SNAKE ASSEMBLAGE DYNAMICS OF ARTIFICIAL WETLANDS IN SOUTH-CENTRAL PENNSYLVANIA: IMPLICATIONS FOR WETLAND MANAGEMENT AND CONSERVATION

By
Daniel F. Hughes

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Date	Dr. Pablo R. Delis Chairman of Thesis Committee Assistant Professor Shippensburg University
Date	Dr. Walter E. Meshaka, Jr. Curator State Museum of Pennsylvania
Date	Dr. Todd M. Hurd Professor Shippensburg University
Date	Dr. David R. Long Professor Shippensburg University

ABSTRACT

Pennsylvania exhibits a variety of geographic and climatic features. Along with a diverse topography, the state is home to twenty-two species of snakes. The temperate deciduous forest characteristic of Pennsylvania is the matrix ecosystem surrounding a network of wetlands that serve as critical habitats enriching local biodiversity. Artificial wetlands can be as good as natural wetlands for some specific aquatic or semi-aquatic species. Little is known, however, about the status of snake and specifically wetland snake communities in Pennsylvania. This study examines the natural history of the snake assemblages occupying artificial wetlands in an anthropogenically impacted environment.

In 2012, seven months of surveys were used at Letterkenny Army Depot (LEAD), within Franklin County, south-central Pennsylvania. A combination of cover boards and opportunistic surveying was used to sample the characteristics of the snake community in four differently sized artificial wetlands.

Seventy-three individuals were captured, included in five different snake species; the Common Garter Snake (n = 49), Northern Water Snake (n = 18), Milk Snake (n = 4), Eastern Racer (n = 1), and Ringneck Snake (n = 1). This study detected 38 % of the 13 snake species expected in the county. Snakes were captured in all seven months and the seasonal activity was bimodal, with peaks occurring in June (n = 16) and August (n = 17). Most snake captures occurred at the largest wetland site (47 %). The Common Garter Snake was the most frequent snake captured and was found in all seven months. Gravid female Common Garter Snakes exhibited a peak in June (n = 8) and had an average clutch size of 12.22 embryos. Common Garter Snakes displayed no significant relationship between body size and clutch size.

To my knowledge, this is the first study focused exclusively on wetland-associated snake assemblages in Pennsylvania. The findings suggest that these protected wetlands maintain healthy levels of snake abundance and snake species richness, comparable to unprotected and protected wetlands elsewhere. The results seem to offer the notion that even wetlands significantly impacted by human activities in forested environments have the potential to support relatively natural snake assemblages. This study can be used as a resource for the conservation of wetland-associated snake populations and the management of these wetlands at LEAD, with potential applications in other areas of intensive land use in Pennsylvania. Future wetland creation practices at LEAD should focus on incorporating a diversity of land management techniques, concentrating on creating a myriad of habitat types contiguous to the man-made wetland.

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INTRODUCTION

The northeastern United States exhibits a vast diversity of biomes, several of which occur in Pennsylvania. The range of major physiographic provinces in Pennsylvania begins in the extreme southeast with the Coastal Plains, a low flat region of sand and gravel that is underdeveloped and poorly drained (PGC, 2005). Bordering the Coastal Plain and extending northwest is the Piedmont Plateau, composed of low ridges separating valleys of various widths (NCDC, 2011). Contiguous to the Piedmont region is the Ridge and Valley Region, which is characterized by low elevations, forested ridges, and extensively farmed valleys (NCDC, 2011). The Appalachian Mountains border the western edge of the Ridge Valley Region and the mountainous topography has created a climate with a much lower annual temperature and a greater annual snowfall than in the extreme east or southwest of the state. The extreme degree in variation in temperature and topography across latitudes within the state, may drastically impact many characteristics of the biology and ecology of native biota, specifically the emergence and entrance into hibernation, length of activity periods, distribution patterns and life history characteristics (Hulse et al., 2001). Pennsylvania's diverse topography and landform patterns affect existing seasonal environmental temperatures, imposing range restrictions upon segments of the routine herpetofauna, causative to limiting their geographic distribution and activity patterns to explicit biomes and restrictive seasons within the state (Hulse et al., 2001).

Along with Pennsylvania's geographic and climatic features, the state is home to thirty-nine species of reptiles, of which twenty-two are snakes (Meshaka and Collins, 2009). The basic biological functions of snakes are strongly influenced by the ambient temperature. Generally, snakes have limited dispersal capabilities; therefore many of

Pennsylvania's native species are restricted to distinct regions within the state (Hulse et al., 2001). The Appalachians to the west, the Coastal Plains to the east, low valleys and many wetlands, are all trademarks of the Ridge Valley Region in south-central Pennsylvania. This suite of heterogeneous environmental characteristics makes this a geographically unique and diverse region. In spite of its inherent biological value, there is a dearth of site-specific empirical data describing the natural history and population demographics of the indigenous snake communities, characteristic of this region.

More than 2,700 species of snakes exist worldwide, with 154 species native to the United States (Ernst, 2003). Of the 22 native species to Pennsylvania, three snakes belong to the venomous ovoviviparous family Viperidae, 10 are in the harmless viviparous snake family Natricidae, and six are in the harmless oviparous family Colubridae (Meshaka and Collins, 2009; Ernst, 2003). Based on the geographic ranges (Hulse et al., 2001; Meshaka and Collins, 2009; Ernst, 2003), the species that can be found in Franklin County, south-central Pennsylvania (Hulse et al., 2001) with an ecological tendency to live near wetlands are; the Ringneck Snake, *Diadophis punctatus* (Linnaeus, 1766), the Eastern Hognose Snake, *Heterodon platirhinos* (Latreille, 1801), the Northern Water Snake, *Nerodia sipedon* (Linnaeus, 1758), the Queen Snake, *Regina septemvittata* (Say, 1825), the Redbelly Snake, *Storeria occipitomaculata* (Storer, 1839), the Eastern Ribbon Snake, *Thamnophis sauritus* (Linnaeus, 1766), and the Common Garter Snake, *Thamnophis sirtalis* (Linnaeus, 1758). Five of these species have been detected in previous studies in Franklin County (Delis et al., 2010; Meshaka and Delis, 2013); the Ringneck Snake, the Eastern Hognose Snake, the Northern Water Snake, the Redbelly Snake, and the Common Garter Snake. The Queen Snake was observed in a stream in Franklin County (Samuel J. Pelesky, personal communication). In Pennsylvania, the paucity of information pertaining to the basic life history and current status are recognized as the biggest challenges to conserving the herpetofauna of the state (Hulse et al., 2001). Land management programs in Pennsylvania often overlook the importance of site-specific natural history and population data when formulating management plans for their native species, and frequently herpetofaunal concerns are completely absent from these plans. The snake assemblages inhabiting wetlands in south-central Pennsylvania suffer from this absence of basic biological information and consequently these key organisms are excluded from management plans.

According to the US Environmental Protection Agency, wetlands are defined as lands where saturation with water is the dominant factor determining the nature of soil development, and the types of plant and animal communities living in the soil and on its surface (Ortynsky, 2004). Wetlands serve numerous functions; they prevent flooding, filter and clean water supplies, and provide critical habitat for countless species (PGC, 2005). Many natural wetlands are often drained for agricultural or developmental purposes. In Pennsylvania, particularly, wetland losses are estimated at twenty-five hectares per year (PGC, 2005). Wetland losses dramatically impact aquatic and semi-aquatic species that depend on wetland habitats for food, refuge, protection, and other resources necessary for their survival. The destruction of natural wetlands may force former inhabitants to find a new wetland habitat. During the movement from a destroyed wetland to a new habitat, organisms especially amphibians and reptiles, can encounter unfavorable habitats, such as roads and cleared areas. These modified landscape features may increase mortality risk and limit movement of individuals between populations, further isolating populations and increasing their risk of decline (Attum, 2008). Furthermore, many amphibians, particularly forest-dependent species (i.e. *Ambystoma* spp.), utilize isolated wetlands as seasonal breeding grounds and if these wetlands are extirpated then community dynamics will be impacted and ecosystem health may be negatively affected (Gibbons et al., 2006).

Temperate deciduous forests, characteristic of the northeastern United States, especially Pennsylvania, are a vital component of terrestrial ecosystems. Within forested landscapes, wetlands serve as critical habitats that enrich local biodiversity. These wetlands serve numerous functions including but not limited to; foraging grounds and nesting sites for migratory birds, breeding sites for amphibians, and are home to specific plant communities. Customarily, amphibians make up the majority of the nutritional intake for many aquatic and semi-aquatic snake species, among other wetland vertebrates (Conant, 1998; Hulse et al., 2001; Meshaka and Collins, 2009; Seigel et al., 1987). Amphibians are key components of wetland ecosystems and based on the known diets of many aquatic and semi-aquatic snake species, amphibians supply an appreciable portion of the energy transferred between wetlands and the surrounding habitats (Gibbons et al., 2006). At an isolated wetland adjacent to a forested peripheral in western South Carolina, Gibbons and coworkers, (2006) estimated amphibian density to be approximately 38,000 individuals per Ha and a productivity estimate of 159 Kg/Ha/Yr, these estimates demonstrate that isolated wetlands contribute substantially to the overall productivity of the surrounding landscape adding energy to the community and increasing the overall biomass within the ecosystem (Gibbons et al., 2006). Therefore, forested wetlands play a key role in ecosystem productivity and in nourishing community dynamics by intertwining a mosaic of habitats which promotes high levels of biodiversity and ecosystem vigor.

In some cases artificial wetlands can be as good as natural wetlands for many aquatic or semi-aquatic species (Ortynsky, 2004; Mazerolle, 2006; Gibbons et al., 2006). For example, a study that compared habitability of natural wetlands to man-made wetlands suggested that amphibian tadpoles were more likely to occur in man-made pools than natural pools (Mazerolle, 2006). Gibbons and colleagues, (2006) determined that an isolated artificial wetland in a forested environment in South Carolina, promoted increased amphibian diversity and numbers, particularly the forest-dependent salamanders, since its classification as a federally protected site in 1951. Thus the creation of isolated artificial wetlands in forested locales may contribute significantly to regional biodiversity and augment ecosystem health. Consequently, as perpetually more natural wetlands are lost across Pennsylvania, it is imperative that persistent efforts are applied to the investigation and protection of artificial wetlands serving as surrogates for natural wetlands. Therefore, if artificial wetlands can become routinely implemented into management plans, these habitats may function as critical habitats for the survival and proliferation of numerous aquatic and semi-aquatic snake species in Pennsylvania.

The greatest constraint in conservation for either individuals or entire snake assemblages is the fundamental lack of biological information (Dodd, 1993). Therefore, results from this study will contribute our understanding of snake assemblages across the northeastern United States. Deductions drawn from this study may enhance our understanding of management protocols regarding protected artificial wetland-associated snake assemblages in south-central Pennsylvania. Additionally, the conclusions may be used to help establish and enact conservation and management policies for the future of the herpetofaunal populations at the Letterkenny Army Depot and other federally operated institutions across Pennsylvania. My research might be used as a foundation for future studies focused on the snake populations associated with the Letterkenny Army Depot and for understanding the ecology of snakes occupying artificial wetlands.

Previous studies conducted in Franklin County indicated that the area possess a good representation of Pennsylvania’s native herpetofauna (Delis et al., 2010; Meshaka and Delis, 2013). Based on this background, the objective of my study was to examine the natural history of the snake assemblage occupying artificial wetlands in a relatively protected yet anthropogenically-impacted environment. Specifically, the goals of this study was to determine the following: the snake species composition and relative abundance, adult sex ratios, morphometric characteristics between snakes at the different wetlands, activity patterns in relation to distance from peak site of human disturbance, microhabitat selection and preferences, local temperature environment (ambient air, board surface, soil surface, and internal body temperatures), seasonal trends in wetland characteristics, and finally the abiotic factors that most affect snake abundance (i.e. modified landscapes, anthropogenic activity, and habitat alteration). Comparisons of information gathered in this study to previous studies and to Pennsylvania generally may elucidate the impacts of human disturbance on snake populations inhabiting protected artificial wetlands and what role does the persistence and construction of artificial wetlands play in the snake assemblage structure. In this conservation context, the larger questions of my study are: how do geographically variable life history traits (i.e. age to sexual maturity, size at first reproduction, number of offspring etc.) and the natural history of this snake assemblage vary from other populations?; what are the relationships between the species-specific responses to the geography and the local thermal environment?; how do the demographics and natural history characteristics of this population occupying artificial wetlands at this protected site, compare to other Pennsylvanian snake populations?

MATERIALS AND METHODS

STUDY SITE

Research was conducted at the Letterkenny Army Depot (LEAD), in the southeast section of the Ridge and Valley Physiographic Province, within Franklin County, south-central Pennsylvania (Swenson, 2007). The Letterkenny Army Depot is approximately seven-thousand hectares in area, and is at latitude 39°58’N and longitude 77°42’W (Delis et al., 2010) (Figure 1). This federally owned ammunitions depot was established in 1942. Access inside is restricted to the general public barring special permission. Since its establishment, the depot has undertaken many missions including the stripping, demolition, testing, disposal, and deactivation of ammunitions (Swenson, 2007). In the last two decades, the depot has been split into Zone I and Zone II, each with different land use patterns. Zone II has been restored from military mission activities for over a decade which has allowed the environment to revert to a more natural condition, relatively similar to an undisturbed area. However, Zone I is still used for ammunitions storage and testing, and the surrounding environment is subjected to substantial landscape modifications, chemical exposures, heavy human traffic, and noise pollution. All of these anthropogenic activities have the potential to impact the surrounding natural environments within the depot. In March of 1989, the Property Disposal Office Area of LEAD, Zone I, was placed on the National Priorities List with a Hazard Ranking Score of 37.51 (Swenson, 2007). Accordingly, the hazardous materials involved with the storage and maintenance of ammunition may have resulted in a profoundly adulterated environment within Zone I (Figure 2).

The depot's geography is composed of hills and valleys with a low average elevation. At the time of this study, the dominant flora of LEAD primarily consists of deciduous forest tree species. Some of the most dominant tree species were; the Red Oak, *Quercus rubra*, the Black Oak, *Quercus kelloggii*, the Black Cherry, *Prunus serotina*, and the Red Maple, *Acer rubrum* (Tetra Tech Inc., 2001). Aquatic habitats in LEAD included natural and artificial lakes, streams and a variety of wetland types such as palustrine forested ponds, open water ponds, scrub ponds, and riverine tributaries (Tetra Tech Inc., 2001). However, the wetlands located within Zone I are all artificial, and based on the heavy anthropogenic and pollution disturbance regimes of the area, these wetland features may have been subjected to substantial ecological and environmental distress.

Of the roughly six artificial wetlands in Zone I, four were selected to monitor snake populations (Figure 2) and were considered the best representatives of the diverse habitat and microhabitats features of the area. Additionally, wetland site considerations were based on the relative distances, in meters, to the following: distance to other wetlands, distance to the undisturbed region (Zone II), distance to major roads, distance to the impact zone, and distance to natural water sources or drainages (i.e. Muddy Run). The farthest distance between selected sites is over three kilometers from the most southern to the most northern sites (Figure 2). The wetlands chosen for this study are: Cole's Pond (Figure 3) was approximately 500 meters in perimeter. Henry's Pond (Figure 3) was approximately 600 meters in perimeter. Henry's Pond was the most northern site and the closest site to the undisturbed region of Zone II. Shirley's Pond (Figure 3) was just over 750 meters in perimeter. Lake Letterkenny (Figure 3) encompassed more than 950 meters in perimeter. Lake Letterkenny was also the most southern of the four sites, the largest wetland, and closest to the high disturbance zone.

DATA COLLECTION

The study was conducted from April 2012 to October 2012, which encompassed the peak months of activity of snakes in Pennsylvania (Meshaka, 2010). To estimate the snake species richness and relative abundances, a combination of cover boards and opportunistic surveying was used. Early in March of 2012, 54 cover boards were deployed in the following pattern: 10 cover boards placed at Cole's Pond, 12 cover boards at Henry's Pond, 15 cover boards at Shirley's Pond, and 17 cover boards at Lake Letterkenny. The number of boards deployed around each wetland was dependent upon the perimeter of the wetland, in meters. To standardize the cover board deployment the approximate perimeter of the wetland was divided by 50 meters. As a result, homogeneous conditions were achieved at each wetland with respect to an even distribution of cover boards, (~ 50 m apart) (Figure 3). Larger wetlands tended to have more boards deployed at them (Figure 3). These boards were checked on nine occasions, one survey per month and twice in the months September and October. Cover boards were deployed around the perimeter of the selected wetland sites in areas of natural travel ways and at the expected concentration points of the local snake population in an attempt to maximize captures. The cover boards consisted of corrugated metal sheets with dimensions near two meters in length by approximately one meter in width. The corrugated metal sheets were galvanized to ensure that rust-resistance and usability were maximized. Visits occurred on cool mornings or later in the afternoon as ambient air temperatures began to fall except on the visit of 10 July 2012 which, because of logistical constraints, occurred during the hottest period of the day. The use of cover boards and sampling periodicity served as the standardized survey method for the data collection in this study to estimate relative abundance and activity patterns as per Meshaka (2010) and

Meshaka and Delis (2013). Opportunistic surveys consisted of following regular routes, turning over debris, inspecting depressions or crevices, checking cover boards and capturing snakes in open fields. Additional opportunistic samplings were conducted during the standardized sampling day, on foot between the four wetlands and two supplementary opportunistic outings in September and October.

The following data were recorded immediately upon the capture of each snake during the standardized and opportunistic surveys: species identification, time of day, location, date, sex determined by caudal palpation (Seigel et al., 1987), health, body size as snout-vent length (SVL) and tail length (TL) measured to the nearest 0.1 cm with the use of a tape measure, presence of food determined by ventral palpation or forced regurgitation, records of ecdysis determined by visual inspection of cloudy eyes, cloacal temperature, and records of gravid females determined by ventral palpation. All females determined to be gravid were palpated to estimate clutch size. Health was assessed by visually inspecting for wounds, parasites, eye color, cloaca health, shed health, and infections. Shortly after capture, a minimum of four distinct digital photographs were taken of each snake when feasible, one dorsal image, one ventral image, one close-up head image, and one cloacal image. Each snake captured was also marked with Biomark ® or AVID ® Passive Integrated Transponder (PIT) tags subcutaneously or intracoelomicly using a hypodermic needle as per Meshaka and coworkers, (2010). Subsequently, individual PIT tags were scanned with a Biomark Pocket Reader or AVID MiniTracker. When a snake was too small to be marked with the PIT tags a cohort mark was applied as per Delis and coworkers, (2010) and a subsequent photograph was taken of the mark for future recognition. Opportunistic captures were included only in determining morphometrics, incidence of gravid females, cloacal temperature, estimates of clutch size, microhabitat preference, incidence of ecdysis, and presence of meals. Captured snakes were handled and processed swiftly and gently led back under the same cover board of capture.

