31.6	0.2161	0.0023
2010	3	12	15	20.0	0.1600	0.0013	8	7	15	53.3	0.2489	0.7837
Totals	**41**	**174**	**215**	**19.1**	**1.5115**	**5.6412**	**64**	**146**	**210**	**30.5**	**1.9013**	**4.9865**
Avg. Prop. of Females (Weighted)						**0.1907**					**0.3048**	
Total Var. of Prop. of Females (Weighted)						**0.0262**					**0.0237**	
Demographic Variance (Weighted)						**0.0070**					**0.0091**	
Environmental Variance						**0.0192**					**0.0147**	
% Demographic						**26.8%**					**38.1%**	
% Environmental						**73.2%**					**61.9%**	

TABLE 8: Summary results of offspring output for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Results are categorized by the total number of live offspring bore as male, female and unknown (U) with the proportion of each sex per litter. In addition, total investment is accounted for by including the number of stillborn, partially developed (Part.Dev.) and unfertilized ova (Unfert.).

	Live Offspring						**Total Investment**			
Snake	**♀♀**	**♂♂**	**U**	**Total**	**%♀**	**%♂**	**Stillborn**	**Part.Dev.**	**Unfert.**	**Total**
35	0	9	0	9	0%	100%	0	0	2	11
131	0	1	0	1	0%	100%	1	0	0	2
132	2	6	0	8	25%	75%	0	0	0	8
162	8	4	0	12	67%	33%	0	0	0	12
174	2	3	0	5	40%	60%	0	0	0	5
192	1	6	0	7	14%	86%	1	0	2	10
113	3	6	0	9	33%	67%	0	0	0	9
164	1	1	0	2	50%	50%	0	0	1	3
306	0	3	0	3	0%	100%	0	0	1	4
335	0	2	0	2	0%	100%	2	3	3	7
458	4	0	0	4	100%	0%	0	0	0	4
617	3	5	0	8	38%	63%	0	0	0	8
624	4	6	0	10	40%	60%	0	0	0	10
687	2	0	1	3	67%	0%	0	0	3	6
540	6	3	0	9	22%	33%	0	0	0	9
554	4	10	0	14	14%	71%	0	0	0	14
588	8	7	0	15	47%	40%	0	0	0	15
615	6	3	0	9	56%	33%	0	0	0	9
703	0	0	3	3	0%	0%	1	0	4	8
Total	**54**	**75**	**4**	**133**			**5**	**3**	**16**	**154**
Mean	**2.84**	**3.95**	**0.21**	**7.00**	**0.35**	**0.56**	**0.26**	**0.16**	**0.84**	**8.11**
St.Dev.	**2.65**	**2.99**	**0.71**	**4.16**	**0.28**	**0.34**	**0.56**	**0.69**	**1.30**	**3.56**

TABLE 9: Annual variation in the sex ratio of offspring represented as the percent of females for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Results are summarized for the entire region to provide the variance due to demographic and environmental factors.

Year	**♀♀**	**♂♂**	**Total**	**%**	***p*(1-*p*)**	
2001	13	29	42	31.0	0.2137	0.2119
2002	4	12	16	25.0	0.1875	0.2727
2009	13	11	24	54.2	0.2483	0.6229
2010	24	23	47	51.1	0.2499	0.3981
Total	**54**	**75**	**129**	**41.9**	**0.8994**	**1.7161**
Avg. Prop. Of Females (Weighted)						**0.4186**
Total Var. of Prop. of Females (Weighted)						**0.0133**
Demographic Variance (Weighted)						**0.0070**
Environmental Variance						**0.0063**
% Demographic						**52.4%**
% Environmental						**47.6%**

TABLE 10: Annual survival probabilities and standard deviations derived from Eastern Massasauga capture histories during 1999 – 2010 census seasons at South Shore State Park, Clinton County, Illinois using three methods. Results are partitioned by model used (J-S-C = Jolly-Seber-Cormack) sex and stage class with the overall result being the harmonic mean of all three survival probability estimations.

	J-S-C		Pradel		Bayseian MCMH		Overall	
Sex/Stage	**Mean**	**Std.Dev.**	**Mean**	**Std.Dev.**	**Mean**	**Std.Dev.**	**Mean**	**Std.Dev.**
Male								
Neonate	0.145	0.101	0.100	0.072	0.588	0.248	0.161	0.108
Juvenile	0.600	0.070	0.586	0.069	0.785	0.173	0.645	0.087
Adult	0.870	0.025	0.859	0.026	0.911	0.083	0.879	0.033
Female								
Neonate	0.310	0.182	0.315	0.183	0.657	0.231	0.378	0.196
Juvenile	0.651	0.060	0.634	0.061	0.834	0.142	0.695	0.075
Adult	0.913	0.021	0.901	0.022	0.936	0.062	0.916	0.027

TABLE 11: Estimates of unique area occupied (ha), carrying capacity (*K*), and the equivalent estimate of habitat area increase with varying levels of core area overlap among individuals for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois. For the extrapolation the total amount of grassland are at South Shore State Park (25.6 ha) was divided by the mean 50% kernel density isopleths from past radio-telemetric studies (0.22ha) found in Dreslik (2005). This initial state represented no overlap in core areas occupied among individuals.

