Preliminary morphometrics, growth, and natural history observations of the short-headed garter snake, *Thamnophis brachystoma* at two urban sites in Erie County, Pennsylvania, USA

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ABSTRACT - We used mark-recapture techniques to study the short-headed garter snake, *Thamnophis brachystoma* at two urban sites (Shannon Road and McClelland Park) in Erie County, Pennsylvania, USA. Mean snout-vent length (SVL) and weight was greater in females than males regardless of age class; whereas relative to total length, tail length was consistently greater in males than in females. Sex ratios did not differ significantly from 1:1 regardless of age-class. At Shannon Road, adults significantly outnumbered juveniles 3.3 to 1. While at McClelland Park, juveniles (N = 63) were nearly twice as numerous as adults (N = 31). Data regarding estimated growth are also reported. The results of the present study conform to previously published data from populations in Pennsylvania and a population near Olean, New York.

INTRODUCTION

The short-headed garter snake, *Thamnophis brachystoma* (Fig. 1) is relatively small with a recorded maximum length of 578 mm (Lethaby, 2004). It is found primarily in early successional habitats in the Allegheny High Plateau of north-western Pennsylvania and south-western New York, USA (Price, 1978). Introduced populations have been reported in New York (Bothner, 1976), Ohio (Novotny, 1990; Novotny et al., 2011), and Pennsylvania (Price, 1978; McCoy, 1982). In Erie County, Pennsylvania extralimital populations occur in glaciated regions, as far west as 1.5 km of the Ohio-Pennsylvania border (Gray, 2005). The first report of *T. brachystoma* in Erie County was based on 2 specimens collected from near Corry (Richmond, 1952). Since then, numerous other *T. brachystoma* populations have been discovered in Erie County. Urban populations within the city of Erie have been attributed to human introduction (Conant, 1975; Price, 1978; McCoy, 1982). Sometime between 1952 and 1970, Neil Richmond inadvertently released a number of *T. brachystoma* near Erie (Engelder, 1988). In 1970, D.R. Hower collected a specimen (Carnegie Museum of Natural History, CM 53678) 1.6 km south of Wesleyville.

Although *T. brachystoma* (Cope, 1892) was first described about 125 years ago there remain significant gaps in our understanding of the natural history and ecology of this species especially in urban environments. In Pennsylvania, it is of conservation concern due to its uncertain status, limited distribution, and evidence of population declines (Bothner, 1986; Jellen, 2010). For these reasons we chose to study the natural history of *T. brachystoma* at two urban sites in Erie, Pennsylvania, USA that are likely the same population from which Hower collected his specimen. The present paper summarises the morphometrics and growth of *T. brachystoma* from these sites and places these in the context of other unpublished sources regarding the ecology and natural history of this species. This study complements previously published data on population size and density, biomass, movement and site fidelity for *T. brachystoma* at the same two sites (Lethaby & Gray, 2015, 2016).

Figure 1. Adult female Short-headed garter snake, *Thamnophis brachystoma* from the Shannon Road site in Erie, Pennsylvania, USA

STUDY SITES

There were two study sites, both within the city of Erie, Pennsylvania. They were 1.4 km apart and separated by open green spaces, tree covered areas and some housing (Fig. 2).

Shannon Road

This site (Fig. 3), the property of The Behrend College of Pennsylvania State University, is approximately 5.8 ha, of which ca. 3.6 ha of old field habitat was sampled. Grasses, black-berry (*Rubus* sp.), wild strawberry (*Fragaria virginiana*), and goldenrod (*Solidago* sp.) were common, as were the shrubs red-osier dogwood (*Cornus sericea*) and

Figure 2. Map of the study sites in south-eastern Erie, Pennsylvania, USA. A) McClelland Park. B) Shannon Road. Map courtesy of Google Earth.

northern arrow-wood (*Viburnum recognitum*). Tree species occurring mainly along the perimeter of the sampled habitat included paper birch (*Betula papyrifera*), red maple (*Acer rubrum*), black-locust (*Robinia pseudoacacia*), northern red oak (*Quercus rubra*), basswood (*Tilia americana*), eastern cottonwood (*Populus deltoides*), and willow (*Salix* sp.). Potential earthworm prey at Shannon Road included *Allolobophora chlorotica*, *Aporrectodea* sp., *Lumbricus rubellus*, and *L. terrestris*. In addition to *T. brachystoma* two other species of snake were present, *Storeria dekayi* and *Storeria occipitomaculata*.