MICROHABITAT SELECTION

To determine the extent to which snakes exhibited species-specific microhabitat selection and/or preference, 26 cover boards were placed within two meters of the water's edge and 28 cover boards were placed at least 10 meters away from the water's edge. In addition, cover board positioning was varied with respect to degree of sun exposure. Boards that were positioned in areas that would expose them to direct sunlight for more than 90 % of the day were given a score of 0, and boards positioned in areas that would expose them to direct sunlight for less than 10 % of the day were given a score of 2, subsequently a score of 1 delineated boards receiving moderate exposure to the sun, ~50 % of the day. Post-capture, internal body temperatures in degrees Celsius were immediately taken by thrusting the end of the quick-reading Fluke® 51II thermometer into the cloaca. The bulb on this instrument is small enough to enter the cloaca of the all of the snakes captured, except a few of the smallest individuals. In those cases internal temperature was measured orally or the datum was discarded. The snakes were handled as little as possible while inserting the thermal probe into the cloaca to minimize human heat transfer to the snake. Ground surface temperatures and cover board surface temperatures were measured using a Pro-Exotics® PE-2 tempgun, and recorded in degrees Celsius immediately post capture.

WETLAND CHARACTERISTICS

Various wetland parameters were measured in order to determine the extent, if any, of their impact on the snake assemblage. Measurements of pH, conductivity (μS), and temperature (°C) were measured via an OAKTON® Waterproof pH /CON 10 pH/Conductivity/°C monitor at each of the four wetland locations. Wetland measurements were obtained once a month from May-October, during the standardized sampling days. The device's versatile multi-sensor probe was placed in the water, 0.5 - 1.0 m depth and 2.0 - 3.0 m from land, until the measures visible on the screen became static, ≥180 seconds. Shortly after the decipherable quantities on the screen stabilized, data were recorded. Additionally, data concerning the time of day, location, date, water levels and recent weather patterns were also recorded. Quick-grab water samples were collected in 20 ml vials, then labeled and stored at room temperature, approximately 20 °C, until needed.

STATISTICAL ANALYSES

The SPSS® and Microsoft Excel® statistical software were utilized to calculate and analyze descriptive statistics including mean, standard error, standard deviation, ANOVA simple regression analysis, One Sample *t*-tests, and Chi-Squared tests when appropriate sample sizes were available. Statistical significance of the sex ratios were determined using a Chi-Squared Goodness of Fit test. Contingency table analyses were used to determine if the snake species abundances at the four wetland sites differed significantly. All statistical analyses were characterized as significant at $\alpha < 0.05$. All tables and figures were based on samples collected from the standardized sampling methods unless otherwise noted in figure legends. Species richness, relative abundance, morphometrics, and life history traits were compared to prior findings of the snakes in Pennsylvania (Hulse et al., 2001) and compared to similar studies conducted in Zone II of LEAD (Delis et al., 2010; Meshaka and Delis, 2013), western Pennsylvania (Meshaka, 2010), northeastern Ohio (Meshaka et al., 2008), and north-western Pennsylvania (Gray, 2011). Data on relative abundance and species distribution are displayed as percentages in relative frequency bar graphs. Assemblage structure as a percent occurrence of each species in a given site was calculated by dividing the number of individuals of each species captured from a given site by the total number of individuals of all species captured from that same site and multiplying by 100. Relative abundance of all species was determined by dividing the number of snakes captured at a specific site by the number of cover boards deployed at that site.

RESULTS

SPECIES COMPOSITION AND ASSEMBLAGE STRUCTURE

During the course of the study, seventy-three snakes were captured and five species were detected using both standardized cover board searches and opportunistic sampling. The following species are listed in order of decreasing abundance; the Common Garter Snake (n = 49), the Northern Water Snake (n = 18), the Milk Snake, *Lampropeltis triangulum* (Lacépède, 1789) (n = 4), the Eastern Racer, *Coluber constrictor* (Linnaeus, 1758) (n = 1), and the Ringneck Snake (n = 1) (Figure 4). Emphasizing the standardized searches only, 53 snakes were captured under cover boards, comprising four species; the Common Garter Snake (n = 35), the Northern Water Snake (n = 13), the Milk Snake (n = 4), and the Eastern Racer (n = 1) (Table 1). The presence of the Ringneck Snake, an additional species, was detected during the September opportunistic sampling survey. The snake species relative abundance varied significantly among the wetland sites (4 x 5 Contingency Table Comparison; $X^2 = 39.6$, df = 12, $p < 0.001$). The highest number of species (n = 3) and the highest abundance of snakes captured (n = 25) via the standardized method were recorded at Lake Letterkenny (Table 1). The lowest number of species (n = 0) and the lowest abundance of snakes captured (n = 0) via the standardized method were recorded at Cole's Pond (Table 1). Counting all species captured by means of the standardized and opportunistic methods, the relative abundance was greatest for the Common Garter Snake; which comprised 67 % of all captures (Figure 5). Considering standardized and opportunistic methods pooled together, most captures occurred at Lake Letterkenny with 47 % of the total (Figure 6). The second highest number of captures occurred at Henry's Pond with 30 % (Figure 6). Three marked individuals were recaptured during this study and all of them were at Lake Letterkenny and were Northern Water Snakes. The species distribution and composition at each site, using standardized capture methods, was greatly unbalanced, with the Common Garter Snake making more than 60 % of all captures, except for Lake Letterkenny which still favored the Common Garter Snake but was more balanced with the Northern Water Snake occurring in a high abundance (Table 1).

SEASONAL ACTIVITY

Snakes were detected under cover boards in all seven months of the study, April to October (Figure 7). The lowest captures of snakes were in April (n = 4), July (n = 4), and October (n = 2). The fewest numbers of species were found in April, July, August, and September with two species in each of those months. The highest numbers of species were found in May, June, and October with three species in each of those months. The Eastern Racer and the Ringneck Snake were each detected once in June and September, respectively. The Common Garter Snake was found in all seven months from April to October, while the Northern Water Snake was found in five months from May to September, and the Milk Snake was captured in April, May, and October. The monthly distribution of all captures for all species combined was bimodal in shape, with 45 % of all captures having occurred in June and August (Figure 7). Two species were dominant throughout the months, the Common Garter Snake (n = 49) and the Northern Water Snake (n = 18). Sixty-seven individuals were found of these two species using all methods, which comprises 92 % of all captures. The three other species were encountered infrequently throughout the months: The Milk Snake (n = 4), the Eastern Racer (n = 1), and the Ringneck Snake (n = 1). All these three species using all methods comprises only 8 % of all captures.

SPECIES ACCOUNTS

Thamnophis sirtalis - The Common Garter Snake (Figure 8) was the most frequently encountered species in this study and using standardized and opportunistic captures it was encountered at all wetland sites (Table 2). It was the most abundant species at each site and comprised 90 % of the captures at Henry's Pond (Table 1). Forty-nine individuals of this species were captured using standardized and opportunistic methods, which comprised more than 65 % of all the snakes captured (Figure 5). The Common Garter Snake dominated the standardized searches, with 35 captures, accounting for 66 % of all snakes captured using this protocol (Table 1). During opportunistic searches, this species was also the most frequently encountered, encompassing >55 % of all opportunistic captures. Common Garter Snakes were captured most at Henry's Pond (n = 20) and the least at Cole's Pond (n = 2) (Table 1). The male/female sex ratio in this species was 1:21 skewed towards females, and deviated significantly from a 1:1 ratio (Chi-squared test: = 31.114, $p < 0.0001$).

The seasonal activity pattern of the Common Garter Snake was bimodal, with peaks occurring in June and August (Figure 9). The species seasonal activity ranged from April to October, with most captures occurring in August (n = 14) (Figure 9). A single adult male (38.0 cm SVL; 11.0 cm TL) was captured in September (Figure 9). By means of standardized captures, female Common Garter Snakes comprised 60 % (n = 21) of all captured individuals and were encountered most frequently, four of the seven months (Figure 9). Females displayed a unimodal activity pattern with a peak in August. Average adult female SVL (45.79 ± 1.10 cm, Range: 36.0-59.5 cm) and TL (12.74 ± 0.33 cm, Range: 6.5-17.0 cm) was calculated from 34 new individuals (Table 3). Juveniles were captured and detected in four of the seven months, displaying a unimodal activity pattern with a peak in May (Figure 9) and their average SVL (27.12 ± 1.62 cm, Range: 20.5-35 cm) and TL (7.96 ± 0.49 cm, Range: 5.6-11.0 cm) (n = 10) (Table 3). Young-of-the-year (YOY) were detected in two of the seven months, August and September, with unimodal activity pattern with the peak occurring in August (Figure 9). Average YOY SVL (16.75 ± 0.85 cm, Range: 14.5-18.5 cm) and TL (4.75 ± 0.32 cm, Range: 4.0 5.5 cm) was calculated from four individuals (Table 3). The two smallest individuals, 14.5 and 16.5 cm in SVL respectively, were captured in August (Figure 10).

From standardized and opportunistic surveys gravid female Common Garter Snakes were detected in three of the seven months, May, June, and July with a peak in June (n = 8) (Figure 11). Considering all of the Common Garter Snake captures in June, 89 % of them were gravid females (n = 8) (Figure 11). Average clutch size of gravid females was 12.2 embryos (n = 8). Gravid female mean cloacal temperature was 25.96 ± 1.16 °C, and ranged between 20.0- 32.6 °C (Table 4). Gravid females displayed no significant relationship between SVL and clutch size (R^2 = 0.0047) (ANOVA simple linear regression; F = 0.00259, p = 0.961) (Figure 12). Using standardized methods the smallest gravid female captured was SVL 40 cm TL 10 cm, found at Henry's Pond 6/4/2012 at 10:30 a.m. under a cover board approximately 2 m from the wetland and with moderate sun exposure. By means of standardized methods, 87 % of all gravid females were captured under boards at a distance of more than 10 m from the wetland and under board conditions moderate to more than 90 % sun exposure (Figure 13). Additionally, 66 % of all juveniles were captured under boards at a distance of more than 10 m from the wetland and under board conditions moderate to more than 90 % sun exposure (Figure 13).

The mean snout-vent lengths of the Common Garter Snake from this study to a study in the region, males showed no significant difference, while females from this study tended to possess a smaller mean snout-vent length (T-test: $t = -7.57$, $p < 0.0001$) (Table 8). Females from this study exhibited no significant difference in the mean snout-vent length when compared to Pennsylvania generally (T-test: $t = 1.72$, $p = 0.094$) (Table 3). Taken into account the total body lengths, females from this study were larger when compared to Pennsylvania generally (T-test: $t = 3.01$, $p = 0.005$) (Table 3).

Measurements displayed for mean cloacal temperatures are comprised of all standardized, opportunistic, and recapture methods. During sampling periods, mean cloacal temperatures of the Common Garter Snake were documented well above the mean local environmental temperatures, mean board surface temperatures, and mean soil surface temperatures. Mean cloacal temperatures of the Common Garter Snake ranged from 19.7 °C to 36.6 °C (Table 4). Snakes with an average SVL >36cm had an average cloacal temperature (26.91 ± 0.61 °C, Range: 19.7-33.9 °C); (n = 34), and snakes with an average SVL <36cm had an average cloacal temperature (29.21 ± 1.0 °C, Range: 24.6-36.6 °C); (n = 13) (Table 4). Snakes captured and measured before 12 p.m. had a mean cloacal temperature (27.63 ± 0.78 °C, Range: 20.0-36.6 °C); (n = 23), whereas snakes measured after 12 p.m. had a mean cloacal temperature (28.72 ± 1.08 °C, Range: 22.7-35.6 °C); (n = 12) (Table 4). Snakes captured in the months from May to July, had an average cloacal temperature (26.64 ± 0.80 °C, Range: 20.0-32.6 °C); (n = 15), while snakes captured from August to October had an average cloacal temperature (28.08 ± 0.72 °C, Range: 19.7-36.6 °C); (n = 30) (Table 4).

Adequate sample sizes from standardized and opportunistic trappings of the Common Garter Snake allowed for the relationships between the localized thermal environment and internal body temperatures to be explored. The association between cloacal temperature and snout-vent length of thirty-nine Common Garter Snakes exhibited a non-significant negative relationship (ANOVA simple linear regression; $F = 2.491$; $p = 0.123$) (Figure 14). The association between cloacal and board surface temperatures of thirty-five Common Garter Snakes exhibited a significant positive relationship (ANOVA simple linear regression; $F = 31.812$; $p < 0.0001$) (Figure 14). The association between cloacal and soil surface temperatures of thirty-five Common Garter Snakes exhibited a significant positive association (ANOVA simple linear regression; $F = 28.672$; $p < 0.0001$*) (Figure 14).

Nerodia sipedon - The Northern Water Snake (Figure 15) was the second most common species encountered (n = 18) using standardized and opportunistic methods, yet it was found exclusively at Lake Letterkenny and Shirley's Pond (Table 2). This species was captured, using standardized methods, with the most frequency at Lake Letterkenny (n = 10), and with much less frequency at Shirley's Pond (n = 3) (Table 1). The Northern Water Snake constituted 25 % (n = 18) of all standardized and opportunistic snake captures (n = 73) (Figure 4), while also contributing 25 % (n = 13) of all the standardized captures (n = 53). The male/female sex ratio in this species was 1:3 skewed towards females, yet an inadequate sample size did not allow for an accurate statistical analysis.

The seasonal activity pattern of the Northern Water Snake was unimodal, with a peak occurring in June (Figure 16). The species seasonal activity ranged from May to September, with the most captures occurring in June (n = 5) (Figure 16). Male encounters were rare (n = 2), two were captured by standardized and opportunistic sampling throughout this seven month study, one in June and the other in September (Figure 17). Average male SVL (35.25 ± 1.75 cm, Range: 33.5-37.0 cm) and TL (12.5 ± 0.0 cm Range: 12.5-12.5cm (n = 2) (Table 4). Using standardized trappings females comprised 23 % (n = 3) of all captured individuals and were encountered two of the seven months (Figure 16). Females displayed a unimodal activity pattern with a peak in June (Figure 16). Mean SVL (60.63 ± 5.16 cm, Range: 51.5-71.0 cm) and TL (17.38 ± 1.53 cm, Range: 14.5-20.5 cm) was calculated from four adult females (Table 4). Juvenile captures were most common and occurred in five of the seven months, displaying an evenly dispersed activity pattern with no distinct peak (Figure 16). Mean SVL (37.75 ± 3.27 cm, Range: 21.0-48.5 cm) and TL (12.1 ± 1.21 cm, Range: 6.5-19.0 cm) was calculated from 10 juveniles (Table 4). The smallest Northern Water Snakes were captured in June and September, SVL 16.0 cm and 17.5 cm respectively, and was suggestive that they were the YOY or neonates (Figure 17). Using standardized methods, YOY were detected in one of the seven months, this capture occurred in May (Figure 16). Mean YOY SVL (16.75 ± 0.75 cm, Range: 16.0-17.5 cm) and TL (5.0 ± 0.5 cm, Range: 4.5-5.5 cm) (n = 4) (Table 4). By means of standardized methods, 92 % of all Northern Water Snakes were captured under boards at a distance of less than 2 m from the wetland and under board conditions moderate to more than 90 % sun exposure (Figure 18). Additionally, 100 % of all juveniles, females, and YOY were captured under boards at a distance of less than 2 m from the wetland and under board conditions moderate to more than 90 % sun exposure (Figure 18).

Males exhibited no significant difference when comparing the mean snout-vent lengths of the Northern Water Snake from this study to a study in the region (T-test: $t = -7.286$, $p = 0.087$) (Table 8). In addition, females from showed no significant difference to the same regional study (T-test: $t = -0.208$, $p = 0.848$) (Table 8). Compared to Pennsylvania generally, males showed no significant difference in body size (T-test: $t = -5.286$, $p = 0.119$) (Table 3). Similarly, females from this study exhibited no significant difference of body size when compared to Pennsylvania generally (T-test: $t = -1.816$, $p = 0.167$) (Table 3). Taken into account the total body lengths, females from this study possessed no significant difference in body sizes when compared to Pennsylvania in general (T-test: $t = -1.898$, $p = 0.154$) (Table 8).

Measurements displayed for mean cloacal temperatures include standardized, opportunistic, and recapture methods. Mean cloacal temperatures of Northern Water Snakes ranged from 20.2 °C to 34.6 °C (Table 4). The mean cloacal temperature for the Northern Water Snake were documented well above the mean local environmental temperatures, mean board surface temperatures, and mean soil surface temperatures (Table 4). Cloacal temperatures ranged 20 °C and 30 °C in 85 % of measured Northern Water Snakes (Table 4). Snakes with a mean SVL equal to or exceeding 51 cm had an average cloacal temperature (24.24 ± 1.48 °C, Range: 20.2-28.4 °C) (n = 5) and snakes with a mean SVL less than 51 cm had an average cloacal temperature (27.07 ± 0.89 °C, Range: 22.5-34.6 °C) (n = 15) (Table 4). Northern Water Snakes captured and measured before 12 p.m. exhibited mean cloacal temperature (27.94 ± 0.86 °C, Range: 25.2-31.4 °C) (n = 8) whereas snakes captured after 12 p.m. exhibited a mean cloacal temperature

(25.31 ± 1.13 °C, Range: 20.2-34.6 °C) (n = 12) (Table 4). Snakes captured in the months from May to July, possessed a mean cloacal temperature (27.25 ± 0.59 °C, Range: 25.2.0-31.4 °C) (n = 10), however snakes captured from August to October had a mean cloacal temperature (25.47 ± 1.47 °C, Range: 20.2-34.6 °C) (n = 10) (Table 4).

Lampropeltis triangulum - The Milk Snake (Figure 19). This species was found at two sites, Lake Letterkenny and Henry's Pond (Table 2), but were relatively rare at both of them (Table 1). Four males were captured using standardized methods; none appeared to be sexually mature. Two of the captures occurred in April (26.4 cm SVL and 3.9 cm TL; 37.7 cm SVL and 5.8 cm TL), one occurred in May (38.5 cm SVL and 7.0 cm TL), and the last capture occurred in October (32.0 cm SVL and 5.0 cm TL). Two captures occurred under boards positioned less than two meters from the wetland and the other two captures took place under boards positioned more than 10 meters from the wetland (Table 5). All four captures occurred under boards in the moderate sun exposure condition.

Coluber constrictor - The Eastern Racer (Figure 20). A single immature male, based on common juvenile pattern of coloration, 32.5 cm in SVL and 10.5 cm in TL, was captured during a standardized search in June. This individual was found under a cover board positioned more than 10 m away from Henry's Pond (Table 5) and was in a condition of maximum sun exposure. This juvenile eastern racer was not recaptured during this study.

Diadophis punctatus - The Ringneck Snake (Figure 21). A single sexually mature male, with immaculate venter, 27.5 cm in SVL and 8.5 cm in TL, was captured during an opportunistic search in September at Cole's Pond. This snake was encountered under a cover board positioned more than 10 m away from the wetland and in a condition of minimum sun exposure. This individual was not recaptured during this study.