	Percent Core Area Overlap												
	99%	**98%**	**95%**	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**	**0%**
Unique Area	0.0022	0.0044	0.0110	0.0220	0.0440	0.0660	0.0880	0.1100	0.1320	0.1540	0.1760	0.1980	0.2200
Estimated K	11636	5818	2327	1164	582	388	291	233	194	166	145	129	116
Estimated Habitat Increase	9900%	4900%	1900%	900%	400%	233%	150%	100%	67%	43%	25%	11%	0%

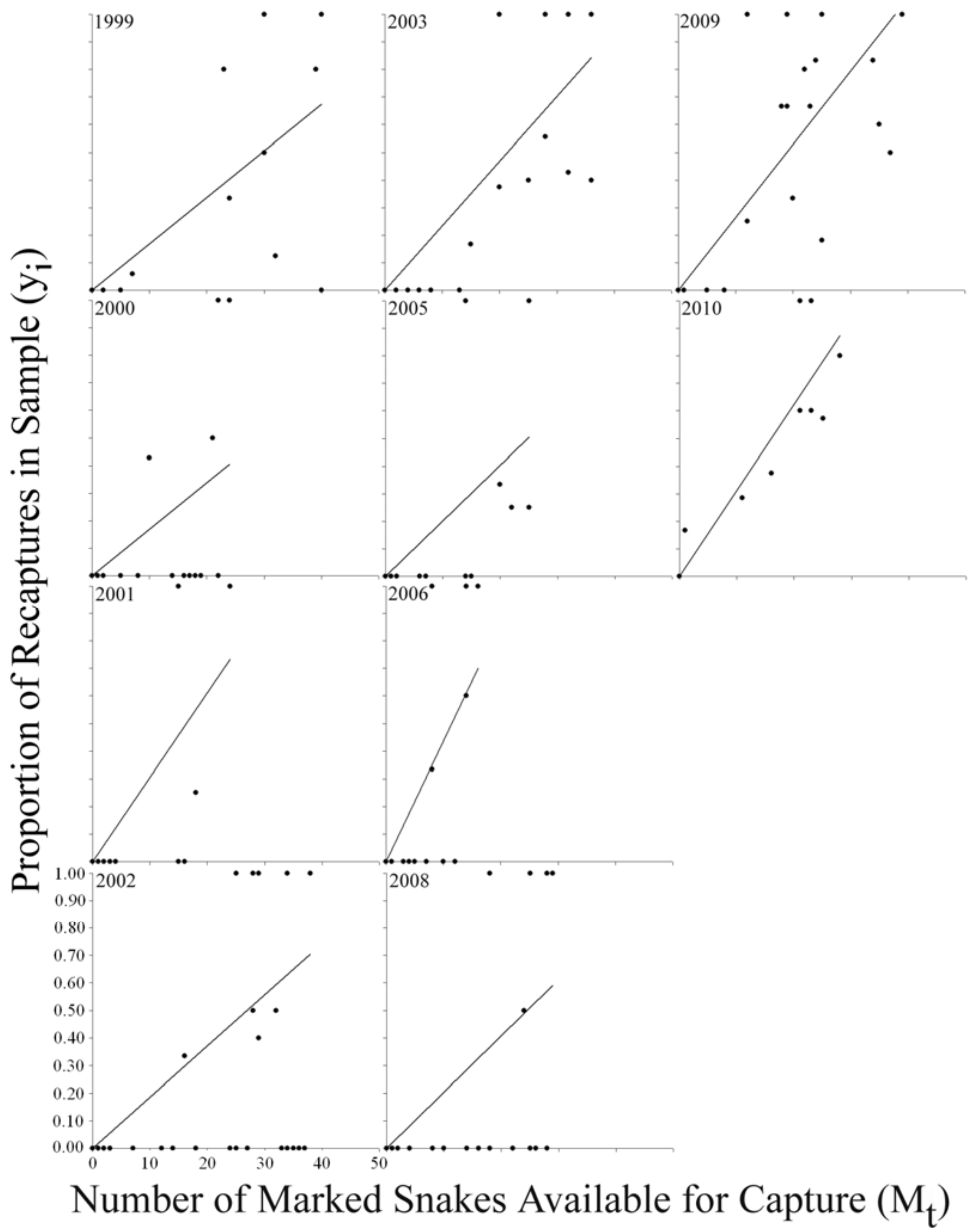

FIGURE 1: Linear regression plots of the proportion of recaptures in the sample and the number of marked snakes available for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010.