McClelland Park

This site (Fig. 4), the property of the City of Erie, is approximately 22 ha, of which ca. 4.8 ha of old field habitat was sampled. It is within 400 m of Hower's collection site. The dominant herbaceous plants in the sampled area were mugwort (*Artemisia vulgaris*), grasses and sedges, along with goldenrod (*Solidago* sp.). Tree species occurring mainly along the perimeter of the sampled habitat included Norway maple (*A. platanoides*), northern red oak (*Q. rubra*), eastern cottonwood (*P. deltoides*), and black-locust (*R. pseudoacacia*). McDannel Run bisects the eastern section of the property, and flows in a northerly direction, eventually emptying into Lake Erie. Potential earthworm prey at McClelland Park included *Aporrectodea* sp., *L. rubellus*, and *L. terrestris*. In addition to *T. brachystoma*, a single specimen of one other snake species (*Thamnophis sirtalis*) was observed.

METHODS

During April – August 2011 we used a combination of plywood coverboards (0.61 x 0.61 m) and pre-existing

Figure 3. Cover board in Short-headed garter snake, *T. brachystoma* habitat at Shannon Road site in Erie, Pennsylvania, USA, 14 July 2011

cover objects (primarily flat rocks) and debris to sample *T. brachystoma* at the two Erie County sites. Dimensions of pre-existing cover objects and debris were not obtained. Plywood coverboards were employed at 16 sampling plots at Shannon Road and 7 sampling plots at McClelland Park. Individuals were captured by hand, sexed, and their snout-vent length (SVL) and tail length (tl) measured to the nearest millimeter by gently straightening each snake along a metric ruler. The snakes were weighed with Pesola spring balances, accurate to 0.1 g (snakes ≤ 10 g), 0.25 g

Figure 4. Short-headed garter snake, *T. brachystoma* habitat at McClelland Park site in Erie, Pennsylvania, USA, 14 July 2011

(snakes 10 – 30 g), and 1.0 g (snakes larger than 30 g). Sex of mature *T. brachystoma* was determined by examining the base of the tail. In males, the hemipenes cause the sides of the base of the tail to bulge, whereas in females, the base of the tail is more tapered (Rossman et al., 1996). In male neonates and young ca. 150 mm or less, the hemipenes were manually everted by grasping the snake at mid-tail and rolling the thumb on the ventral surface towards the cloaca. Snakes were considered mature if at least 220 mm SVL in males, and at least 250 mm SVL in females (Pisani & Bothner, 1970; Rossman et al., 1996). In addition to the aforementioned data, we also noted number of dorsal scale rows at midbody, number of pre-oculars and post-oculars, as well as the number of supralabials and infralabials. Any scale anomalies, such as cleft or fused scales, and whether or not the tail was complete was also recorded as an aid to individual recognition. Snakes were individually marked with a portable cautery unit (Winne et al., 2006).

Daily growth rate was estimated by obtaining the difference in SVL between the initial and latest capture, then dividing this by the number of days between capture dates. Only snakes that were recaptured at least 30 days after their initial capture were used. Furthermore, only instances for which the increase in SVL between initial and latest capture was greater than 4% were considered. This was done to exclude individuals that had not grown.

Descriptive statistics used to summarise morphometric data included the mean ± 95% confidence interval, range, and sample size. Student's t-tests (two tailed, $\alpha = 0.05$) were used to compare SVL, tail length as a proportion of total length (tl/TL), and weight between sexes and within and between sites. Snakes with incomplete tails were not used for some comparisons, such as relative tail length. Prior to performing a t-test, an F-test was used to determine whether variances were homogenous. In the event variances were heterogeneous, a t-test assuming unequal variances was employed (Runyon et al., 1996) and is indicated with t′. Chi-square tests were used to determine if sex ratios and immature to adult ratios were significantly different from a 1:1 ratio ($\alpha = 0.05$). Yates' correction for continuity was used in the calculation of Chi-square tests (Fowler et al., 1998). Data from both sites were pooled to increase sample sizes. With the exception of Chi-square tests, which were calculated by hand, all statistical analyses were performed with Microsoft Excel 2010.