WETLAND CHARACTERISTICS

Mean water temperature across all sites was 22.4 °C (Appendix 1). Shirley's pond exhibited the most alkaline mean pH (8.55) (Appendix 1). Henry's Pond has the most neutral mean pH (7.27) (Appendix 1). Shirley's Pond had the highest mean conductivity (215.3 μS) (Appendix 1). Henry's Pond exhibited the lowest mean conductivity (112.72 μS) (Appendix 1).

DISCUSSION

SPECIES COMPOSITION AND ASSEMBLAGE

This seven month capture-recapture study documented the presence of five snake species. Comparatively, this study detected 63 % of the eight snake species previously identified by Delis and coworkers (2010) in a study conducted within Zone II of LEAD, and correspondingly this study detected 63 % of the snake species identified by Meshaka and Delis (2013) in a more recent study conducted within the same region (Table 6). The species list accrued during this study marginally diverges from that of two aforementioned studies conducted within the region (Delis et al., 2010; Meshaka and Delis, 2013). Both previous studies detected three species not found in this survey and amassed species lists comprised of eight snake species, compared to the five found in this study (Table 6). All snake species detected in the course of this study were previously recorded and considered to be characteristic of the region. I did not detect five snake species formerly reported in similar studies in the region (Delis et al., 2010; Meshaka and Delis, 2013) (Table 6). The undetected species in this study were the Eastern Rat Snake, *Scotophis alleghaniensis*, (Holbrook, 1836), the Copperhead, *Agkistrodon contortrix*, (Linnaeus, 1766), the Timber Rattlesnake, *Crotalus horridus*, (Linnaeus, 1758), the Eastern Ribbon Snake, and the Redbelly Snake (Table 6). The latter four species are regarded as uncommon and are rarely observed within Franklin County. For example, the Redbelly Snake was detected once in 2009 (Meshaka and Delis, 2013) and once in 2013 (Pablo R. Delis, personal communication). The Eastern Ribbon Snake was detected once in 2003 during the study by Delis and coworkers (2010). The Timber Rattlesnake was reported once during the study by Delis and coworkers (2010), and the Copperhead has been captured by both studies from 2003 to 2013 (Delis et al., 2010; Meshaka and Delis, 2013). Paucities in captures during this study of the four snake species may corroborate assertions of actual rarity, at least some, of these snakes in this part of the state (Hulse et al., 2001; Meshaka and Delis, 2013). An additional explanation for the lower than expected snake species richness may be due to the wetland focused sampling protocol, which has limitations, possibly underrepresenting snake species that utilize more diverse habitats. For example, the apparent rarity of the Eastern Rat Snake, during this study could be explained by sampling techniques that were better suited for the capture of terrestrial species rather than semi-arboreal species, such as members of the genus *Scotophis* (Ernst, 2003).

The snake with the highest frequency of capture at LEAD's wetlands was expected to be the Northern Water Snake. This is partially attributable to this species ecological propensity to occupy a vast diversity of wetland landscapes (Conant and Collins, 1998; Ernst, 2003; Hulse et al., 2001). Also, in my study the majority of the cover board deployments were concentrated at wetland habitats. Yet, the Northern Water Snake was captured intermittently and significantly less frequently than expected; exclusive of the Lake Letterkenny site (Table 1). It remains to be seen why this species was counter-intuitively captured in such low numbers overall. In a prior study in Zone II of LEAD, the Northern Water Snake was captured relatively infrequently as well, with 16 new captures and 24 total captures during 2008 – 2011 at two open forested wetland sites (Meshaka and Delis, 2013). Thus, based on these findings it appears that the Northern Water Snake may be an uncommon snake species within the region. Patttishall (2008) observed increased site fidelity and reduced movement patterns by Northern Water Snakes in urbanized and modified areas compared to more natural areas. Therefore, it is possible that the individuals of the Northern Water Snake population within Zone I of LEAD, a heavily modified environment, may have been less inclined to travel from their long-standing preferred locations, thereby underutilizing the cover boards. Old (2007) noted that an artificial levee feature of the Embarras River in central Illinois actually increased the abundance of the Northern Water Snake population by providing basking locations and quick escape routes from predators. To that end, differential predation by herons and egrets on such aquatic species, especially one that must bask could explain the lower than expected numbers. The differences in sampling technique (i.e. varying the board distance to the water's edge) revealed dissimilarities in percentages of snake species captured, the most notable discrepancy being the Northern Water Snake. Greater than 90 % of all Northern Water Snakes were captured under boards less than 2 m from the edge of the water. Therefore, if the sampling technique concentrated all cover boards near the edge of the water, an entirely different snake assemblage may have been detected, with an increased possibility of the Northern Water Snake being the most frequently captured snake species. Ultimately, it is somewhat unclear as to why the Northern Water Snake appears to be such an uncommon component of this assemblage, when it seems to be a suitable region for it to be the dominant snake species.

The Common Garter Snake was, by a large margin, the dominant species in these assemblages having been ubiquitous at all wetland sites (Table 2). It has been noted that when present, the Eastern Racer can dominate grassland snake assemblages, especially large grasslands across the northeast (Meshaka et al., 2009). In large grassland habitats in south-central Pennsylvania, which is the preferred habitat for the Eastern Racer, this species is routinely dominant, exerting pressure on the assemblage structure by serving as the prevailing predator, preying upon larger individuals of several snake species such as the Common Garter Snake (Meshaka et al., 2009). Therefore, it may have been that the expectations were too high for the cover board locations contiguous to large open grassland habitats receiving increased occurrences of the Eastern Racer. Yet, additional lines of evidence for the possible high occurrences of the Eastern Racer were based on numerous observations of the species in Zone II of LEAD, determined from prior studies by Delis and coworkers (2010) and Meshaka and Delis (2013). Contrary to expectations, a solitary juvenile male Eastern Racer was detected throughout the extent of this study. Without the influence and burden from the large potential predatory species, the Eastern Racer, the Common Garter Snake populations have prospered around these particular wetland topographies. Thus, the seemingly absence, or at least extremely low densities, of the Eastern Racer at these wetlands appears to have influenced the assemblage structure, with no predatory snake species to apply pressure on the assemblage. Under these conditions, the Common Garter Snake has proliferated, becoming the dominate species. Therefore, cover board locations concentrated around woody wetland habitats far from large open grassland habitats may function as innocuous refuges that are suboptimal for the Eastern Racer and should be regarded as poor quality habitat for this species, safeguarding the Common Garter Snake from their predator.

A study conducted in western Pennsylvania and northeastern Ohio (Meshaka et al., 2009) corroborated the finding that in the absence of the large predator, the Eastern Racer; the Common Garter Snake can dominate the highly uneven assemblage, successfully out-competing other syntopic snake species for prey items such as earthworms and slugs. The Common Garter has also been noted to prey on smaller snake species as another method for competition with its syntopic neighbors; however this behavior seems to occur in very low frequencies and appears to transpire under distressed circumstances (Meshaka et al., 2009).

Accompanied with high numbers of the Common Garter Snake, this study detected very low numbers of several species common to the region. This is suggestive that the other snake species such as the Ringneck Snake and the Milk Snake are being outcompeted for dietary resources or were missed due to exclusive sampling focus on open-water habitats. Considering the deficiency of snake species richness and the substantially low abundances of any other snake species besides the Common Garter Snake, my study seems to support the domino effect theory as outlined by Meshaka and coworkers (2009) as the explanation for the pattern observed around these wetlands.

As a component to the domino effect theory, it has been noted of some snake assemblages in Pennsylvania, that even if they possess high species richness, the species evenness is highly unbalanced (Meshaka et al., 2008; Meshaka et al., 2009). This study's high occurrences of the Common Garter Snake is not atypical, rather it is characteristic of numerous snake assemblages across Pennsylvania (Meshaka et al., 2008; Gray, 2011), as the Common Garter Snake is the most frequently encountered serpent of the northeast (Hulse et al., 2001). In a study conducted in Erie County, Pennsylvania, the Common Garter Snake comprised 49.2 % of all the snake observations (Gray, 2011), and was encountered in a considerably greater abundance than any of the five snake species detected in this study.

Established by this seven-month investigation, the snake species list for the open-water wetlands studied in Zone I at LEAD encompasses just over one-half of the expected snake species richness in the region. The number of snake species detected in this study continued to increase throughout the sampling season, suggesting that future survey seasons may ultimately yield a more comprehensive species list. The total species encountered in this study should be considered a preliminary assessment, and this study best serves as a conservative estimate on the true species richness of LEAD's Zone I wetlands. The conservative nature of the species list accrued here can be partially attributed to the study being subjected to the sampling constraint of only one survey season. Ultimately, it remains unknown the extent to which one single sampling season could be representative of the true species evenness and richness of these wetland snake assemblages in my study.

SEASONAL ACTIVITY

The snake assemblage detected in Zone I of LEAD exhibited a bimodal pattern of seasonal activity, with the highest numbers occurring in June (n = 16) and in August (n = 17) of the April to October sampling period (Figure 7). The lowest number of captures occurred in October (n = 2) (Figure 7). In Zone II of LEAD, Meshaka and Delis (2013) detected a unimodal peak in snake activity with the highest numbers occurring in May (n = 59). Seasonal activity of snakes was bimodal with June and July peaks, in western Pennsylvania (Meshaka, 2010) and was unimodal with a June peak in northwestern Pennsylvania (Gray, 2011). The considerably low number of snakes captured in July (n = 4) was unexpected since this month has persisted as a productive interval for the activity periods of snakes in other regions of Pennsylvania (Meshaka, 2010; Meshaka et al., 2008; Meshaka and Delis, 2013). The range of the average board surface temperatures from May to October was 19.67-34.15 °C, and the range of the average soil surface temperature from May to October was 11.95-29.02 °C. The peak average temperatures for board surfaces and soil surfaces both came in the month of July, 34.15 °C and 29.02 °C, respectively (Figure 7). The lowest average temperatures for board surfaces and soil surfaces both came in the month of October, 19.67 °C and 11.95 °C (Figure 7). Thus, the dearth of snake captures in the months of July and October correspond to the extreme limits of the measured temperatures. The maximum tolerable temperature for the Common Garter Snake is approximately 40 °C and it has been indicated that few snakes are active below 20 °C and above 30 °C (Carpenter, 1956). Above 30 °C, snakes level of exertion generally produces behaviors to avoid heat, and at temperatures below 20 °C, they generally become increasingly inactive (Carpenter, 1956). Therefore, a plausible explanation for the low abundances observed during July, a historically productive month, is that the survey was conducted during a time of dangerously high heat conditions, consequently compelling snakes to seek refuge in cool areas in order to avoid physiological stress.

The two species for which adequate samples were acquired exhibited single peaks in their activity patterns, June for the Northern Water Snake and August for the Common Garter Snake. The Common Garter Snake has displayed some variation in seasonal activity patterns across Pennsylvania. Several Pennsylvanian populations exhibited unimodal peaks occurring in May (Hulse et al., 2001), July (Meshaka et al., 2009), and June (Meshaka and Delis, 2013). Other bimodal peaks were observed in Pennsylvania, such as April and June (Gray, 2011) and May and September (Meshaka et al., 2009).

However, the unimodal seasonal activity pattern of the Northern Water Snake in Zone I may typify the most common activity pattern for this species in Pennsylvania (Hulse et al., 2001; Meshaka and Delis, 2013).

SEX RATIOS

This study provided inadequate sample sizes for the Milk Snake, the Ringneck Snake, and the Eastern Racer to generate significant conclusions or accurate comparisons amongst Pennsylvania's snake populations concerning the sex ratios for the species. The female-biased sex ratio for the Common Garter Snake was consistent with findings of other studies utilizing cover boards for the standardized capture methodology in Pennsylvania (Meshaka et al., 2009; Meshaka, 2010; Meshaka and Delis, 2013). On the other hand, the female-biased sex ratio observed in this study for the Northern Water Snake was inconsistent with prior findings from the region (Meshaka and Delis, 2013). In light of small sample sizes for this species, it remains unclear if the female bias in captures was real or an artifact of sampling. The large number of captured females for the Common Garter Snake and the Northern Water Snake is relatively consistent with the limitations derived from cover board surveys, in which gravid females preferentially pursue the thermoregulatory benefit that the boards provide, possibly to promote the gestational development of young in these ovoviviparous species.

The relatively small sample sizes and skewed sex ratios constrained the scope of which sex-specific activity patterns could be detected. However, through adequate detections of the Common Garter Snake inferences regarding sex-specific activity could be realized with credible accuracy. Male Common Garter snakes were all but absent from this study with a sole encounter in September. Gravid Females exhibited a peak in activity in June; subsequently YOY were first detected and showed a peak in numbers in the month of August. The high number of YOY detected in August and the peak activity of gravid females coming in June seems to corroborate analogous parturition patterns of several Pennsylvania studies (Meshaka and Delis, 2013; Hulse et al., 2001). Male and female Northern Water Snakes had a unimodal seasonal activity, with a peak in June, supporting claims of Pennsylvanian populations displaying courtship and mating in June (Hulse et al., 2001). Juveniles were observed throughout most of the sampling months. Being of a smaller size and not sexually mature, juveniles may preferentially utilize the cover boards for thermoregulation more often than adults, as it is advantageous for a juvenile to grow rapidly to achieve a larger size, minimize opportunistic predation, and ultimately reach sexual maturity. Adult Common Garter Snakes have higher survival rates and are less prone to predation (Ernst, 2003). Larger snakes typically have more extensive energy reserves than smaller snakes and these stores are advantageous during extended bouts of brumation. Therefore, for juveniles to achieve maximal growth, it is beneficial to optimize the thermoregulatory process by cover board supplementation, accruing sufficient energy stores in order to survive hibernation.

BODY SIZES

The Milk Snake (n = 4), the Ringneck Snake (n = 1), and the Eastern Racer (n = 1) were not abundant. Therefore, it is not possible to generate reliable inferences and use in accurate comparisons with other Pennsylvanian populations with regard to body sizes. However, sufficient individuals of the Northern Water Snake and the Common Garter Snake were captured to allow for some deductions with regarding body sizes. The minimum body sizes for the Common Garter Snake at sexual maturity were set as per Hulse and colleagues (2001); males (27.0 cm) and females (36.0 cm). Discerning the YOY of the Common Garter Snake was roughly based on average SVL of neonates as per Hulse and coworkers (2001), set at 20.0cm SVL. The minimum body sizes for the Northern Water Snake at sexual maturity were set as per Hulse and colleagues (2001); males (32.0 cm) and females (51.0 cm). Discerning YOY of the Northern Water Snake was based on average SVL of neonates as per Hulse and coworkers (2001), at 20.0 cm. The Common Garter Snake exhibited the greatest variability in body size, especially for females. Females of the Northern Water Snake also showed a high level of variability in body size compared to males. Dimorphism of body size amongst sexes has been reported for both species (Hulse et al., 2001). The occurrence of sexual dimorphism in these two species is consistent with smaller mean body sizes in males than in females. When comparing the mean snout-vent lengths of the Common Garter Snake from this study to a study in the region, males showed no significant difference, while females from this study tended to possess a smaller mean snout-vent length from the females measured by Meshaka and Delis (2013) (Table 8). Conversely, females from this study exhibited no significant difference in the mean snout-vent length when compared to Pennsylvania in general (Hulse et al., 2001) (Table 3). However, taken into account the total body lengths, females from this study possessed a disposition to being larger when compared to Pennsylvania in general (Hulse et al., 2001) (Table 3). When comparing the mean snout-vent lengths of the Northern Water Snake from this study to another study in the region (Meshaka and Delis, 2013), males exhibited no significant difference, additionally females showed no significant difference (Table 8). When compared to Pennsylvania generally (Hulse et al., 2001), males showed no significant difference in body size (Table 3). Similarly, females from this study exhibited no significant difference of body size when compared to Pennsylvania generally (Hulse et al., 2001) (Table 3). Females from this study possessed no significant difference in body sizes when compared to those of

Pennsylvania in general, taking into account total body lengths (Hulse et al., 2001) (Table 3). The variations in body sizes of the Common Garter Snake and Northern Water Snake from the wetlands of Zone I, compared to other populations, seems to support the high levels of phenotypic plasticity of both species.

MICROHABITAT SELECTION

Sufficient cloacal temperature data were obtained for two of the five snake species detected; the Common Garter Snake and the Northern Water Snake. Sixty-nine percent of all records for the Common Garter Snake had cloacal temperatures between 20 °C and 30 °C (Table 4), this is comparable to a population in Michigan, in which 70 % of the Common Garter Snakes showed the same temperature range (Carpenter, 1956). These findings support the notion that the Common Garter Snake actively seeks 20 °C - 30 °C optimal internal temperature range (Carpenter, 1956; Peterson, 1987). The cloacal temperatures of the Common Garter Snakes were somehow correlated with the temperatures on the board surfaces and the temperatures on the soil surfaces but did not show a relationship with the body sizes (SVL) (Figure 14). These correlations between soil and board surfaces and cloacal temperatures suggest that these snakes are exhibiting temperature control through behavioral thermoregulation, by optimizing the use of the cover boards. The patterns associated with cloacal temperatures of the Common Garter Snake seems to indicate that heating mechanisms used may be influenced by behavioral thermal selection by optimal utilization of the thermal environment, for instance cover boards (Peterson, 1987). Optimal utilization of the thermal environment has several important implications including the achievement of body temperatures at which many physiological processes are maximized. Peterson and coworkers (1987) noted that possible constraints upon thermoregulation, such as predation risk, competition, or energetic costs of thermoregulatory adjustments seldom prevented snakes from obtaining optimal internal temperature levels when broad options of thermal environments were available. Therefore, the underlying assumption is that the animals consistently attempt to thermoregulate within their preferred range, in order to maximize the proficiency of metabolic processes. Nevertheless, there is an inherent bias in snake studies that use cover boards, since certain snake demographics utilize the boards more frequently, such as juvenile snakes, gravid females, and snakes with a recent meal. Additionally, some snake species do not exploit cover boards and have a tendency to avoid them all together, for example the Eastern Rat Snake is nearly absent from cover board snake surveys despite frequent opportunistic encounters of this species in the field (Meshaka and Delis, 2013). Therefore, my study also highlights the possible limitation to using exclusively cover boards in snake surveys, which may result in a low detection of species diversity. Varying the deployment of cover boards in snake surveys, with respect to positioning from important landscape features (i.e. grasslands, wetlands, and artificial structures) may reveal unanticipated results, thus proper qualifications must be inferred based on each specific sampling. Future studies should apply an increased variety of trapping and sampling techniques in an attempt to avoid potential constraints associated with cover boards.

The Northern Water Snake was found at Shirley's Pond and Lake Letterkenny, which included more than 50 % of all the cover boards deployed and had the two largest perimeters of all the sites. Therefore, larger wetland sites may offer more tracts of open-canopy terrain along the edge of the water, with an overall increase in available basking areas. Consequently, this may provide an advantage for optimal thermoregulation and less competition for this aquatic species. Perhaps this is the reason why more individuals were encountered at the larger wetland sites of this study.