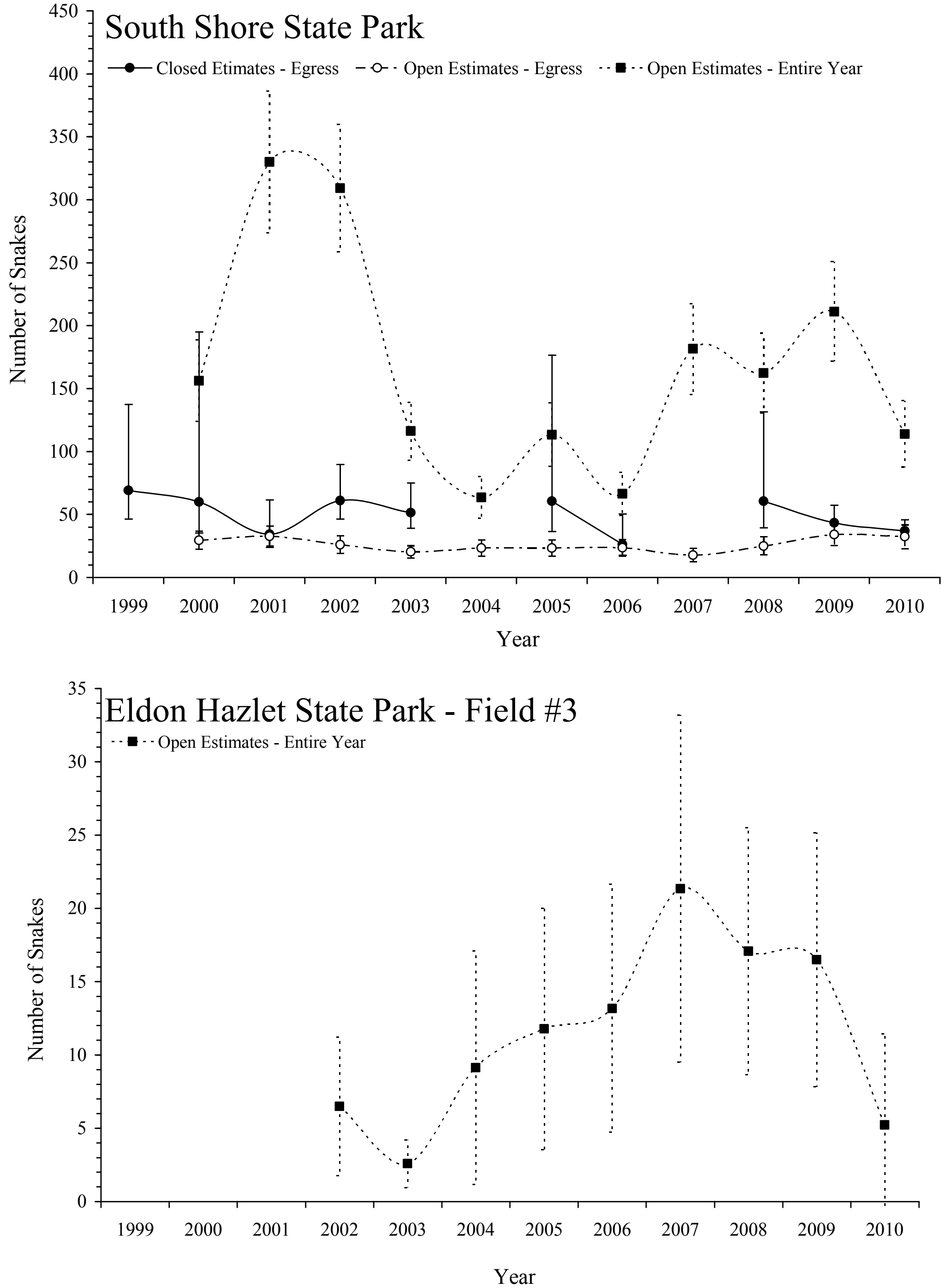

FIGURE 2: Annual estimates and 95% confidence intervals for the South Shore State Park and Field #3 - Eldon Hazlet State Park populations of the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. The graph for South Shore State Park includes the closed and open model estimates of population size whereas the graph for Field #3 includes only open population estimates from captures throughout the entire year.