Our data were compared with unpublished data collected during a study of *T. brachystoma* in the vicinity of Olean, New York, USA (Pisani & Bothner, 1970). The data sheets, photomicrographs, and prepared slides of the current study are to be deposited in the Natural History Museum at the Tom Ridge Environmental Center.

RESULTS

Unless otherwise stated the results presented below are from the analysis of data from the Shannon Road and McClelland Park sites combined.

Morphometrics of immature *T. brachystoma*. There were significant differences in mean SVL and weight between immature males and immature females, with females being longer and heavier (Table 1). A significant difference in

Table 1. Summary of mean snout-vent(SVL) length (mm), relative tail length (tl/TL), and weight (g) of immature *T. brachystoma* from Erie, Pennsylvania, USA. Sample size (N). Statistically significant results are marked with an asterisk.

	Mean ± 95% C.I.	range	(N)	t-test (two-tailed)
male SVL	194.4 ± 6.2	159.1 - 218.6	33	
female SVL	209.6 ± 7.9	162.8 - 249.5	43	t' = -3.06, *df*= 73, *P*= 0.003*
male tl/TL	0.245 ± 0.003	0.228 - 0.262	32	
female tl/TL	0.226 ± 0.003	0.212 - 0.256	39	t = 9.24, *df*= 69, *P*< 0.0001*
male weight	5.1 ± 0.4	3.0 - 7.2	33	
female weight	6.2 ± 0.5	3.4 - 9.5	43	t' = -3.49, *df*= 73, *P*= 0.0008*

Table 2. Summary of mean snout-vent (SVL) length (mm), relative tail length (tl/TL), and weight (g) of adult *T. brachystoma* from Erie, Pennsylvania, USA. Sample size (N). Statistically significant results are marked with an asterisk.

	Mean ± 95% C.I.	range	(N)	t-test (two-tailed)
male SVL	273.4 ± 11.7	227.3 - 336.0	32	
female SVL	315.8 ± 12.8	250.5 - 447.0	50	t' = -4.95, *df*= 79, *P*= 0.0001*
male tl/TL	0.256 ± 0.003	0.239 - 0.274	31	
female tl/TL	0.223 ± 0.003	0.186 - 0.240	42	t = 14.53, *df*= 71, *P*< 0.0001*
male weight	12.7 ± 1.6	7.8 - 21.6	32	
female weight	23.4 ± 3.5	7.8 - 56.3	50	t' = -5.68, *df*= 67, *P*= 0.0001*

Table 3. Comparison of adult *T. brachystoma* snout-vent length (SVL), total length (TL) and relative tail length (tl/TL) between sites in New York and Pennsylvania, USA. Measurements are in millimeters. The mean ±95% confidence intervals are listed, followed by sample sizes in parenthesis.

	Pennsylvania from Hulse et al. 2001	New York from Pisani*	Pennsylvania from current study
SVL	♂ 273.1 ±14.6 (N = 102)	266.6 ±5.9 (N = 74)	273.4 ±11.7 (N = 32)
	♀ 325.3 ±14.2 (N = 93)	302.9 ±9.1 (N = 42)	315.8 ±12.8 (N = 50)
TL	♂ 366.8 ±21.0 (N = 93)	358.3 ±8.0 (N = 73)	366.9 ±16.1 (N =31)
	♀ 418.0 ±18.8 (N = 74)	390.6 ±11.2 (N = 42)	398.5 ±15.8 (N =42)
tl/TL	♂ 0.256 ±0.004 (N = 93)	0.256 ±0.003 (N = 73)	0.256 ±0.003 (N = 31)
	♀ 0.230 ±0.004 (N = 74)	0.225 ±0.005 (N = 42)	0.223 ±0.003 (N =42)

*Statistics calculated from unpublished data generously provided by George Pisani

tail length relative to total length was detected between immature males and immature females, with males having relatively longer tails (Table 1). One (3%) immature male and four (9%) immature females were stub-tailed.