As anticipated, the Northern Water Snake was predominately found under cover boards positioned near (< 2 m) the edge of the water (n = 12) versus boards positioned distantly (> 10 m) from the edge of the water (n = 1). This proclivity for seeking refuge near the water's edge can be associated with the species predilection for the aquatic escape route when startled (Hulse et al., 2001), and may also serve as an optimal vantage point when hunting their preferred diet of fish (Hulse et al., 2001), which several studies elsewhere have shown can constitute 50 % to 90 % of the overall diet (King, 1986; Raney, 1947). Thus, the microhabitat selection of the Northern Water Snake may be associated with the trophodynamics of their diet and is consistent with the known requirements of this species (Hulse et al., 2001; Ernst, 2003).

IMPLICATIONS FOR CONSERVATION

Although highly uneven in structure, the snake assemblages of these artificial wetlands can be viewed as satisfactory with respect to species richness and demographic traits. However, a single season of sampling, despite the high number of cover boards could easily be a source of underrepresentation of species and abundance. To my knowledge, this is the first study focused exclusively on wetland-associated snake assemblages in Pennsylvania. The dearth of biological information concerning the indigenous aquatic and semi-aquatic snake species of the state is recognized as the greatest constraint for conservation for either individuals or entire snake assemblages (Dodd, 1993). My findings indicate a similarity between abundance and species richness of snake assemblages in these artificial wetlands to those of natural and man-made wetlands in south-central Pennsylvania (Meshaka and Delis, 2013). The two dominant snake species which comprised more than 90 % of the snake assemblage were semi-aquatic and aquatic, and the regularity with these two species were encountered was similar to other Pennsylvanian assemblages occupying wetland habitats. The detection of a sensitive wetland snake species in 2006, the Queen Snake, basking near a stream in Zone I (Samuel J. Pelesky, personal communication), opens the possibility that the wetland features of Zone I may not be as polluted as formerly suspected. Thus, the possible high-quality wetland features of Zone I ostensibly heightened the expectations of a more diverse snake assemblage and increased encounters of the Northern Water Snake. Yet, although the Northern Water Snake was significantly more numerous than the other three snake species combined, its capture rates fell short of anticipated abundance and was encountered at a distant second to the Common Garter Snake. One of the goals is that my findings will increase efforts into the investigation of artificial wetlands serving as alternatives for natural wetlands. The long-term goal is to raise conservation awareness and understanding of the value of protecting wetlands and their snake assemblages. My findings offer some lines of support to the concept that creating wetlands in forested environments in Pennsylvania will play a positive ecological role for the native aquatic and semi-aquatic snake species. In my opinion, future research should focus on comparing natural and artificial wetland-associated snake assemblages at protected and unprotected sites.

IMPLICATIONS FOR WETLAND MANAGEMENT

The monthly fluctuations in pH and conductivity during this study may suggest some inconsistencies in source water and periodic changes of nutrient in-flux to the wetlands. Yet, more investigation into this topic is needed to understand the impact on the snake community. The consistently high conductivity recorded at Shirley’s Pond (mean: 215.3 µS), may have been influenced by the local geology of the region. Another possible source of higher levels of conductivity at Shirley's Pond may be general contaminants known to be in the area (Swenson, 2007). For example, an oil burn pit is located in the south-east section of Zone I, approximately 800 m away from the wetland. It was principally operated in the 1970s for the disposal of waste oil and solvents from industrial missions at LEAD (Landry, 2009). Several times, critical removal actions of soils at the pit were performed by the depot in the late 1990s, and investigations near the pit conducted through 2002 indicated that significant volatile organic compounds were present in the pit area groundwater (Landry, 2009). Thus, it is possible that this pit may have produced materials that influenced the conductivity measurements at Shirley's Pond. Future studies should continue to monitor the water chemistry at Shirley's Pond and nearby subsurface and above-surface runoff, additionally incorporating a more in depth analysis investigating potential explanations for the high levels of conductivity and the long-term impacts it may have on the resident biota.

Wetlands support high species diversities and serve as essential habitat for many groups of organisms, yet they are under constant threats of destruction for agricultural and commercial development (Gibbons, 2006; PGC, 2005). Thus, for the conservation of wetland-associated biota, it remains imperative that critical habitats are protected. My findings support that these wetlands maintain generally healthy levels of snake abundance and snake species richness, somewhat comparable to those of unprotected and protected wetlands elsewhere (Dalrymple, 1991; Karns, 2005; Meshaka and Delis, 2013). This is especially significant given the intensive land use (i.e. roads, munitions, hazardous material storage, and groundwater contamination) of Zone I. Therefore, if the protection of wetlands can become routinely implemented into Pennsylvanian management plans, they may function as critical habitats for augmenting regional snake diversity. Additionally, future wetland creation practices should incorporate broad land management techniques, concentrating on a myriad of habitat types, contiguous to and nearby the man-made wetlands. For example, integrating wetlands with nearby grasslands, generating uninterrupted connections between local wetlands, and creating wetlands with a variety of hydroperiods may promote increased biodiversity and enhance ecosystem health. This study can be used as a resource for the conservation of wetland-associated snake populations and the management of these wetlands at LEAD, with potential applications across Pennsylvania.

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Figure 1: Aerial view of Franklin County, south-central Pennsylvania with significant urban areas, Shippensburg, Chambersburg, and the Letterkenny Army Depot (LEAD). Image modified from Google Earth®.

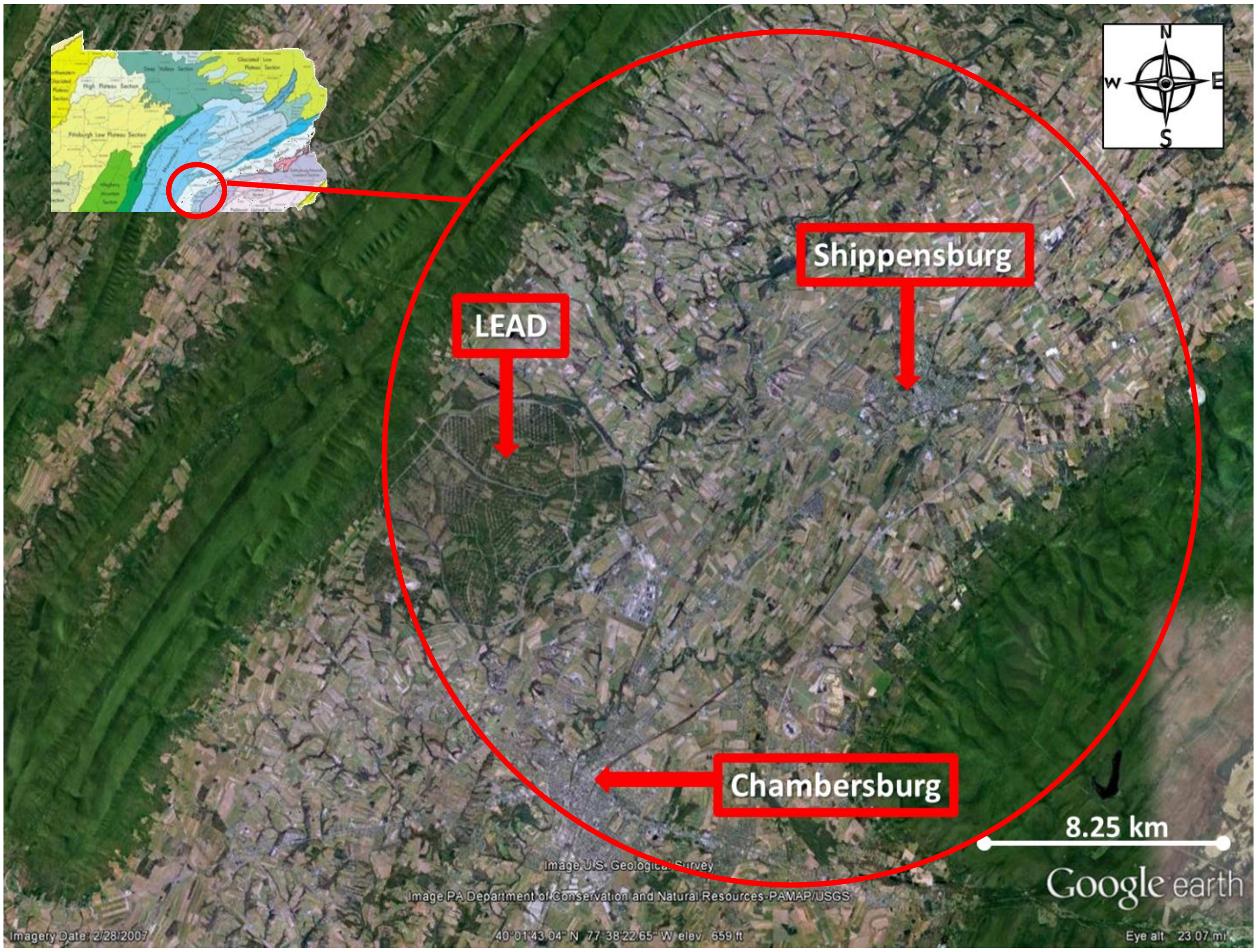


Figure 2: Aerial view of Letterkenny Army Depot (LEAD), Chambersburg, Pennsylvania. Labeled are wetland sites and important areas within LEAD. Image modified from Google Earth®.

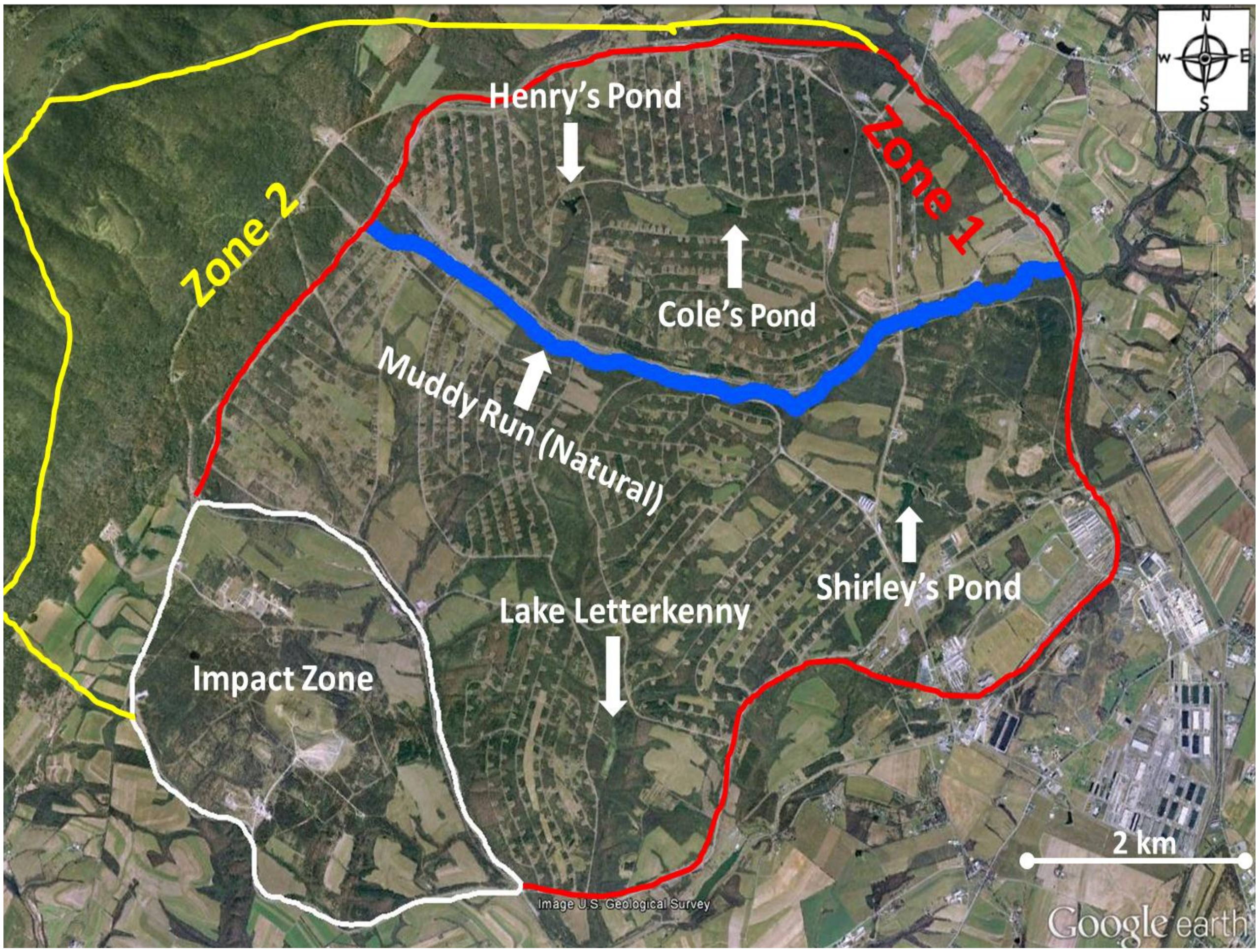


Figure 3: Aerial view of wetland sites within Letterkenny Army Depot (LEAD), Chambersburg, Pennsylvania. A- Cole's Pond; B- Henry's Pond; C- Shirley's Pond; D- Lake Letterkenny. Wetland sites with cover boards locations and important measurements in meters. Image modified from Google Earth®.

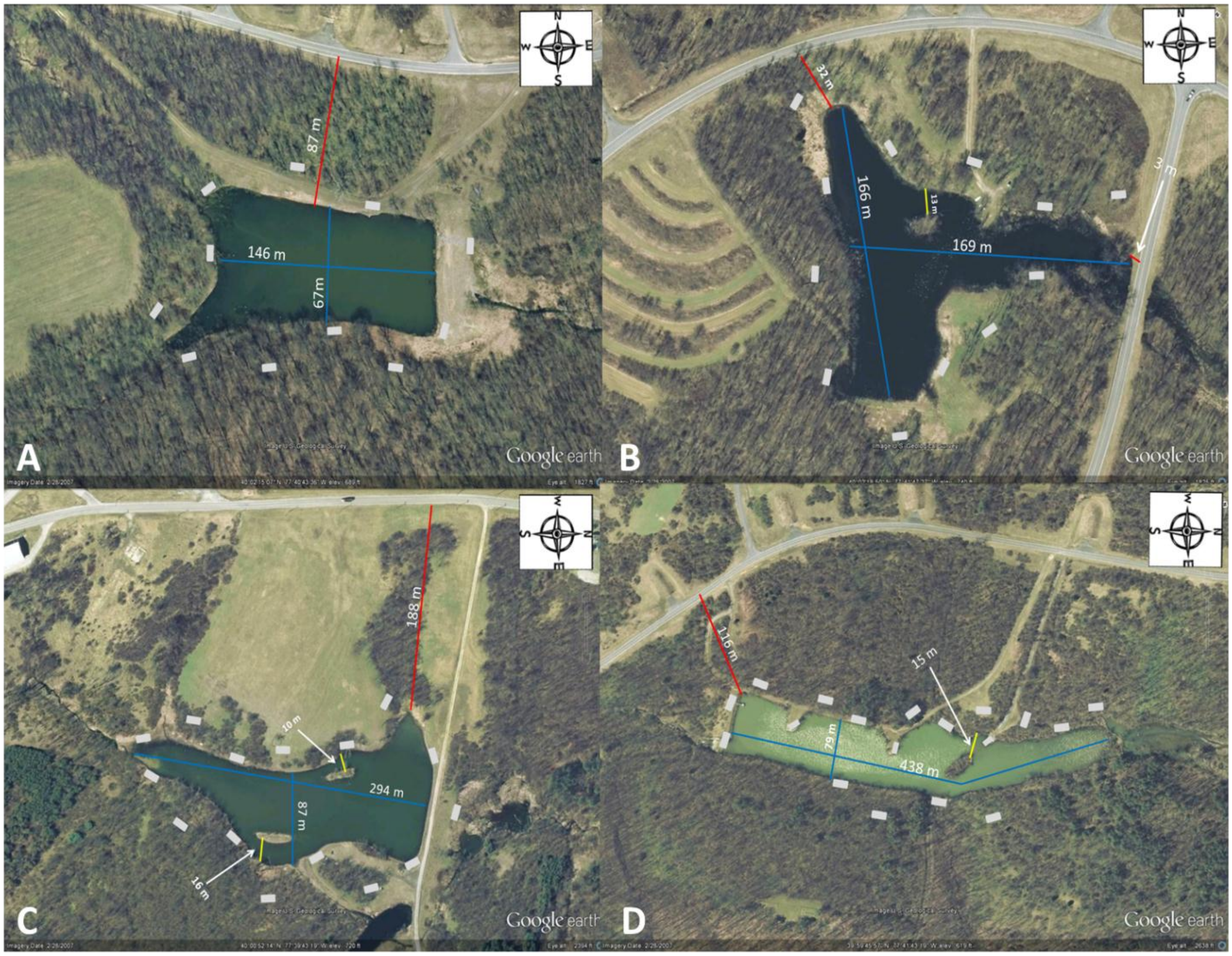


Figure 4: Total number of snakes captured during standardized and opportunistic searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

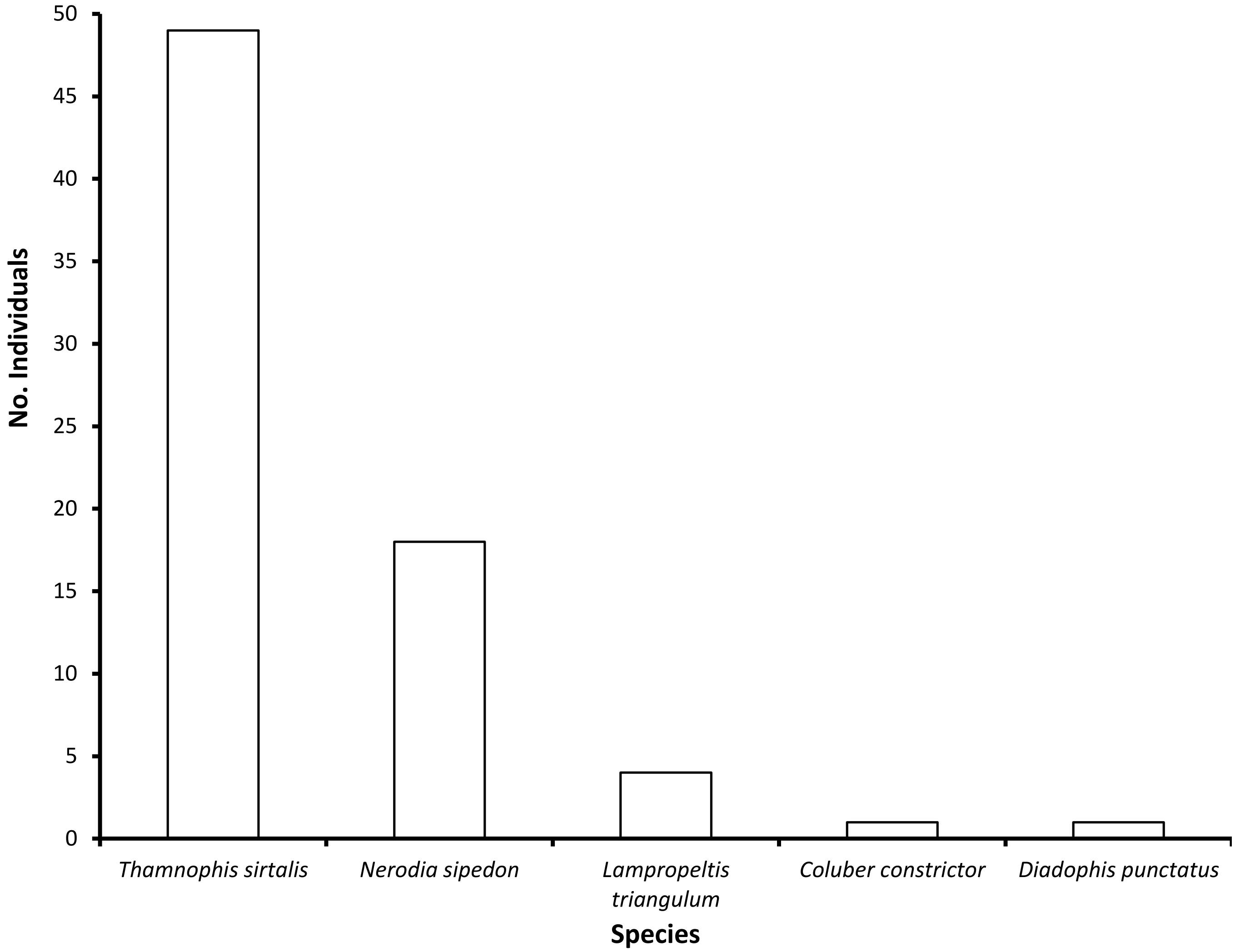


Figure 5: Relative abundance, expressed as a percent, of snake species captured during standardized and opportunistic searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