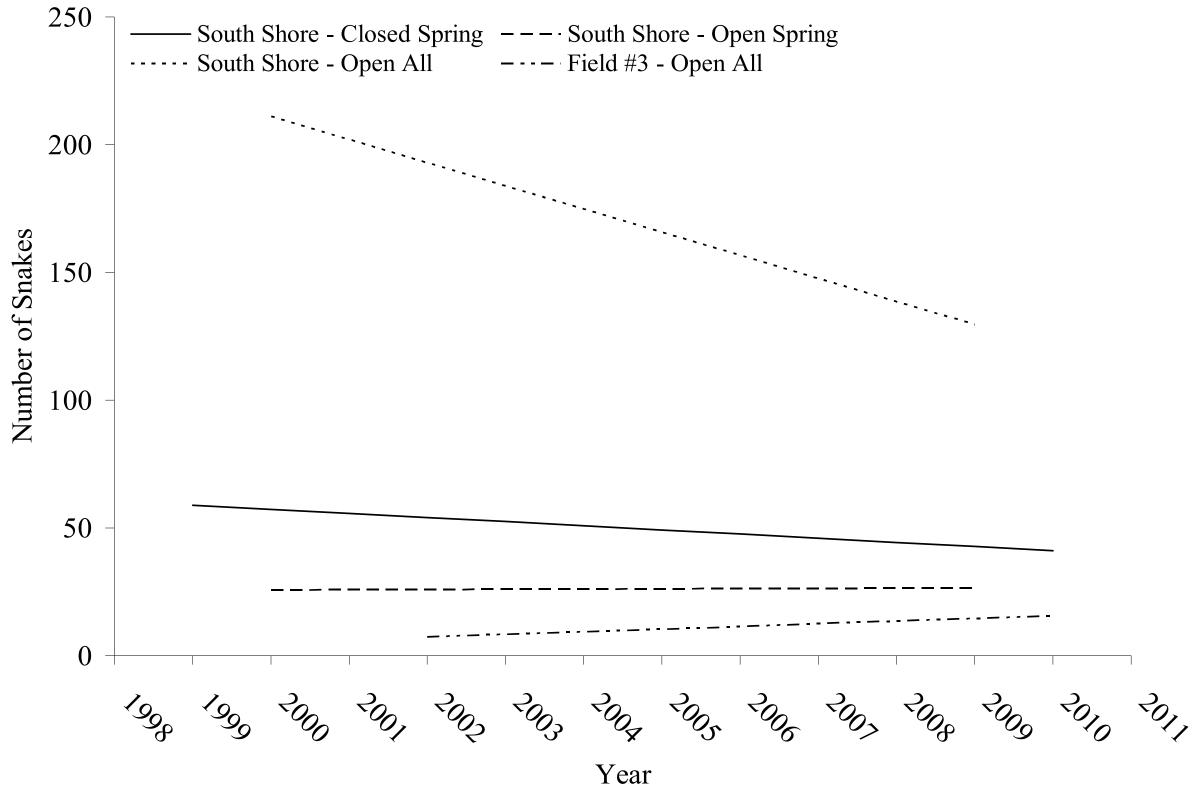

FIGURE 3: Linear regression plot of the population size versus year for all population estimates derived for the South Shore State Park and Field #3 - Eldon Hazlet State Park populations of the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010.