Morphometrics of adult *T. brachystoma*. Among adults, significant differences in mean SVL and weight were detected between males and females, with females being slightly larger and heavier (Table 2). A significant difference in relative tail length was detected between adult males and adult females, with males having relatively longer tails (Table 2). Of 32 adult males only one (3%) was stub-tailed, whereas of 50 adult females eight (16%) were stub-tailed.

Sex ratios and immature to adult ratios. The sex ratio of immature male to female specimens was 33:43 (1:1.3), and did not differ significantly from 1:1 ($\chi 2 = 1.06$, $df = 1$, $P = 0.30$). The sex ratio of adult male to adult female specimens was 30:44 (1:1.5), and did not differ significantly from 1:1 ($\chi 2 = 2.28$, $df = 1$, $P = 0.13$). The ratio of immature to adult *T. brachystoma* was 76:74, almost exactly 1:1 ($\chi 2 = 0.01$, $df = 1$, $P = 0.93$). However, when compared between sites, immature to adult ratios were significantly different ($\chi 2 = 25.22$, $df = 1$, $P < 0.01$), with Shannon Road having a greater proportion of adults (1:3.3) and McClelland Park having a greater proportion of immatures (1:0.5).

Growth. Growth rate of immature *T. brachystoma* (initial SVL 167.4 – 221.8mm) recaptured 31 – 59 days after initial capture averaged 1.22 ± 0.24 mm per day (range 0.82–1.54, n = 8).

Growth rate of two adult *T. brachystoma*, a male (initial SVL 229.7mm) and a female (initial SVL 337.5mm) recaptured 38 and 86 days after initial capture was 0.4 mm per day and 0.59 mm per day, respectively.

DISCUSSION

The average SVL and TL of adult *T. brachystoma* from the Erie County sites were similar to other Pennsylvania specimens (Hulse et al., 2001). When compared to the published mean SVL for adult males (256.2 mm) and females (273.5 mm) for *T. brachystoma* from the vicinity of Olean, New York (Pisani & Bothner, 1970), those from Erie were considerably larger. However, the smallest mature male and female observed by Pisani & Bothner (1970) were 210 mm and 250 mm SVL, respectively. Reviewing the original data for Olean, it was found that six males (mean SVL 171.2 ±19.4 mm) and sixteen females (mean SVL 196.4 ±21.2 mm) were smaller than these values, and presumably immature. Therefore, we excluded the data for these specimens in our analysis. When this was done, the average SVLs and TLs were similar between sites (Table 3). When there are body size differences between snake populations this can be attributed to several factors, including geographic variation in climate, availability and quality of prey, inter- and intraspecific competition, and predation intensity (King, 1989). Olean, New York and Erie, Pennsylvania are at approximately the same latitude, 42.0737° and 42.0803°, respectively, and have similar climates. Olean, however is generally cooler than Erie, likely a result of Olean's higher elevation of 432 m compared to Erie's 222 m. Due to the proximity of the two Erie County sites (approximately 1.4 km apart), it is expected that climate would be similar. Both Erie County sites had similar potential earthworm prey, although there may have been differences in prey abundance. Interspecific competition was also potentially different between sites. *Thamnophis sirtalis* was relatively common around Olean, New York (Pisani & Bothner, 1970). With regards to the Erie County sites, at McClelland Park, where *T. brachystoma* and a single *T. sirtalis* were observed, interspecific competition would presumably not be a factor influencing SVL. Conversely, at Shannon Road, other snake species known to feed on earthworms were present. However, the two species, *S. dekayi* and especially *S. occipitomaculata*, are primarily predators of gastropods (Lazell, 1976; Hulse et al., 2001). In a sample of 84 scats from 74 Pennsylvania *S. dekayi*, forty-seven contained only slug remains (e.g., jaws, radulae, and shells), while six contained only earthworm setae. Both slug and earthworm remains were present in seven (Gray, 2013). Although our study did not focus on the effects of predation intensity, differences existed in potential predators of *T. brachystoma* between sites (see below). Potential predators at the New York sites were not noted (Pisani & Bothner, 1970; Engelder, 1988).