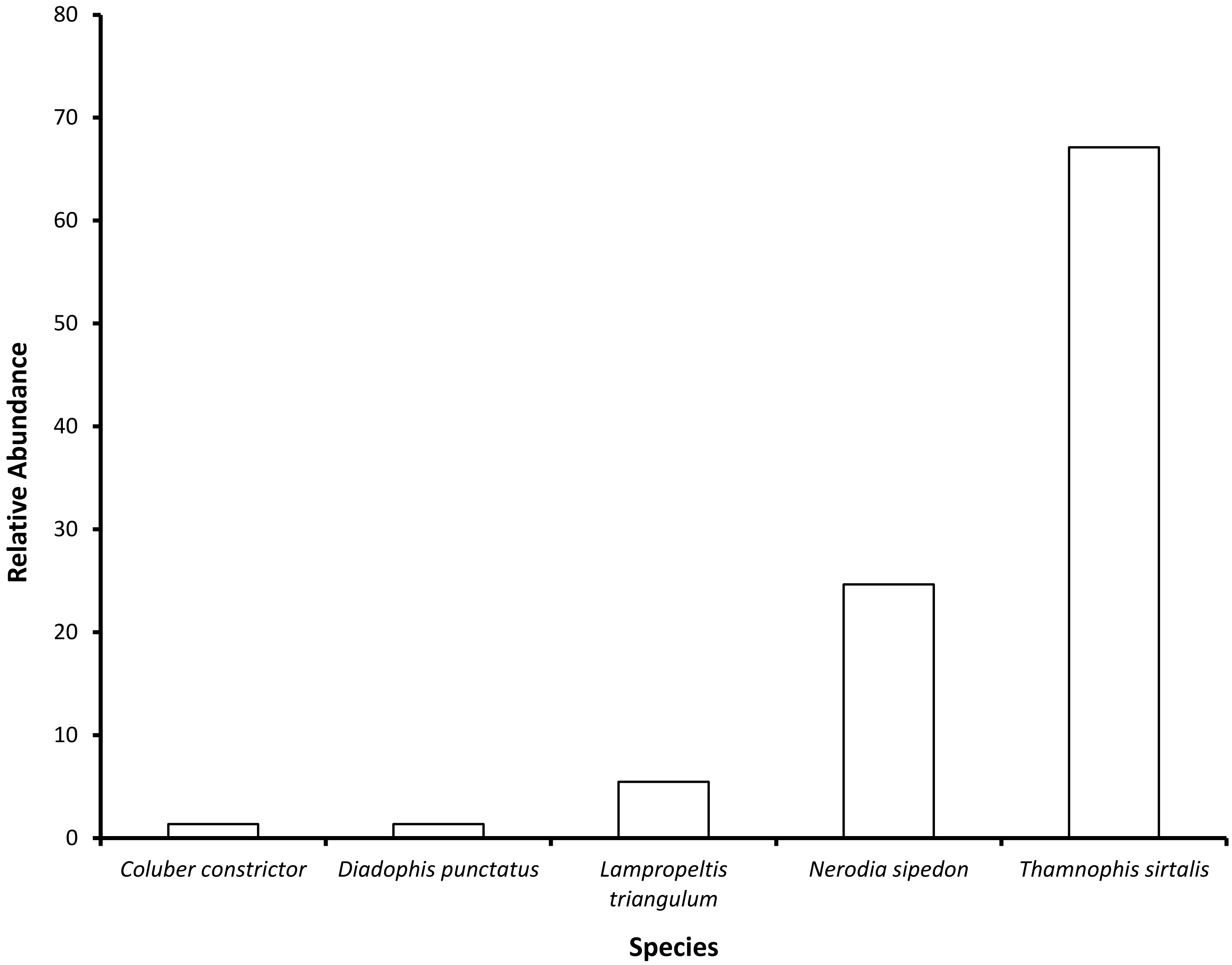


Figure 6: Relative abundance, , expressed as a percent, of individual snakes (n = 73) distributed among the four wetland sites for all species captured during opportunistic and standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

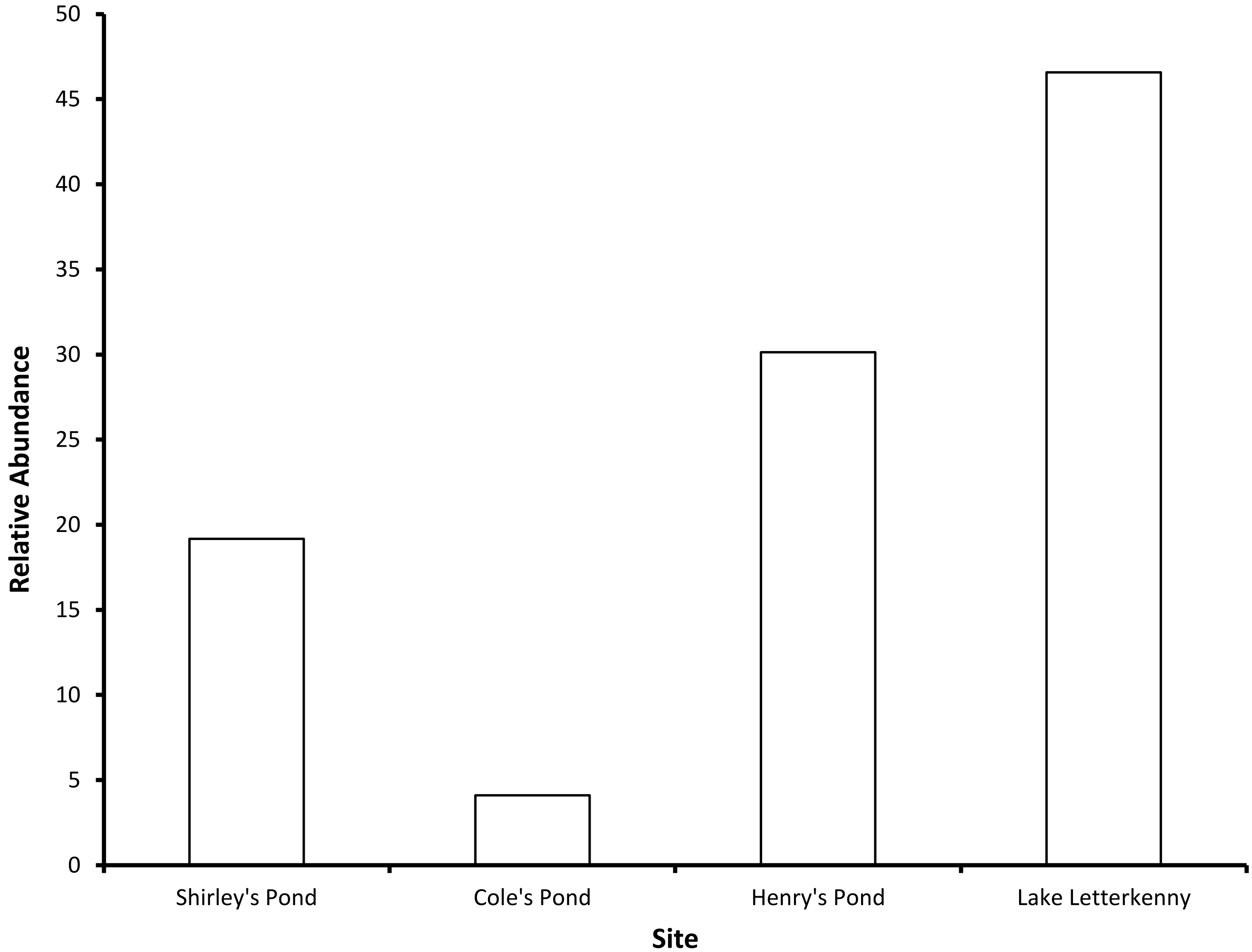


Figure 7: Monthly distribution of individual snakes for all species (n = 62) captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012. Monthly averages of board surface temperature (BST), ground surface temperature (GST) and ambient air temperature (AAT) in Celsius during the sampling day are displayed on a third axis.

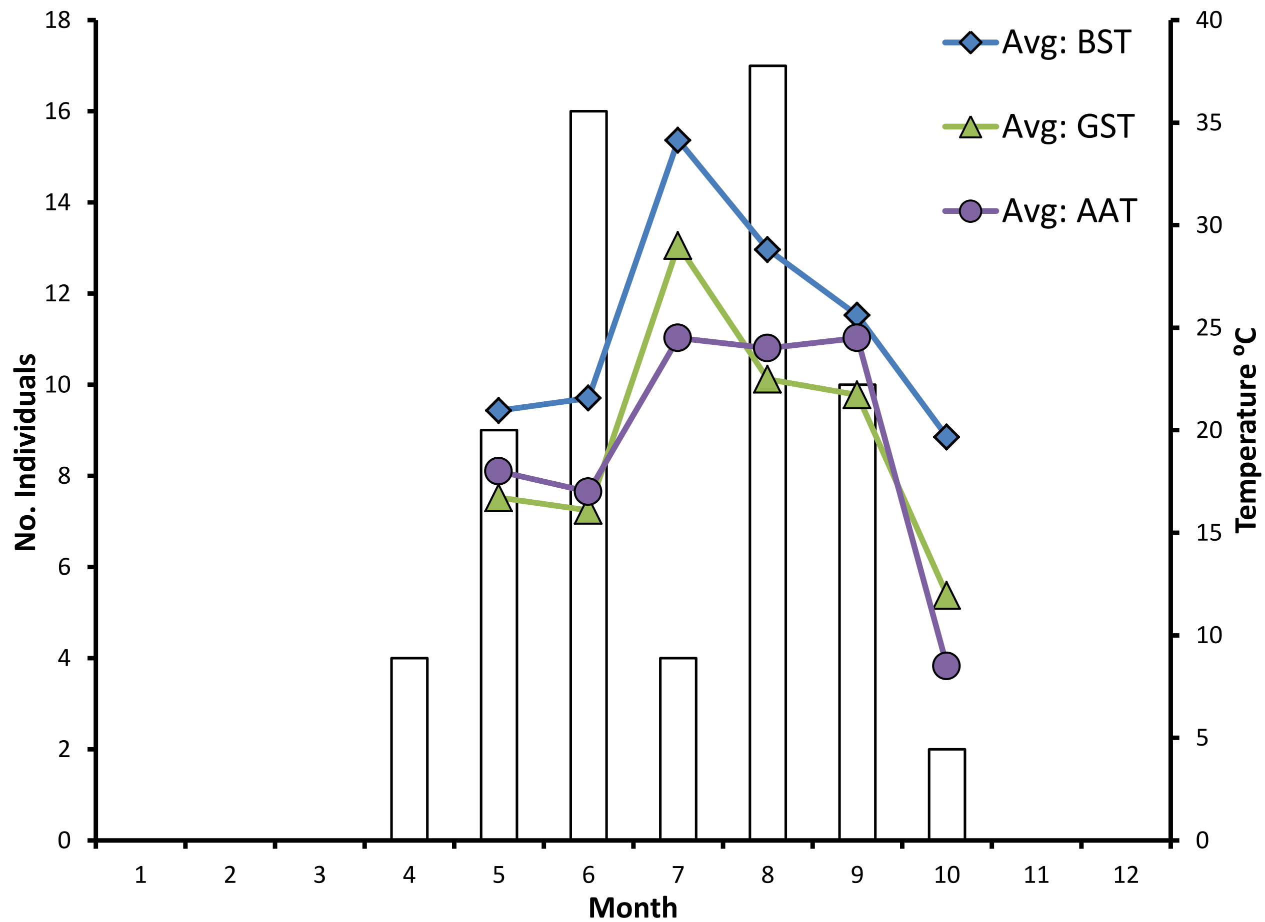


Figure 8: An adult female Common Garter Snake, *Thamnophis sirtalis*, found traversing the limbs of a tree, more than two meters above the ground, on 4 June 2012, at the Letterkenny Army Depot, Chambersburg, Pennsylvania.

Figure 9: Monthly distribution of Common Garter Snakes, *Thamnophis sirtalis*, males (n = 1), females (n = 21), juveniles (n = 9), and young-of-the-year (YOY) (n = 4) captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

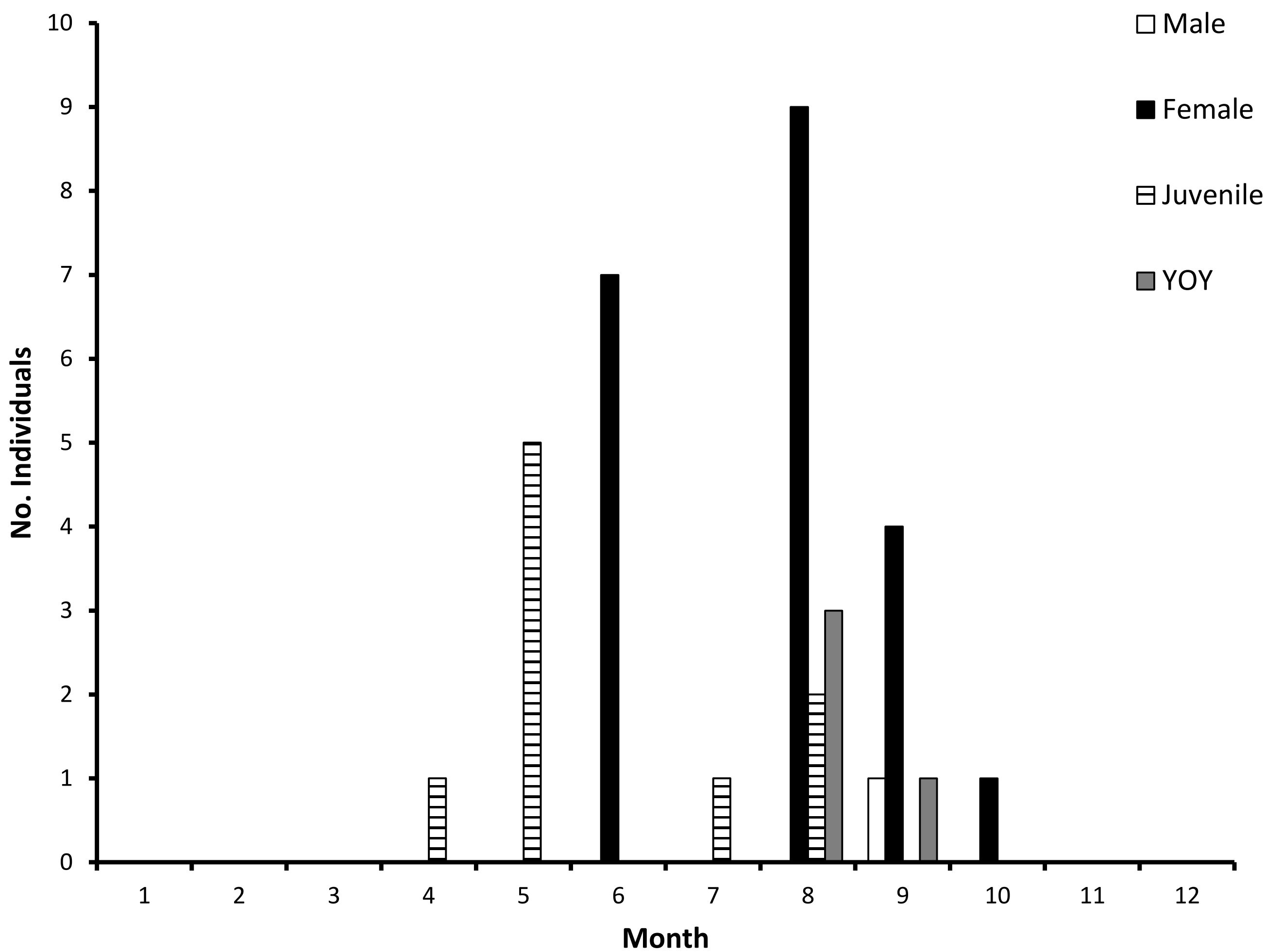


Figure 10: Monthly distribution of body sizes (SVL in cm) for Common Garter Snakes, *Thamnophis sirtalis*, males (n = 1), females (n = 34), juveniles (n = 10), and young-of-the-year (YOY) (n = 4) captured during standardized and opportunistic searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