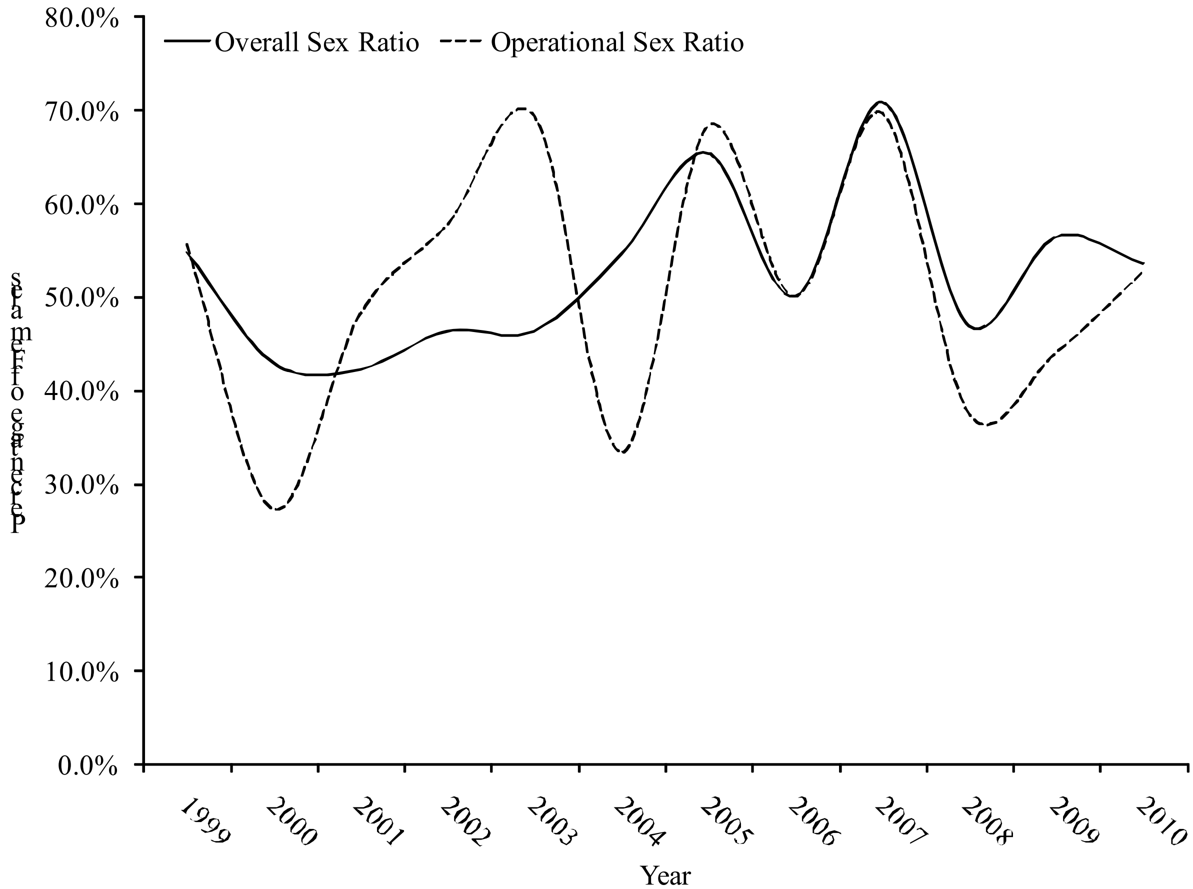

FIGURE 4: Plot of the overall and operational sex ratios with respect to the proportion of females in the population for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010.