Relative tail length and weight were also similar to previous reports (Barton, 1956; Pisani & Bothner, 1970; Ernst & Gotte, 1986; Mibroda, 2014). Typical of snakes in the genus *Thamnophis*, *T. brachystoma* exhibits significant sexual dimorphism in SVL, TL, and relative tail length (Hulse et al., 2001). Stub-tails were more prevalent in female *T. brachystoma* at both Shannon Road and McClelland Park. While snakes with stub-tails were not specifically noted

in Pisani's Olean *T. brachystoma* data, one adult female (347 mm SVL) with a tl/TL of 0.143 likely had a stub-tail. The cause of the stub-tails in *T. brachystoma* from our Erie sites was not determined, but could have been due to attempted predation, incomplete ecdysis, or frost bite during hibernation (Harding, 1997; Hulse et al., 2001; Ernst, 2003). In male snakes, a stub-tail may result in a considerable fitness disadvantage and a threefold reduction in mating success (Shine et al., 1999). This may be because the tail tip in Thamnophis is useful in cloacal alignment with the female (Pisani, 1976).

The sex ratios of *T. brachystoma* at the two Erie County sites were similar to those of Engelder (1988) who reported a sex ratio of 1:1.2 from a presumably introduced population in Horseheads, New York. Whereas Pisani & Bothner (1970) reported male-biased sex ratios in both adults (1.4:1 [$\chi 2 = 4.08$, $df = 1$, $P = 0.04$]) and prenatal and neonate (1.5:1 [$\chi 2 = 4.12$, $df = 1$, $P = 0.04$]) *T. brachystoma* from Olean, New York. Differences in behaviour between sexes that result in one sex being more detectable to researchers may reduce the accuracy of sex ratio estimates (Parker & Plummer, 1987). For instance, males may move about more often in spring in search of mates, and females may become more sedentary when gravid. Additionally, gravid female *T. brachystoma* may require higher temperatures than they can attain via thigmothermy, and thus may bask in the open more frequently than males (Kozubowski, 1980). When cover objects are used, this behaviour could make females less likely to be found under cover objects.

Differences in age-structure among sites may result from variation in predator intensity, or in accessibility and quality of hibernation sites (King, 1989). *Blarina brevicauda* (northern short-tailed shrew), *Microtus pennsylvanicus* (Meadow Vole), and *Peromyscus leucopus* (White-footed Mouse) are known or suspected predators of snakes in general (Fitch, 1975; Ernst & Ernst, 2003), and *T. brachystoma* specifically (Hummer & Roen, 2008). All three species were observed frequently (*B. brevicauda* N = 10; *M. pennsylvanicus* N = 5; *P. leucopus* N = 15) at Shannon Road, but not at McClelland Park. This apparent lack of potential small mammalian predators at McClelland Park may partially explain the greater proportion of immature snakes to adults at this site. Furthermore, population size, density, and total biomass of *T. brachystoma* were all greater at McClelland Park (Lethaby & Gray, 2015). Each site had a single observation of mortality involving a *T. brachystoma* that had been crushed under a cover board. Mortality due to automobiles was not observed at either site.

Growth rate data for *T. brachystoma* are sparse. Barton (1956) reported that neonates approximately doubled their length in the first year, reach sexual maturity during their second, with growth rate steadily decreasing with age. Therefore, the greater rate of growth in juveniles compared to adults was expected. The growth rate of a captive *T. brachystoma* was estimated as 75.6 mm/year during approximately the first 2.5 years; growth rate during approximately 3 subsequent years was 16.1 mm/year (Gray, 2011). Both juveniles and adults of *T. brachystoma* in the present study had greater estimated growth rates than an Erie County, Pennsylvania population of *Storeria dekayi*. Juvenile male and female *S. dekayi* grew on average 16.2 mm/month and 25.2 mm/month, respectively (Gray, 2014) while adult male and female *S. dekayi* grew on average 8.8 mm/month and 3.0 mm/month, respectively. This is likely due to the difference in size between the two species, *S. dekayi* being somewhat smaller. Additional study of the growth rate of *T. brachystoma* would greatly increase our knowledge of possible differences between sexes within and between populations.

The data presented here augment our knowledge of the morphology, growth, and natural history of *T. brachystoma* in urban habitats. These habitats are subject to profound alterations, indeed McClelland Park has been developed into a public dog park (O'Neill, 2015), almost certainly impacting the dynamics of that snake population. The data collected in this study provide a baseline against which future changes in urban populations may be detected and compared with rural populations.

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