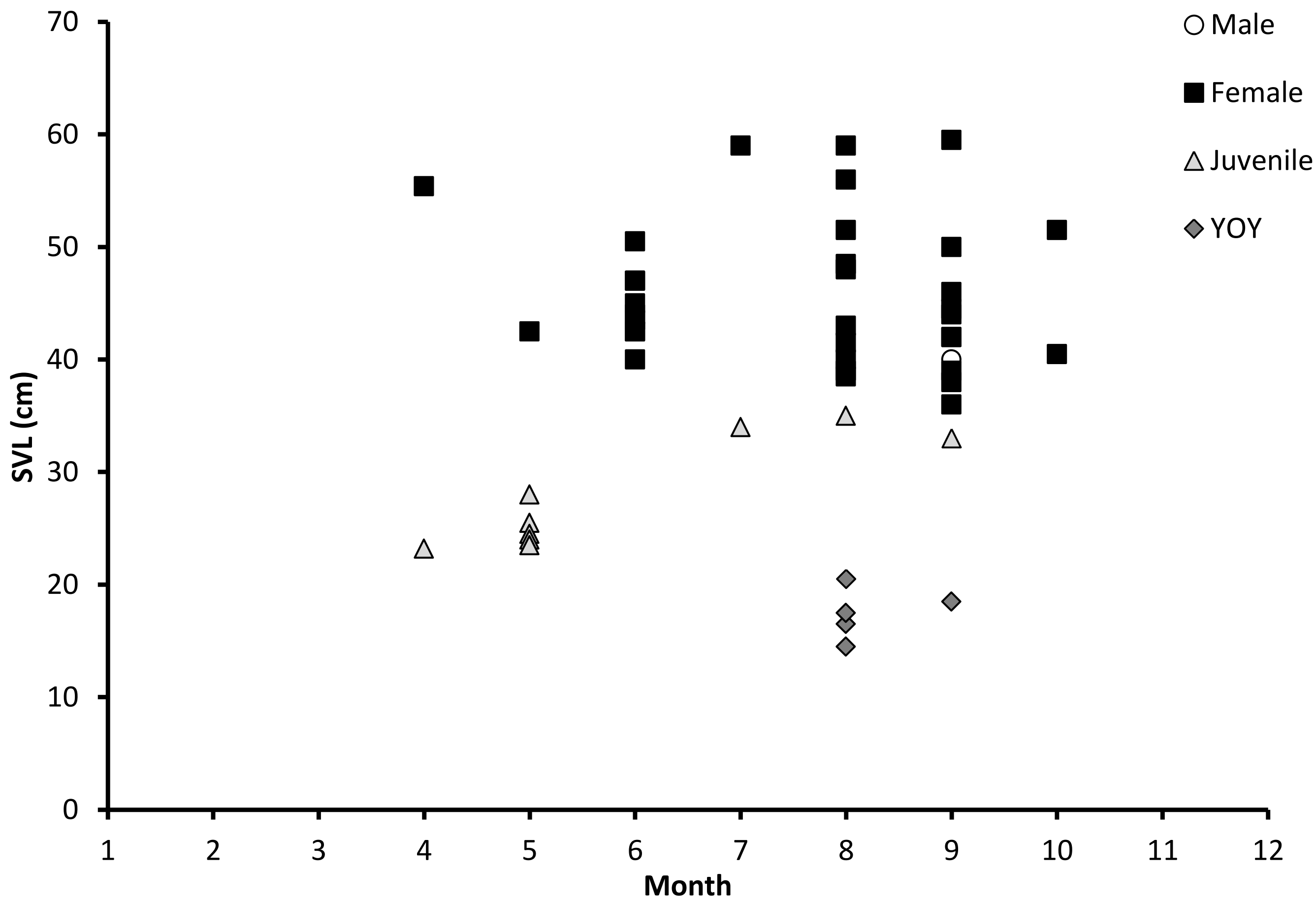


Figure 11: Monthly distribution of Common Garter Snakes, *Thamnophis sirtalis*, gravid females (n = 10), juveniles (n = 10), and young-of-the-year (YOY) (n = 4) captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

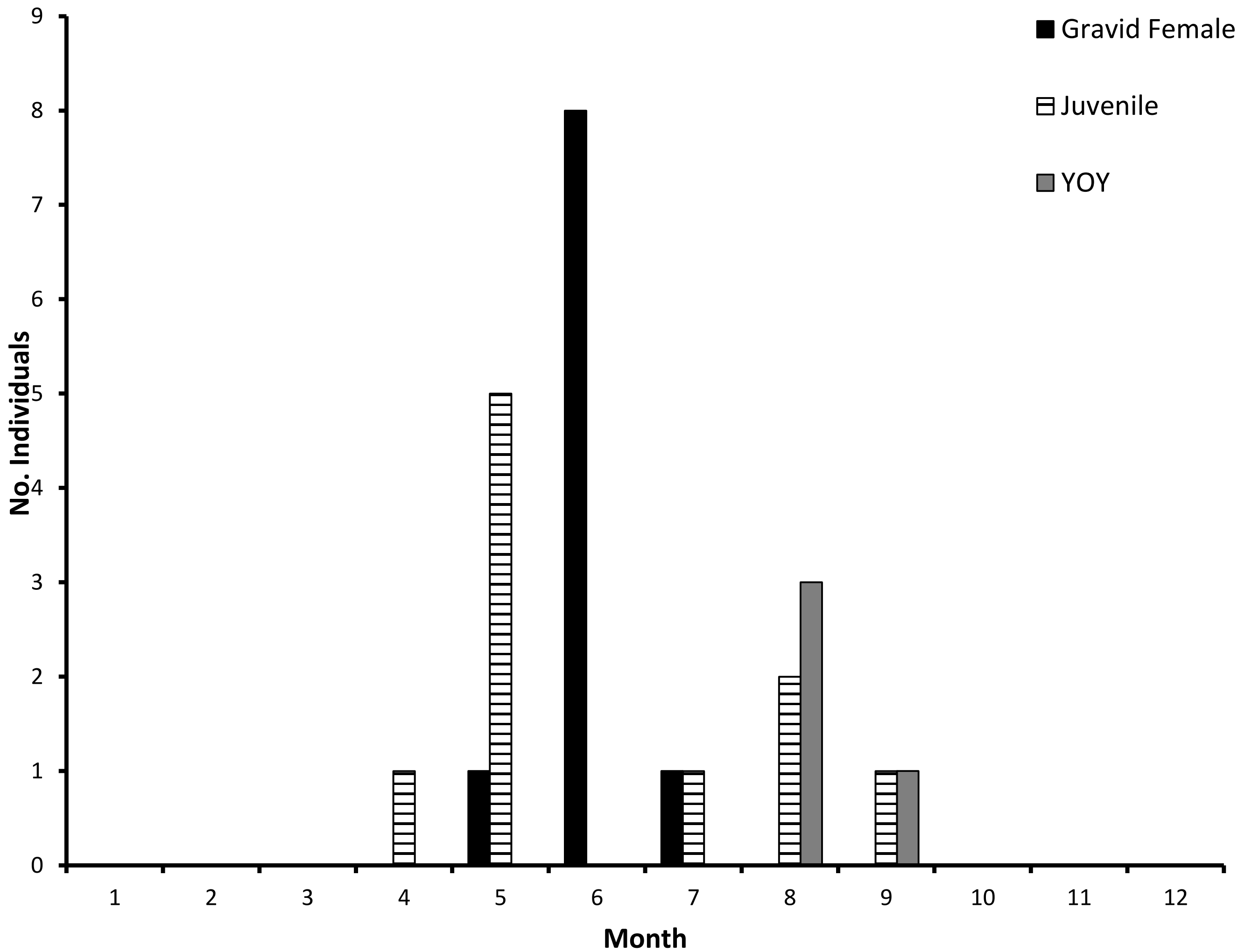


Figure 12: Relationship between clutch sizes and female body sizes (SVL in cm) of the Common Garter Snake, *Thamnophis sirtalis*, (n = 8) captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012. Equation, R^2, and F-statistic from ANOVA simple regression analysis displayed on graph. *Denotes statistical significance.

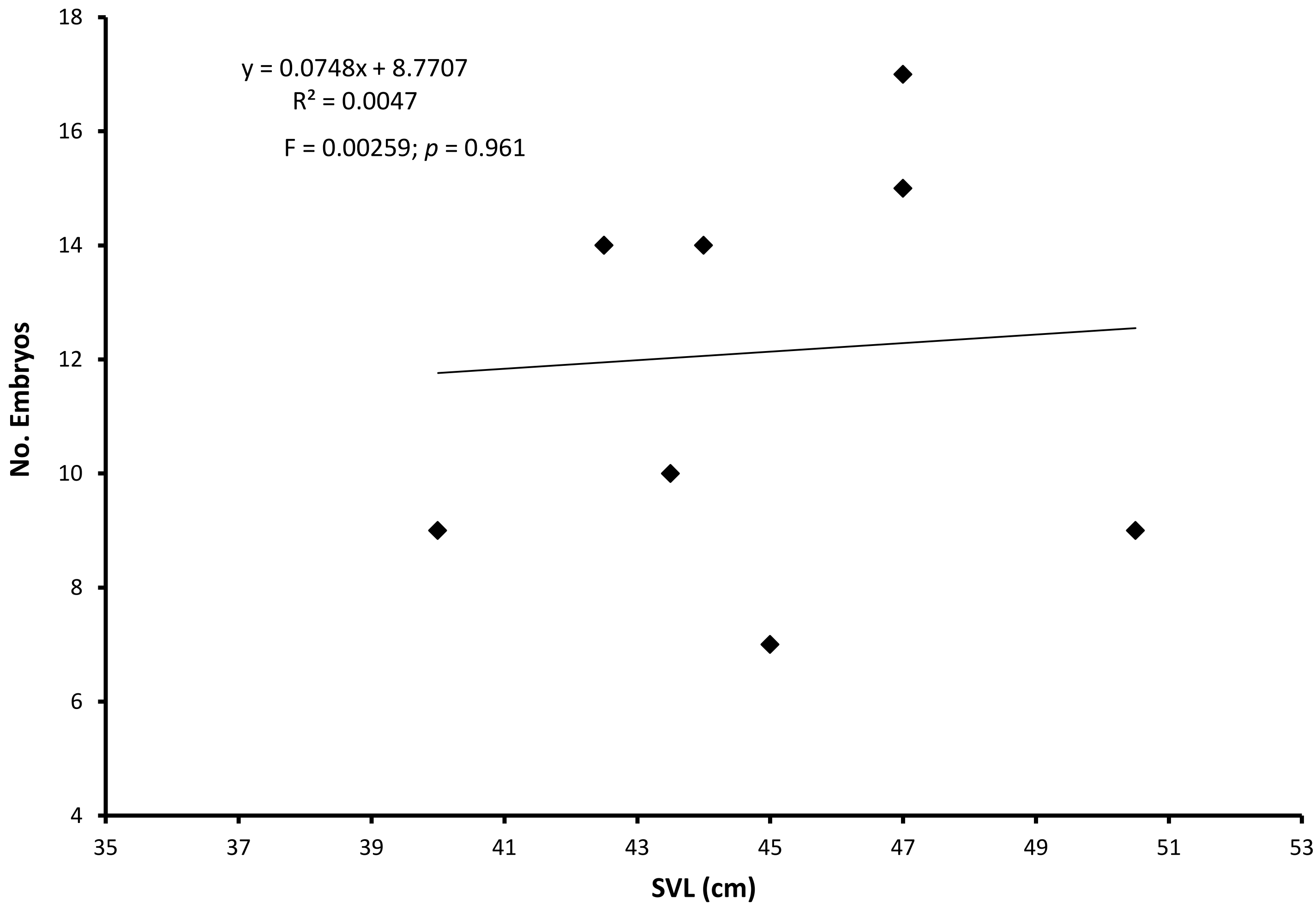


Figure 13: Distribution patterns of Common Garter Snakes, *Thamnophis sirtalis*, (n = 35) captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

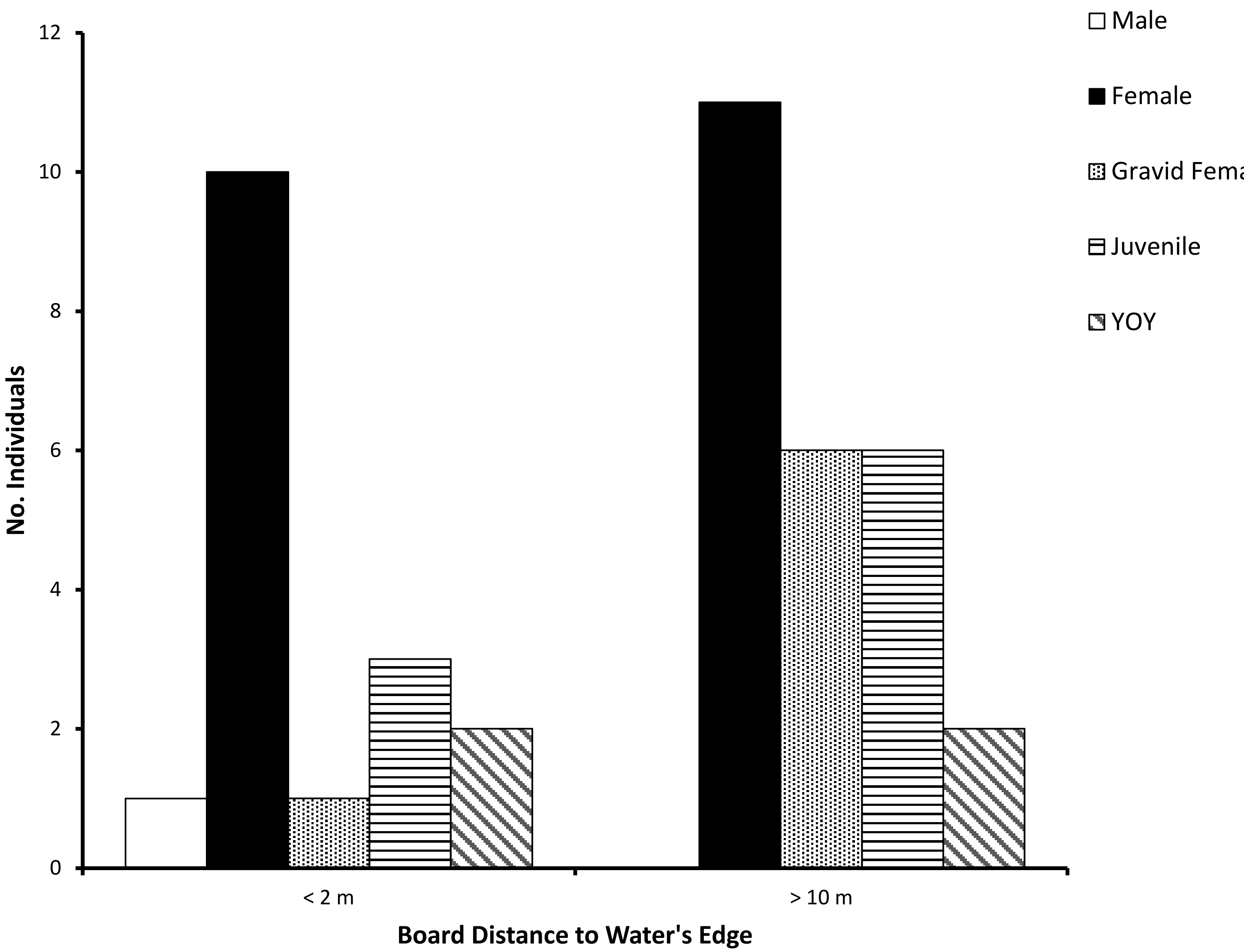
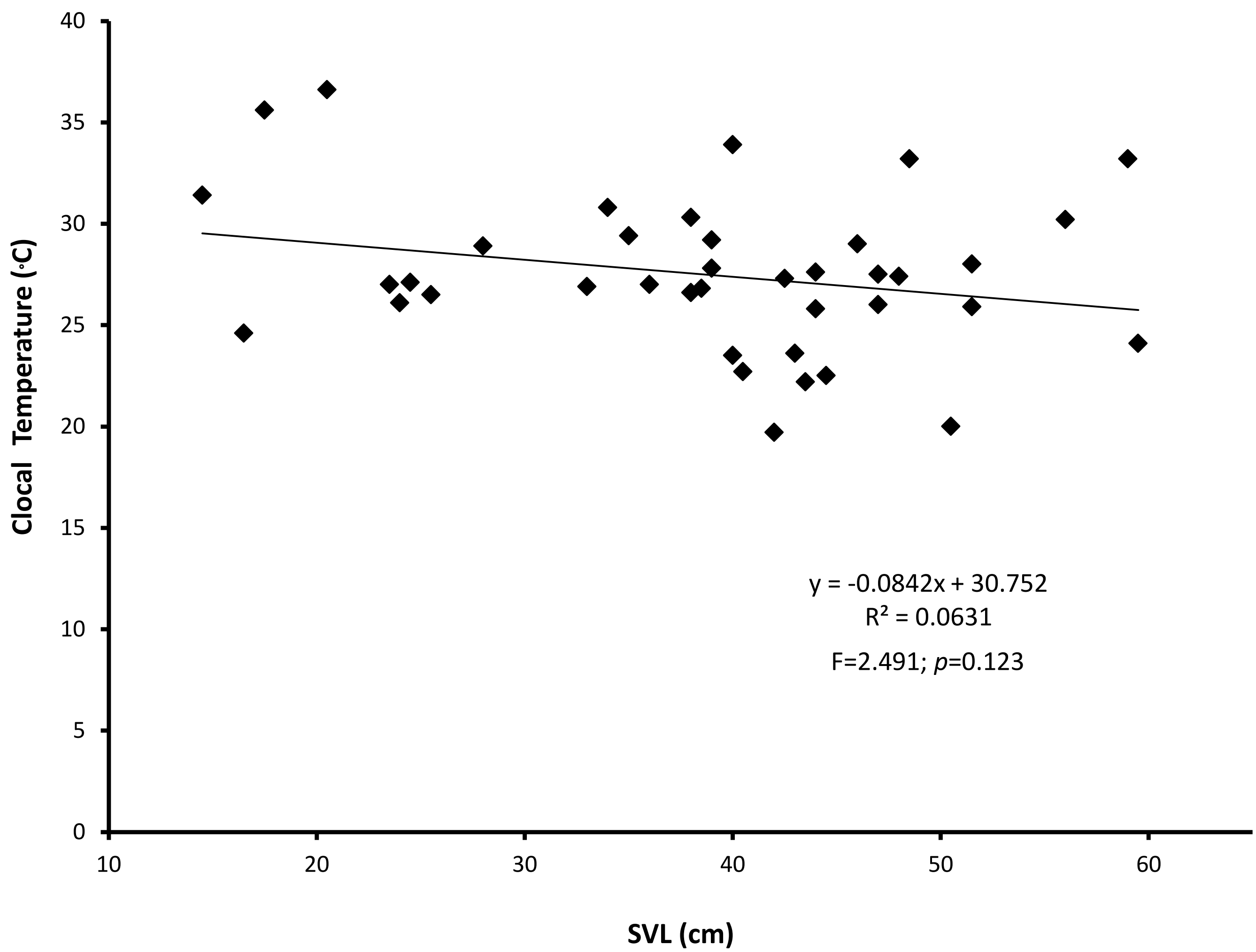
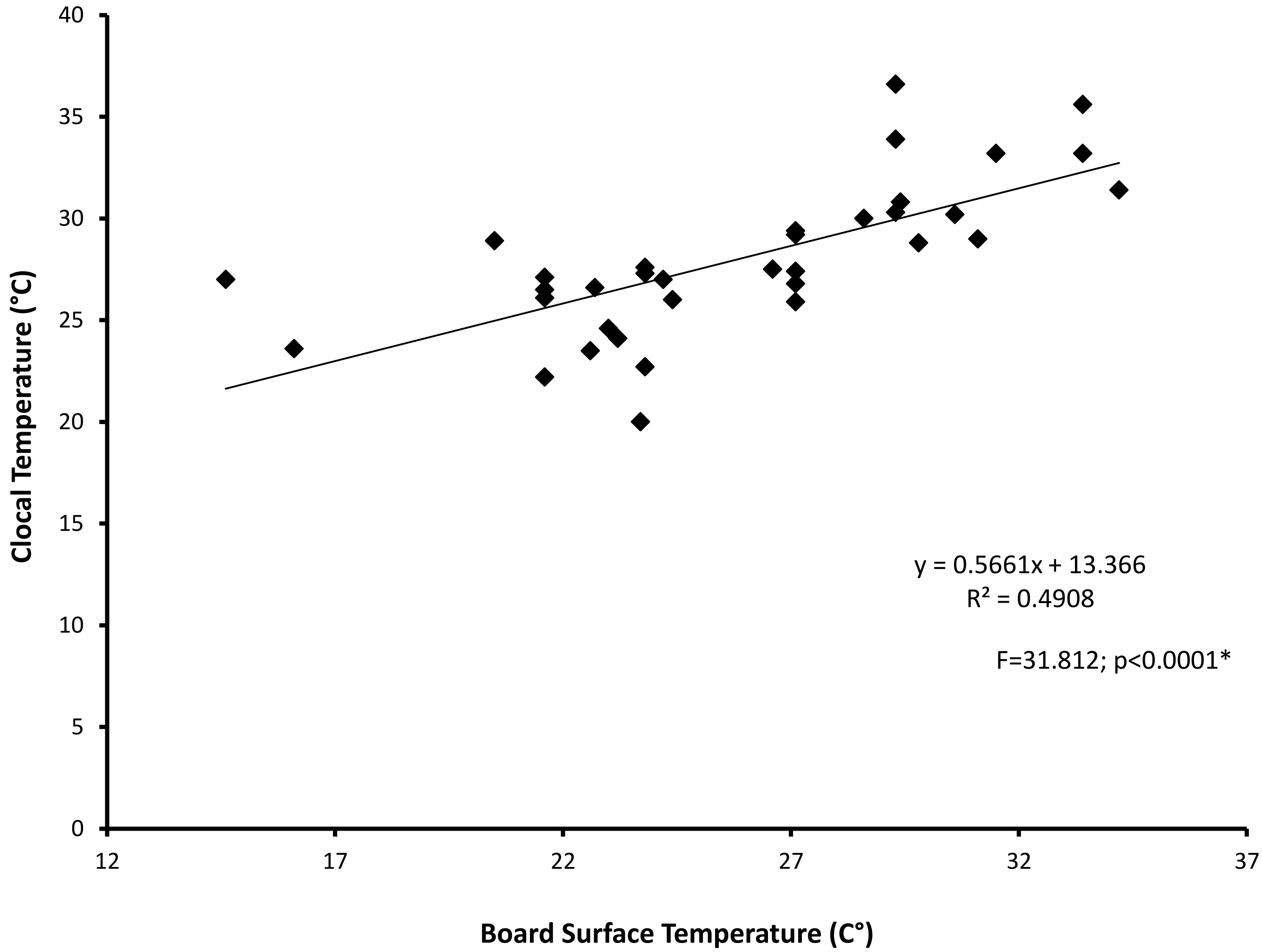