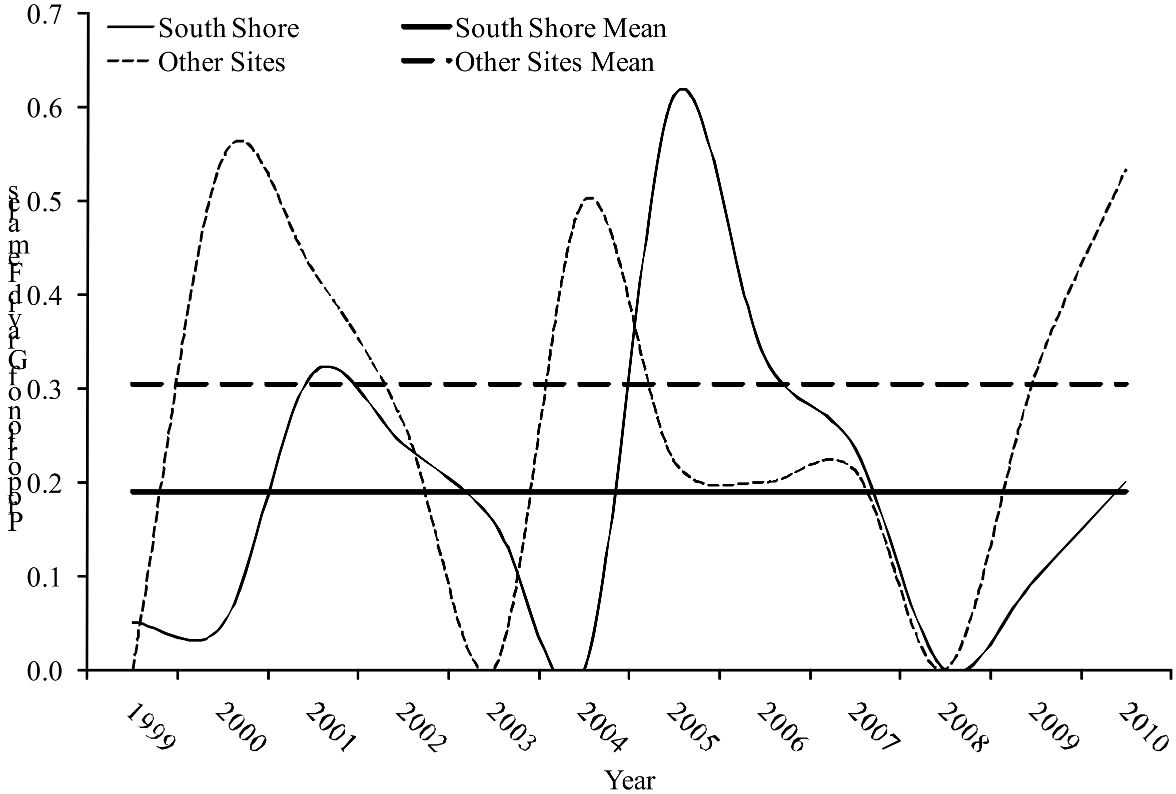

FIGURE 5: Plot of the proportion of reproductive (gravid) females over time and the mean value over the study for the Eastern Massasauga (*Sistrurus c. catenatus*) at Carlyle Lake, Clinton County, Illinois from 1999 – 2010. Results are summarized for South Shore State Park and all other sites combined.

APPENDIX I

Capture/recapture data for all Eastern Massasauga captured at South Shore State Park, Clinton County, Illinois from 1999 – 2010. Period = sampling day (time t), C_t = total snakes caught, R_t = total recaptures, U_t = total new snakes caught, M_t = total marked snakes available for capture.

1999

Date	Period	C_t	R_t	U_t	M_t
04/01/1999	1	2	0	2	0
04/04/1999	2	3	0	3	2
04/06/1999	3	2	0	2	5
04/07/1999	4	17	1	16	7
04/11/1999	5	5	4	1	23
04/13/1999	6	9	3	6	24
04/14/1999	7	1	1	0	30
04/19/1999	8	4	2	2	30
04/22/1999	9	8	1	7	32
04/29/1999	10	5	4	1	39
04/30/1999	11	2	0	2	40
05/04/1999	12	1	1	0	40
Overall	**12**	**59**	**17**	**42**	**40**

2000

Date	Period	C_t	R_t	U_t	M_t
03/29/2000	1	1	0	1	0
04/05/2000	2	1	0	1	1
04/12/2000	3	3	0	3	2
04/13/2000	4	3	0	3	5
04/14/2000	5	2	0	2	8
04/15/2000	6	7	3	4	10
04/16/2000	7	2	0	2	14
04/18/2000	8	1	0	1	16
04/19/2000	9	1	0	1	17
04/26/2000	10	1	0	1	18
04/28/2000	11	2	0	2	19
05/02/2000	12	2	1	1	21
05/04/2000	13	1	1	0	22
05/09/2000	14	2	0	2	22
05/17/2000	15	1	1	0	24
Overall	**15**	**30**	**6**	**24**	**24**

2001

Date	Period	C_t	R_t	U_t	M_t
03/23/2001	1	1	0	1	0
03/27/2001	2	1	0	1	1
04/02/2001	3	1	0	1	2
04/05/2001	4	1	0	1	3
04/06/2001	5	11	0	11	4
04/08/2001	6	1	1	0	15
04/10/2001	7	1	0	1	15
04/13/2001	8	2	0	2	16
04/22/2001	9	8	2	6	18
04/24/2001	10	4	4	0	24
04/25/2001	11	4	4	0	24
Overall	**11**	**35**	**11**	**24**	**24**

2002

Date	Period	C_t	R_t	U_t	M_t
04/01/2002	1	1	0	1	0
04/07/2002	2	1	0	1	1
04/08/2002	3	1	0	1	2
04/09/2002	4	4	0	4	3
04/11/2002	5	5	0	5	7
04/12/2002	6	2	0	2	12
04/13/2002	7	2	0	2	14
04/14/2002	8	3	1	2	16
04/16/2002	9	6	0	6	18
04/17/2002	10	1	0	1	24
04/18/2002	11	1	1	0	25
04/19/2002	12	2	0	2	25
04/20/2002	13	1	0	1	27
04/21/2002	14	1	1	0	28
04/22/2002	15	1	1	0	28
04/23/2002	16	1	1	0	28
04/24/2002	17	1	1	0	28
04/25/2002	18	2	1	1	28

2002 (Cont.)