Figure 14: Relationship between cloacal temperature of the Common Garter Snake, *Thamnophis sirtalis*, and (**A**) snout-vent length (SVL) (n = 39), (**B**) board surface temperature (n = 35) and (**C**) soil surface temperature (n = 35), captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012. Equation, R^2, and F-statistic from ANOVA simple linear regression displayed on graph. *Denotes statistical significance.

A.



B.



40
35
30
25
20
15
10
5
0
Clocal Temperature (°C)
y = 0.5661x + 13.366
R² = 0.4908
F=31.812; p<0.0001*
12
17
22
27
32
37
Board Surface Temperature (C°)

C.

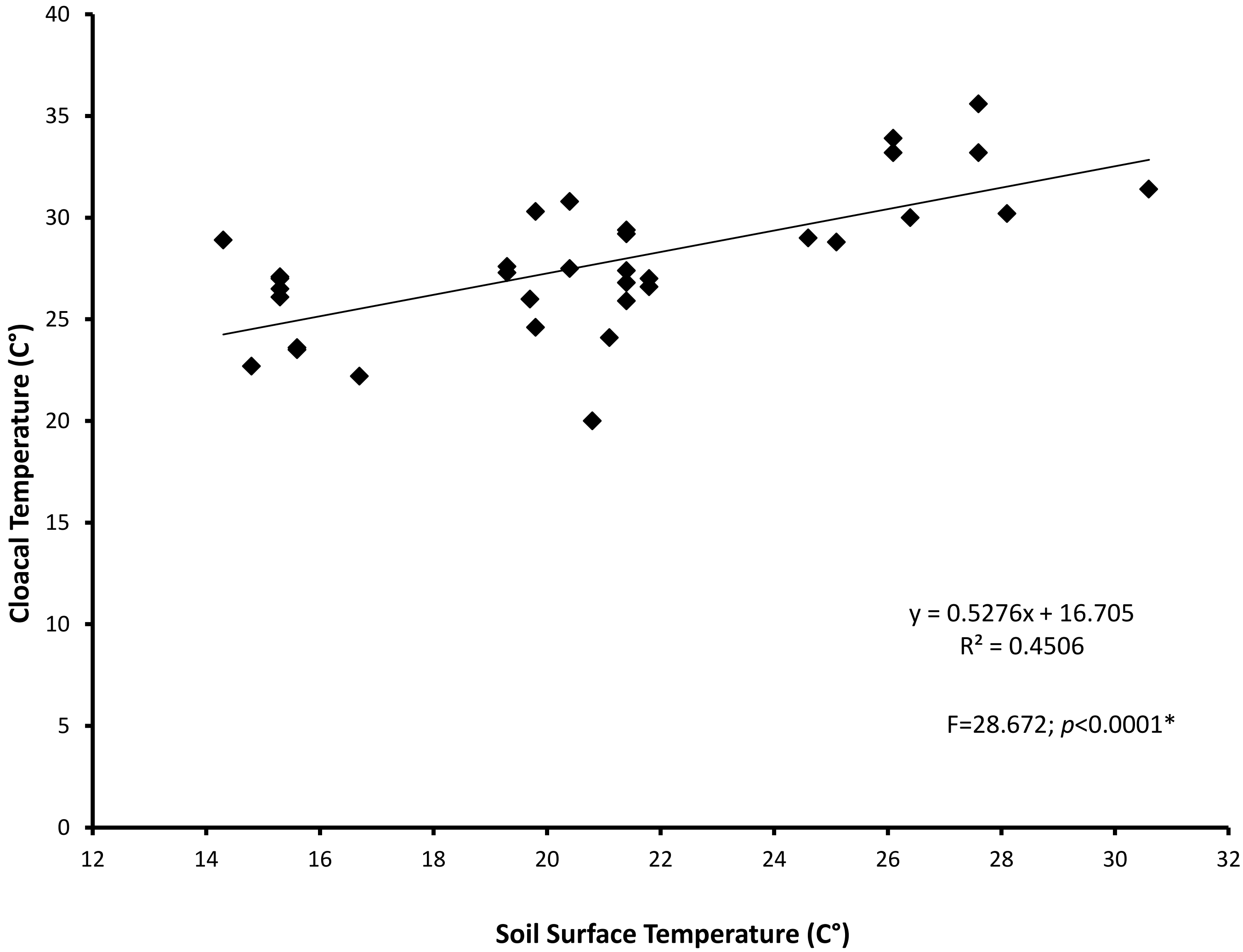

Cloacal Temperature (C°)
40
35
30
25
20
15
10
5
0
12
14
16
18
20
22
24
26
28
30
32
Soil Surface Temperature (C°)
y = 0.5276x + 16.705
R² = 0.4506
F=28.672; p<0.0001*

Figure 15: An adult female Northern Water Snake, *Nerodia sipedon*, found on 12 October 2012, at the Letterkenny Army Depot, Chambersburg, Pennsylvania.

Figure 16: Monthly distribution of Northern Water Snakes, *Nerodia sipedon*, males (n = 1), females (n = 3), juveniles (n = 8), and young-of-the-year (YOY) (n = 1) captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

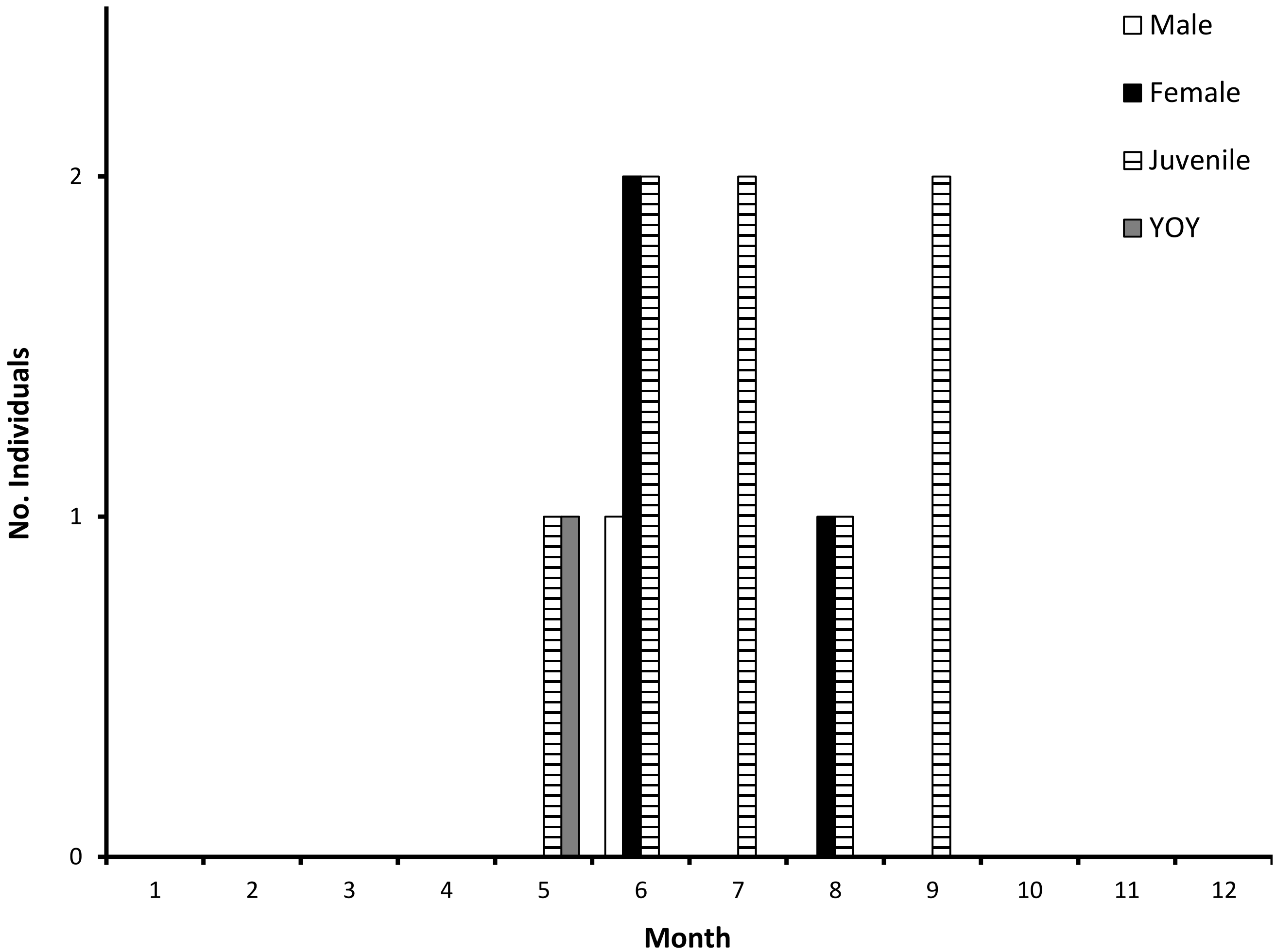


Figure 17: Monthly distribution of body sizes (SVL in cm) for Northern Water Snakes, *Nerodia sipedon*, males (n = 2), females (n = 4), juveniles (n = 10), and young-of-the-year (YOY) (n = 2) captured during standardized and opportunistic searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

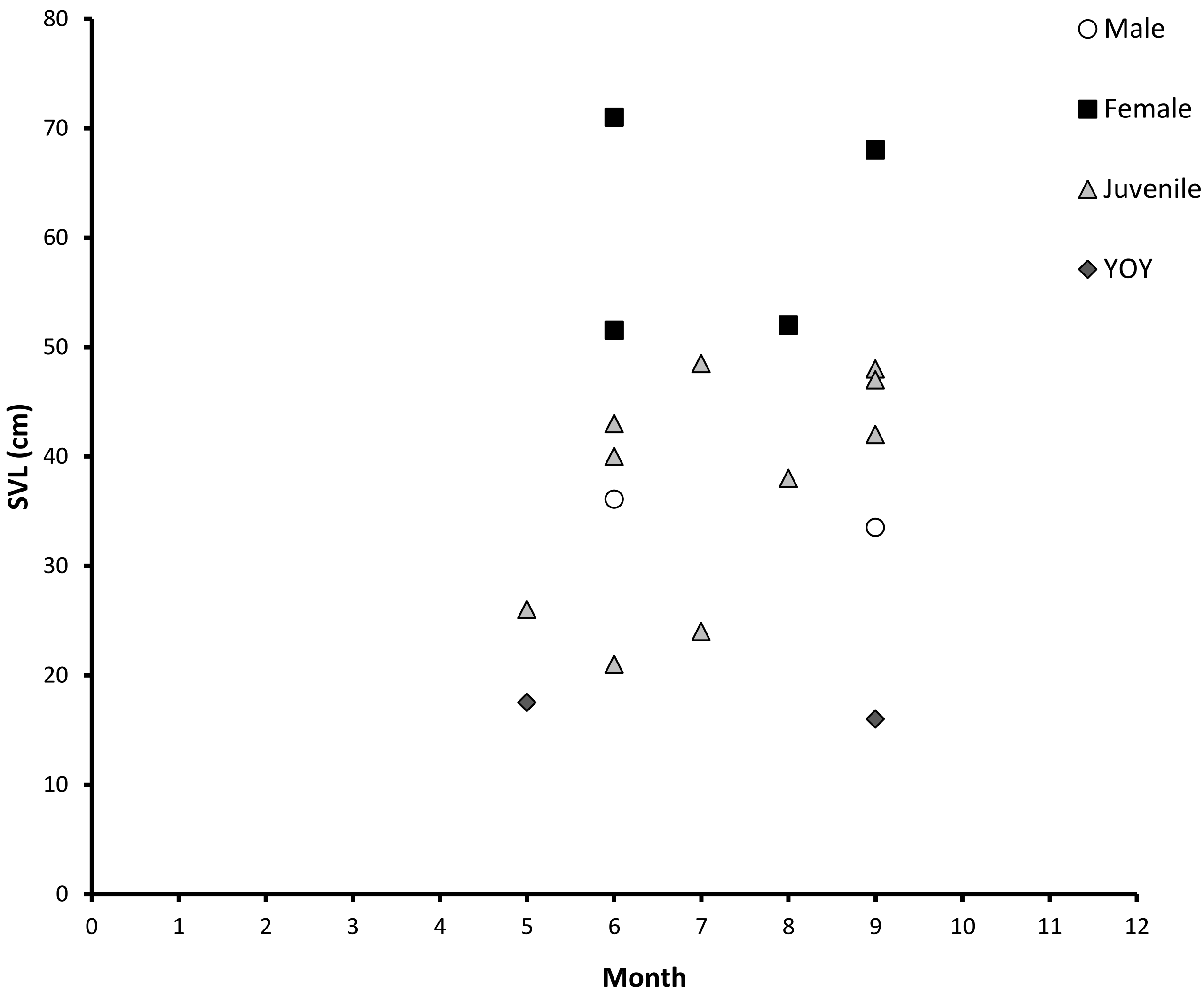


Figure 18: Distribution patterns of Northern Water Snakes, *Nerodia sipedon*, captured during standardized searches inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

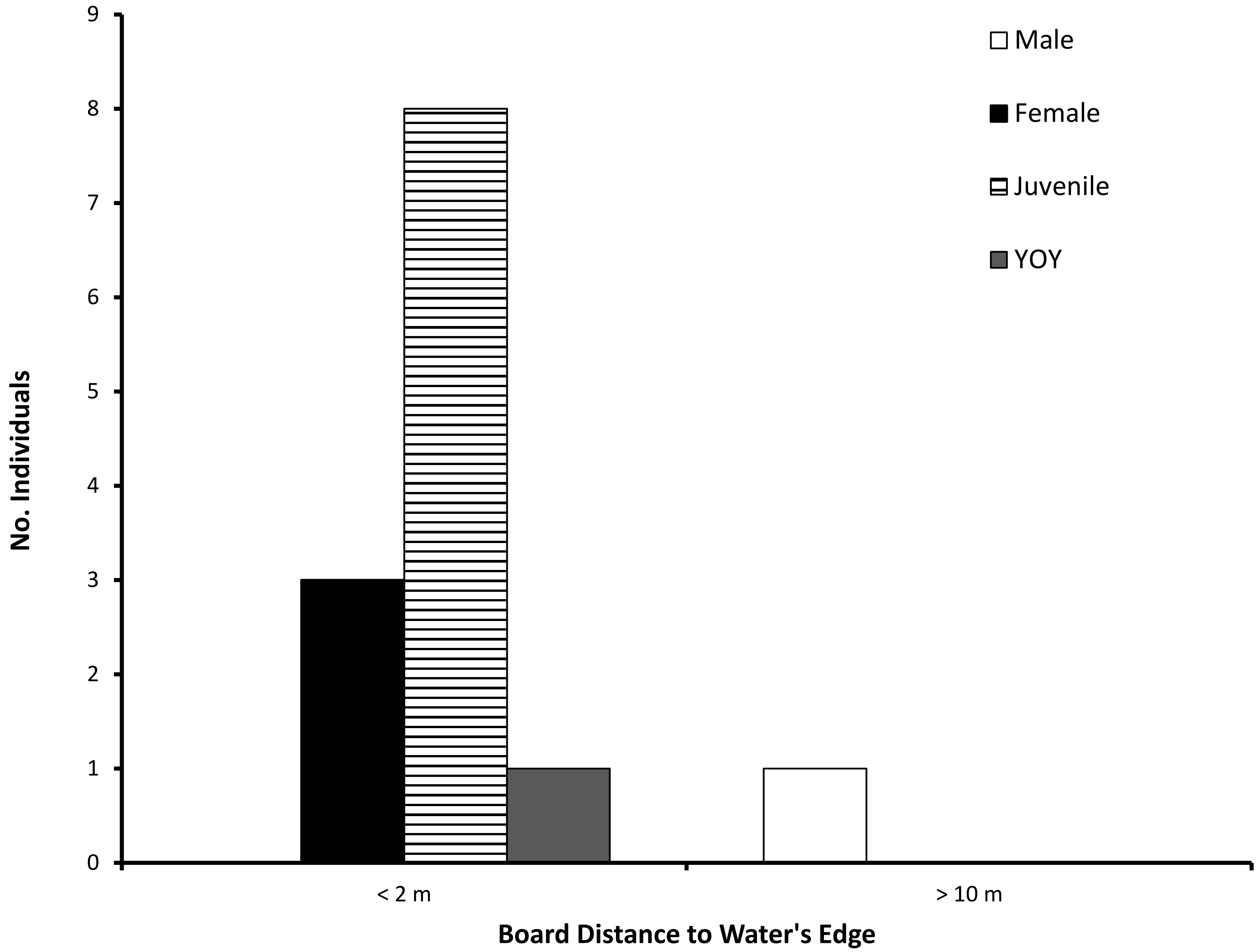


Figure 19: A juvenile male Milk Snake, *Lampropeltis triangulum*, found on 9 May 2012, at the Letterkenny Army Depot, Chambersburg, Pennsylvania.