Date	Period	C_t	R_t	U_t	M_t
04/28/2002	19	1	1	0	29
04/29/2002	20	1	1	0	29
04/30/2002	21	1	1	0	29
05/01/2002	22	1	1	0	29
05/02/2002	23	5	2	3	29
05/03/2002	24	2	1	1	32
05/04/2002	25	1	0	1	33
05/07/2002	26	1	1	0	34
05/08/2002	27	1	1	0	34
05/09/2002	28	1	1	0	34
05/11/2002	29	1	0	1	34
05/13/2002	30	1	0	1	35
05/19/2002	31	1	0	1	36
05/20/2002	32	1	0	1	37
05/24/2002	33	1	1	0	38
Overall	**33**	**56**	**18**	**38**	**38**

2003

Date	Period	C_t	R_t	U_t	M_t
03/15/2003	1	2	0	2	0
03/17/2003	2	2	0	2	2
03/20/2003	3	2	0	2	4
03/22/2003	4	2	0	2	6
03/23/2003	5	5	0	5	8
03/24/2003	6	2	0	2	13
03/26/2003	7	6	1	5	15
03/31/2003	8	1	1	0	20
04/01/2003	9	8	3	5	20
04/02/2003	10	5	2	3	25
04/03/2003	11	2	2	0	28
04/04/2003	12	9	5	4	28
04/10/2003	13	2	2	0	32
04/11/2003	14	7	3	4	32
04/12/2003	15	5	2	3	36
04/13/2003	16	1	1	0	36
04/15/2003	17	3	3	0	36
04/26/2003	18	1	1	0	36
Overall	**18**	**65**	**26**	**39**	**36**

2004

Date	Period	C_t	R_t	U_t	M_t
03/17/2004	1	1	0	1	0
03/18/2004	2	1	0	1	1
03/29/2004	3	5	0	5	1
04/02/2004	4	2	1	1	6
04/03/2004	5	1	0	1	2
04/05/2004	6	2	1	1	3
04/08/2004	7	1	0	1	3
Overall	**7**	**13**	**2**	**11**	**6**

2005

Date	Period	C_t	R_t	U_t	M_t
03/30/2005	1	1	0	1	0
03/31/2005	2	1	0	1	1
04/02/2005	3	4	0	4	2
04/03/2005	4	1	0	1	6
04/04/2005	5	7	0	7	7
04/05/2005	6	1	1	0	14
04/07/2005	7	1	0	1	14
04/08/2005	8	5	0	5	15
04/09/2005	9	3	1	2	20
04/14/2005	10	4	1	3	22
04/15/2005	11	3	3	0	25
04/16/2005	12	4	1	3	25
Overall	**12**	**35**	**7**	**28**	**25**

2006

Date	Period	C_t	R_t	U_t	M_t
03/26/2006	2	2	0	2	1
03/30/2006	3	1	0	1	3
03/31/2006	4	1	0	1	4
04/01/2006	5	2	0	2	5
04/05/2006	6	1	0	1	7
04/06/2006	7	1	1	0	8
04/07/2006	8	3	1	2	8
04/09/2006	9	2	0	2	10

2006 (Cont.)

Date	Period	C_t	R_t	U_t	M_t
04/10/2006	10	2	0	2	12
04/11/2006	11	1	1	0	14
04/15/2006	12	5	3	2	14
04/16/2006	13	1	1	0	16
Overall	**13**	**23**	**7**	**16**	**16**

2007

Date	Period	C_t	R_t	U_t	M_t
03/13/2007	1	2	0	2	0
03/14/2007	2	1	0	1	2
03/24/2007	3	4	0	4	3
03/25/2007	4	2	0	2	7
03/26/2007	5	2	0	2	9
03/29/2007	6	3	0	3	11
03/30/2007	7	1	0	1	14
03/31/2007	8	3	0	3	15
04/02/2007	9	1	0	1	18
04/03/2007	10	1	0	1	19
04/22/2007	11	1	0	1	20
04/23/2007	12	1	0	1	21
04/24/2007	13	2	0	2	22
Overall	**13**	**24**	**0**	**24**	**22**

2008

Date	Period	C_t	R_t	U_t	M_t
03/14/2008	1	1	0	1	0
03/25/2008	2	1	0	1	1
04/05/2008	3	2	0	2	2
04/11/2008	4	4	0	4	4
04/15/2008	5	2	0	2	8
04/17/2008	6	4	0	4	10
04/18/2008	7	2	0	2	14
04/20/2008	8	2	0	2	16
04/21/2008	9	1	1	0	18
04/24/2008	10	4	0	4	18

2008 (Cont.)

Date	Period	C_t	R_t	U_t	M_t
04/25/2008	11	2	0	2	22
04/26/2008	12	2	1	1	24
04/30/2008	13	1	1	0	25
05/10/2008	14	1	0	1	25
05/16/2008	15	2	0	2	26
05/20/2008	16	2	2	0	28
05/21/2008	17	1	1	0	28
05/22/2008	18	1	1	0	28
05/23/2008	19	1	0	1	28
05/25/2008	20	1	1	0	29
Overall	**20**	**37**	**8**	**29**	**29**

2009

Date	Period	C_t	R_t	U_t	M_t
03/07/2009	1	1	0	1	0
03/16/2009	2	4	0	4	1
03/17/2009	3	3	0	3	5
03/18/2009	4	4	0	4	8
03/22/2009	5	1	1	0	12
03/23/2009	6	8	2	6	12
03/24/2009	7	3	2	1	18
03/25/2009	8	2	2	0	19
03/26/2009	9	3	3	0	19
04/01/2009	10	3	2	1	19
04/03/2009	11	3	1	2	20
04/04/2009	12	5	4	1	22
04/15/2009	13	3	2	1	23
04/16/2009	14	6	5	1	24
04/17/2009	15	2	2	0	25
04/18/2009	16	11	2	9	25
04/22/2009	17	6	5	1	34
04/23/2009	18	5	3	2	35
04/25/2009	19	4	2	2	37
04/29/2009	20	3	3	0	39
04/30/2009	21	1	1	0	39
Overall	**21**	**81**	**42**	**39**	**39**

2010

Date	Period	C_t	R_t	U_t	M_t
03/15/2010	1	1	0	1	0
03/16/2010	2	12	2	10	1
03/18/2010	3	7	2	5	11
03/19/2010	4	8	3	5	16
03/23/2010	5	1	1	0	21
03/24/2010	6	5	3	2	21
03/29/2010	7	1	1	0	23
03/30/2010	8	5	3	2	23
03/31/2010	9	7	4	3	25
04/02/2010	10	5	4	1	28
Overall	**10**	**52**	**23**	**29**	**28**

APPENDIX II

Jolly-Seber-Cormack Method B tables for Eastern Massasauga capture/recapture data.

South Shore State Park - Spring Captures - Method B Table

Time of Last Capture	Time of Recapture											
	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1999		9	4	1	0	0	0	0	0	0	0	0
2000			9	0	0	0	0	0	0	0	0	0
2001				9	1	0	0	0	0	0	0	0
2002					10	1	1	0	0	0	0	0
2003						3	4	1	0	0	0	0
2004							2	2	0	0	0	0
2005								3	1	1	1	0
2006									4	1	0	0
2007										3	4	0
2008											7	2
2009												13
2010												
Marked	**0**	**9**	**13**	**10**	**11**	**4**	**7**	**6**	**5**	**5**	**12**	**15**
Unmarked	**16**	**8**	**10**	**8**	**3**	**7**	**7**	**8**	**5**	**8**	**10**	**5**
Caught	**16**	**17**	**23**	**18**	**14**	**11**	**14**	**14**	**10**	**13**	**22**	**20**
Released	**16**	**17**	**23**	**18**	**14**	**11**	**14**	**14**	**10**	**13**	**22**	**20**

South Shore State Park - All Captures - Method B Table

Time of Last Capture	Time of Recapture											
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1999		9	4	1	0	0	0	0	0	0	0	0
2000			18	5	0	0	0	0	0	0	0	0
2001				43	3	1	0	0	0	0	0	0
2002					33	2	2	1	0	0	0	0
2003						5	6	1	0	0	1	0
2004							7	2	0	0	0	0
2005								7	3	1	2	0
2006									9	3	1	0
2007										12	10	2
2008											14	2
2009												26
2010												
Marked	**0**	**9**	**22**	**49**	**36**	**8**	**15**	**11**	**12**	**16**	**28**	**30**
Unmarked	**45**	**61**	**130**	**102**	**22**	**15**	**37**	**17**	**68**	**50**	**71**	**22**
Caught	**45**	**70**	**152**	**151**	**58**	**23**	**52**	**28**	**80**	**66**	**99**	**52**
Released	**45**	**70**	**152**	**151**	**58**	**23**	**52**	**28**	**80**	**66**	**99**	**52**

Eldon Hazlet State Park - Field #3 - All Captures - Method B Table

Time of Last Capture	Time of Recapture 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
2001		3	0	0	0	0	0	0	0	0
2002			1	0	1	0	0	0	0	0
2003				0	0	0	0	0	0	0
2004					2	0	0	0	0	0
2005						1	2	0	1	0
2006							2	0	1	0
2008								1	4	1
2009									1	0
2010										1
Marked	**0**	**3**	**1**	**0**	**3**	**1**	**4**	**1**	**7**	**2**
Unmarked	**4**	**1**	**0**	**3**	**3**	**3**	**5**	**2**	**1**	**0**
Caught	**4**	**4**	**1**	**3**	**6**	**4**	**9**	**3**	**8**	**2**
Released	**4**	**4**	**1**	**3**	**6**	**4**	**9**	**3**	**8**	**2**