Figure 20: A juvenile male Eastern Racer, *Coluber constrictor*, found on 4 June 2012, at the Letterkenny Army Depot, Chambersburg, Pennsylvania.

Figure 21: An adult male Ringneck Snake, *Diadophis punctatus*, found on 24 September 2012, at the Letterkenny Army Depot, Chambersburg, Pennsylvania.

Table 1: Distribution of each species in each site expressed as a percentage of the number of snakes of all species captured. In parentheses is the relative abundance of each species expressed as a fraction of the number of snakes captured from each site over the number of boards at each site using standardized capture methods, at Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

	Wetland Site				**Totals**	
Species	**Lake Letterkenny**	**Henry's Pond**	**Shirley's Pond**	**Cole's Pond**	***Total*** (percent)	***Total*** (snakes)
Thamnophis sirtalis	48 (12/17)	90 (17/12)	67 (6/15)	0 (0/10)	66	35
Nerodia sipedon	40 (10/17)	0 (0/12)	33 (3/15)	0 (0/10)	25	13
Lampropeltis triangulum	12 (3/17)	5 (1/12)	0 (0/15)	0 (0/10)	7	4
Coluber constrictor	0 (0/17)	5 (1/12)	0 (0/15)	0 (0/10)	2	1
Diadophis punctatus	0 (0/17)	0 (0/12)	0 (0/15)	0 (0/10)	0	0
Total (percent)	100	100	100	0	100	53
Total (snakes)	25 (25/17)	19 (19/12)	9 (9/15)	0 (0/10)	53	

Table 2: Species detection across wetland sites captured during standardized and opportunistic searches, inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012. Last column displays the number of sites the species was detected at over the number of available sites.

	Species				
Site	*Thamnophis sirtalis*	*Nerodia Sipedon*	*Lampropeltis triangulum*	*Coluber constrictor*	*Diadophis punctatus*
Lake Letterkenny	**Y**	**Y**	**Y**	**N**	**N**
Henry's Pond	**Y**	**N**	**Y**	**Y**	**N**
Shirley's Pond	**Y**	**Y**	**N**	**N**	**N**
Cole's Pond	**Y**	**N**	**N**	**N**	**Y**
Total	4/4	2/4	2/4	1/4	1/4

Table 3: Snout-vent length (SVL), tail length (TL), and total length (ToL) for species, *Thamnophis sirtalis* and *Nerodia sipedon*, males, females, juveniles, and young-of-the-year sampled from the all of the four wetland sites. The mean ± SE is shown with the range in parentheses, and below it is the standard deviation. The statistic (one-sample *t*-test) was run to test for significant differences between body sizes of this study compared to Pennsylvania in general, taken from Hulse and coworkers (2001). *Denotes statistically significant *t* value.

Thamnophis sirtalis (n = 49)					
Sex	**SVL**	**TL**	**ToL**	**TL/SVL**	**TL/ToL**
Male (n=1)	38.0 ± 0.0 (38.0-38.0) SD=N/A	11.0 ± 0.00 (11.0-11.0) SD=N/A	49.0 ± 0.0 (49.0-49.0) SD=N/A	0.289 ± 0.0 (0.289-0.289) SD=N/A	0.224 ± 0.0 (0.224-0.224) SD=N/A
Statistic	N/A	N/A	N/A	N/A	N/A
Female (n=34)	45.79 ± 1.10 (36.0-59.5) SD=6.40	12.74 ± 0.33 (6.5-17.0) SD=1.92	58.53 ± 1.16 (47.0-76.0) SD=6.77	0.283 ± 0.008 (0.109-0.34) SD=0.049	0.219 ± 0.005 (0.098-0.253) SD=0.032
Statistic	$t = 1.72$ $p = 0.094$	$t = 4.89$* $p < 0.0001$	$t = 3.01$* $p < 0.005$	$t = 0.787$ $p = 0.437$	$t = 0.581$ $p = 0.565$
Juvenile (n=10)	27.12 ± 1.62 (20.5-35) SD=5.12	7.96 ± 0.49 (5.6-11.0) SD=1.55	35.08 ± 2.07 (27.0-46.0) SD=6.54	0.294 ± 0.009 (0.241-0.327) SD=0.029	0.227 ± 0.005 (0.194-0.246) SD=0.017
Statistic	N/A	N/A	N/A	N/A	N/A
Young-of-the-year (n=4)	16.75 ± 0.85 (14.5-18.5) SD=1.71	4.75 ± 0.32 (4.0-5.5) SD=0.65	21.5 ± 1.06 (18.5-23.0) SD=2.12	0.284 ± 0.016 (0.243-0.314) SD=0.032	0.221 ± 0.009 (0.196-0.239) SD=0.019
Statistic	N/A	N/A	N/A	N/A	N/A
Nerodia Sipedon (n = 18)					
Sex	**SVL**	**TL**	**ToL**	**TL/SVL**	**TL/ToL**
Male (n=2)	35.25 ± 1.75 (33.5-37.0) SD=2.47	12.5 ± 0.0 (12.5-12.5) SD=N/A	47.75 ± 1.75 (46.0-49.5) SD=2.47	0.355 ± 0.018 (0.338-0.373) SD=0.025	0.262 ± 0.014 (0.252-0.271) SD=0.014
Statistic	$t = -5.286$ $p = 0.119$	N/A	$t = -5.571$ $p = 0.113$	$t = 0.311$ $p = 0.808$	$t = 0.222$ $p = 0.861$
Female (n=4)	60.63 ± 5.16 (51.5-71.0) SD=10.32	17.38 ± 1.53 (14.5-20.5) SD=3.07	78.00 ± 6.89 (66.5-91.5) SD=13.38	0.286 ± 0.003 (0.286-0.291) SD=0.005	0.223 ± 0.002 (0.218-0.225) SD=0.003
Statistic	$t = -1.816$ $p = 0.167$	$t = -2.169$ $p = 0.119$	$t = -1.898$ $p = 0.154$	$t = 3.506$* $p = 0.039$	$t = 3.464$* $p = 0.041$
Juvenile (n=10)	37.75 ± 3.27 (21.0-48.5) SD=10.35	12.1 ± 1.21 (6.5-19.0) SD=3.84	49.85 ± 4.39 (27.5-66.0) SD=13.87	0.321 ± 0.013 (0.250-0.404) SD=0.042	0.242 ± 0.008 (0.2-0.288) SD=0.024
Statistic	N/A	N/A	N/A	N/A	N/A
Young-of-the-year (n=2)	16.75 ± 0.75 (16.0-17.5) SD=1.06	5.0 ± 0.5 (4.5-5.5) SD=0.71	21.75 ± 1.25 (20.5-23.0) SD=1.77	0.298 ± 0.017 (0.281-0.314) SD=0.023	0.229 ± 0.009 (0.22-0.24) SD=0.014
Statistic	N/A	N/A	N/A	N/A	N/A

Table 4: Summary of data for cloacal temperatures for the Common Garter Snake, *Thamnophis sirtalis*, and the Northern Water Snake, *Nerodia sipedon*, and for air temperatures, ground surface temperatures, and board surface temperatures inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012. The mean ± SE is shown with the range in parentheses. *Two cloacal temperature measurements were omitted from the Common Garter Snake analyses; **Three cloacal temperatures encompassed recaptured individuals and one cloacal temperature measurement was omitted from the Northern Water Snake analyses.

	Species	
	Thamnophis sirtalis	***Nerodia sipedon***
	Number (n) 47* (1 M, 33 F, 9 J, 4 N)	Number (n) 21** (3 M, 5 F, 11 J, 2 N)
	Cloacal Temperatures, °C	
Mean (All)	27.55 ± 0.54 (19.7-36.6) (n=47)	26.36 ± 0.79 (20.2-34.6) (n=21)
Males	26.6 (n=1)	24.7 ± 1.24 (22.5-26.8) (n=3)
Females	26.92 ± 0.63 (19.7-33.9) (n=33)	24.24 ± 1.48 (20.2-28.4) (n=5)
Females, Gravid	25.96 ± 1.16 (20.0-32.6) (n=10)	26.8 ± 1.6 (25.2-28.4) (n=2)
Juvenile	28.81 ± 1.10 (26.1-36.6) (n=9)	27.78 ± 1.11 (22.5-34.6) (n=11)
Neonate	30.1 ± 2.31 (24.6-35.6) (n=4)	26.3 (n=1)
Mean (SVL>36cm); (SVL>51cm)	26.91 ± 0.61 (19.7-33.9) (n=34)	24.24 ± 1.48 (20.2-28.4) (n=5)
Mean (SVL<36cm); (SVL<51cm)	29.21 ± 1.0 (24.6-36.6) (n=13)	27.07 ± 0.89 (22.5-34.6) (n=15)
Mean (Pre-12pm)	27.63 ± 0.78 (20.0-36.6) (n=23)	27.94 ± 0.86 (25.2-31.4) (n=8)
Mean (Post-12pm)	28.08 ± 0.72 (19.7-36.6) (n=12)	25.31 ± 1.13 (20.2-34.6) (n=12)
Mean (May-July)	26.64 ± 0.80 (20.0-32.6) (n=15)	27.25 ± 0.59 (25.2-31.4) (n=10)
Mean (August-October)	28.72 ± 1.08 (22.7-35.6) (n=30)	25.47 ± 1.47 (20.2-34.6) (n=10)
	Environmental Temperatures, °C	
Mean (Air)	19.42 ± 2.58 (8.5-24.5)	
Mean (Ground Surface)	21.08 ± 0.75 (14.3-30.6)	20.13 ± 1.01 (12.8-26.1)
Mean (Board Surface)	25.85 ± 0.78 (14.6-34.2)	26.28 ± 1.08 (20.1-33.9)

Table 5: Distribution of each species at each site expressed as a percentage of the number of snakes of all species captured and in parentheses is the distribution of each species expressed as a fraction of the number of snakes captured from each site over the number of boards at each site from board locations < 2m from the wetland and >10 m from the wetland, using standardized capture methods, inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from April 2012 to October 2012.

< 2meters	**Wetland Site**				**Totals**	
Species	**Lake Letterkenny**	**Henry's Pond**	**Shirley's Pond**	**Cole's Pond**	***Total*** (percent)	***Total*** (snakes)
Thamnophis sirtalis	35 (6/8)	100 (7/6)	50 (3/7)	0 (0/5)	53	16
Nerodia sipedon	53 (9/8)	0 (0/6)	50 (3/7)	0 (0/5)	40	12
Lampropeltis triangulum	12 (2/8)	0 (0/6)	0 (0/7)	0 (0/5)	7	2
Coluber constrictor	0 (0/8)	0 (0/6)	0 (0/7)	0 (0/5)	0	0
Diadophis punctatus	0 (0/8)	0 (0/6)	0 (0/7)	0 (0/5)	0	0
Total (percent)	100	100	100	0	100	30
Total (snakes)	17	7	6	0	30	
> 10 meters	**Wetland Site**				**Totals**	
Species	**Lake Letterkenny**	**Henry's Pond**	**Shirley's Pond**	**Cole's Pond**	***Total*** (percent)	***Total*** (snakes)
Thamnophis sirtalis	75 (6/9)	83 (10/6)	100 (3/8)	0 (0/5)	83	19
Nerodia sipedon	12.5 (1/9)	0 (0/6)	0 (0/8)	0 (0/5)	4.5	1
Lampropeltis triangulum	12.5 (1/9)	8.5 (1/6)	0 (0/8)	0 (0/5)	8	2
Coluber constrictor	0 (0/9)	8.5 (1/6)	0 (0/8)	0 (0/5)	4.5	1
Diadophis punctatus	0 (0/9)	0 (0/6)	0 (0/8)	0 (0/5)	0	0
Total (percent)	100	100	100	0	100	23
Total (snakes)	8	12	3	0	23	

Table 6: List of snake species observed at LEAD from two previous studies conducted under different time and survey conditions, compared to current study. The list of species (on left), denotes all snake species (n=22) found in Pennsylvania (Meshaka and Collins, 2009). Snake species observed in study from 2002-03, conducted at LEAD, Zone II (Delis et al., 2010). Snake species observed in study from 2008-2011, conducted at LEAD, Zone II (Meshaka and Delis, 2013). Snake species observed in current study, 2012. *Endangered species in Pennsylvania; **Candidate species for protection in Pennsylvania.

Pennsylvania Snake Species (Meshaka and Collins, 2009)	**LEAD Zone II** (Delis et al., 2010)	**LEAD Zone II** (Meshaka and Delis, 2013)	**LEAD Zone I** (this study)	**Common Species** (all studies)
Agkistrodon contortrix (Copperhead)	N	Y	N	N
Carphophis amoenus (Eastern Worm Snake)	N	N	N	N
Clonophis kirtlandii * (Kirtland's Snake)	N	N	N	N
Coluber constrictor (Eastern Racer)	**Y**	**Y**	**Y**	**Y**
*Crotalus horridus*** (Timber Rattlesnake)	Y	N	N	N
Diadophis punctatus (Ringneck Snake)	**Y**	**Y**	**Y**	**Y**
Heterodon platirhinos (Eastern Hognose Snake)	N	N	N	N
Lampropeltis triangulum (Milk Snake)	**Y**	**Y**	**Y**	**Y**
Liochlorophis vernalis (Smooth Green Snake)	N	N	N	N
Nerodia sipedon (Northern Water Snake)	**Y**	**Y**	**Y**	**Y**
*Opheodrys aestivus** (Rough Green Snake)	N	N	N	N
Regina septenvittata (Queen Snake)	N	N	N	N
Scotophis alleghaniensis (Eastern Rat Snake)	Y	Y	N	N
Scotophis spiloides (Midland Rat Snake)	N	N	N	N
*Sistrurus catenatus** (Massasauga)	N	N	N	N
Storeria dekayi (Brown Snake)	N	N	N	N
Storeria occipitomaculata (Redbelly Snake)	N	Y	N	N
Thamnophis brachystoma (Shorthead Garter Snake)	N	N	N	N
Thamnophis sauritus (Eastern Ribbon Snake)	Y	N	N	N
Thamnophis sirtalis (Common Garter Snake)	**Y**	**Y**	**Y**	**Y**
Virginia pulchra (Mountain Earth Snake)	N	N	N	N
Virginia valeriae (Smooth Earth Snake)	N	N	N	N
Total (22)	**8**	**8**	**5**	**5**

Table 7: Snout-vent length (SVL), in centimeters, for the species, *Thamnophis sirtalis* and *Nerodia sipedon*, males and females sampled from this study (in-situ) compared to body sizes of the same species from similar studies conducted in Zone II of Letterkenny Army Depot (LEAD) (Meshaka, 2013), in western Pennsylvania at the Powdermill Nature Reserve (PNR) (Meshaka, 2010), northeastern Ohio at the James H. Barrow Field Station (JHBFS) (Meshaka, 2008), and to Pennsylvania generally (Hulse et al., 2001) The mean ± SE is shown with the range in parentheses, and below it is the number of snakes (n).

	Species			
	Thamnophis sirtalis		***Nerodia sipedon***	
Location	**Sex**		**Sex**	
	Male	**Female**	**Male**	**Female**
Zone I (LEAD) (in-situ)	38.0 ± 0.0 (38.0-38.0) n=1	45.79 ± 1.10 (36.0-59.5) n=34	35.25 ± 1.75 (33.5-37.0) n=2	60.63 ± 5.16 (51.5-71.0) n=4
Zone II (LEAD)	38.9 ± 7.0 (27.5-52.2) n=29	54.1 ± 8.9 (38.6-78.1) n=64	48.0 ± 5.1 (39.4- 55.0) n=9	61.7 ± 7.1 (54.4-69.9) n=5
PNR (western, PA)	39.6 ± 5.85 (26.0-53.3) n=109	47.3 ± 6.41 (38.1-67.8) n=298	51.1 ± 3.5 (47.6-54.6) n=2	71.7 ± 12.9 (52.7-84.5) n=8
JHBFS (northeastern, OH)	38.5 ± 4.9 (29.0-53.0) n=49	53.5 ± 6.0 (45.0-68.5) n=43	51.0 ± 9.29 (38.0-69.0) n=3	63.0 ± 0.0 (63.0-63.0) n=1
Pennsylvania	33.8 ± 5.7 (27.0-46.2) n=58	43.9 ± 6.3 (36.0-64.0) n=52	44.5 ± 13.4 (31.5-62.0) n=44	70.0 ± 16.5 (51.4-84.4) n=28

Table 8: Statistical differences in snout-vent length (SVL), in centimeters, for the species, *Thamnophis sirtalis* and *Nerodia sipedon*, measured in this study compared to body sizes of the same species from similar studies conducted in Zone II of Letterkenny Army Depot (LEAD) (Meshaka, 2013), in western Pennsylvania at the Powdermill Nature Reserve (PNR) (Meshaka, 2010), northeastern Ohio at the James H. Barrow Field Station (JHBFS) (Meshaka, 2008), and to Pennsylvania generally (Hulse et al., 2001). Analyzed by the One-sample *T*-test *Denotes statistically significant *p* value.

	Species			
	Thamnophis sirtalis		***Nerodia sipedon***	
Location	**Sex**		**Sex**	
	Male	**Female**	**Male**	**Female**
Zone II (LEAD)	N/A	$t = -7.57$ $p < 0.0001$*	$t = -7.29$ $p = 0.087$	$t = -0.21$ $p = 0.848$
PNR (western, PA)	N/A	$t = -1.37$ $p = 0.179$	$t = -9.06$ $p = 0.07$	$t = -2.15$ $p = 0.121$
JHBFS (northeastern, OH)	N/A	$t = -7.02$ $p < 0.0001$*	$t = -9.0$ $p = 0.07$	$t = -0.46$ $p = 0.677$
Pennsylvania	N/A	$t = 1.72$ $p = 0.094$	$t = -5.29$ $p = 0.119$	$t = -1.82$ $p = 0.167$

Appendix 1: Mean conductivity, pH and temperature measured from the four wetland sites inside Letterkenny Army Depot, Chambersburg, Pennsylvania, from May 2012 to October 2012.

Wetland	Conductivity (µS)	pH	Temperature (°C)
Lake Letterkenny	139.7	8.26	22.3
Shirley's Pond	215.3	8.55	22.9
Henry's Pond	112.7	7.27	22.9
Coles Pond	131.9	7.38	21.6