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Ohio Conservation Plan: Plains gartersnake, Thamnophis radix

Norman Reichenbach
Liberty University, nreichen@liberty.edu

M. Barrie

K. Becka

G. Burghardt

S. Butterworth

See next page for additional authors

Author(s)
Norman Reichenbach, M. Barrie, K. Becka, G. Burghardt, S. Butterworth, C. Caldwell, F. Dierkes, P. Johantgen, K. Stanford, and D. Wynn

Ohio Conservation Plan

Plains gartersnake, *Thamnophis radix*

This plan outlines strategies and methods used in an ongoing study initiated in 1999 to restore a self-sustaining population of the Plains gartersnake (*Thamnophis radix*) in Ohio. Restoring a self-sustaining population would require increases in the current population to where the ratios of *T. radix* to *T. sirtalis* are approximately 1:1 in multiple locations in Killdeer Plains Wildlife Area (KPWA). This ratio would be similar to what was seen earlier by Reichenbach and Dalrymple (1986) at one site in KPWA.

The plan was developed by a team of enthusiastic conservationists representing, the Division of Wildlife (ODW), the Columbus and Cleveland Zoos, Westerville North High School Field Study Class, Liberty University, Northern Illinois University, and the University of Tennessee. A thorough review of the plan will be made in 2012 with revisions and updates as needed.

TAXONOMY AND DESCRIPTION

The Plains gartersnake, *Thamnophis radix*, is in the Order Squamata, Suborder Serpentes, Family Colubridae. Conant et al. (1945:62) provide a good composite description of individuals found in Ohio: “Middorsal stripe bright orange yellow, occupying the median row of scales and adjoining fractions of the adjacent rows. Lateral stripe bright yellow; situated on scale rows 3 and 4. Dorsal ground color dark chocolate brown. A double row of round black spots on each side of the body between the stripes, these approximately 1 to 1 ½ scales in length and about 2 to 2 ½ scales in height; the spots often run together and thus obscure the ground color. A row of similar dark spots between the lateral stripe and the ventrals. Belly light greenish grey, each ventral with a conspicuous black spot at each end; sutures between the ventrals often irregularly bordered with black. There is a tendency in some specimens for spots on adjacent ventrals to run together. Similar, but indistinct, markings on the under side of the tail. Top of head and occipital region black or very dark brown, except for a pair of bright yellow parietal spots. Lower labials, chin and throat uniform pale yellow; sutures between lower labials edged with black in some specimens. Upper labials yellow, their posterior edges broadly bordered with black, especially toward the rear of the head. There are yellow or yellowish areas on the nasals, preoculars and lower postoculars.”

The best field characteristics include the bright orange dorsal stripe and the extensive black posterior edges on the yellow upper labials. These characteristics easily distinguish *T. radix* from *T. sirtalis*, which in Ohio is the most commonly found gartersnake in areas with *T. radix*. The lateral stripe for *T. sirtalis* is also confined to scale rows 2 and 3 while for *T. radix* the lateral stripe is on scale rows 3 and 4. Other species which might be confused with the Plains gartersnake include a) Ribbon snakes (*T. sauritus*), which also have lateral stripes on scale rows 3 and 4, but they are distinctly slender with long tails (more than ¼ or more of their total length (TL) and b) Butler's gartersnakes (*T. butleri*) which have a lateral stripe (on neck) on row 3 and adjacent halves of rows 2 and 4 and proportionately, their head is very small (Conant and Collins, 1998).

U.S. DISTRIBUTION

Thamnophis radix occurs from south central Canada (Alberta, Saskatchewan, and Manitoba), south through the Great Plains to northeastern New Mexico, northern Texas and Oklahoma, and eastward through southern Wisconsin, northern and central Illinois and northern Indiana, with disjunct populations in north-central Ohio, Missouri and Illinois (Rossman et al., 1996; Walley et al., 2003).

HISTORICAL & CURRENT DISTRIBUTION IN OHIO

The disjunct population was not confirmed in Ohio until 1945 (Conant et al., 1945) though Ditmars (1907; 1936) included western Ohio as part of the range for *T. radix*. Conant et al. (1945) speculated that it was possible that Ditmars received *T. radix* from Ohio early in his career. Many specimens were being sent to him for identification from all over the country. This species was actually recorded in Ohio in 1931 as an aberrant *T. sirtalis* collected 2 miles SW of Upper Sandusky, Wyandot County (Conant, 1951). It was noted as having a lateral stripe on the third and fourth scale rows but since *T. radix* was totally unexpected so far east from its (then) known distribution, this specimen was originally recorded as an aberrant *T. sirtalis* (Conant, 1938). This disjunct population in Ohio is a remnant of a much broader eastward range expansion of this species which is associated with the Prairie Peninsula concept of Transeau (1935; Smith, 1957).

The only recent records for this species (since 1978) are for KPWA in Wyandot County. In 2007 Doug Wynn surveyed several historical sites without finding any *T. radix*. Appropriate habitat for *T. radix* was noted at one site in Crawford County on private property since there were tall grasses adjacent to the Little Scioto River. In Marion County, a site in Grand Prairie Township, might have Plains gartersnakes since a cemetery was nearby and contained some fencerow-type habitats. Two sites located at the edge of Big Island Wildlife Area also contained suitable habitat (Wynn and Reichenbach, 2007).

GENETIC DISTINCTIVENESS OF *THAMNOPHIS RADIX* IN OHIO

The genetic distinctiveness of the Ohio population of the Plains gartersnake was studied by a group of faculty and students at The University of Tennessee. Both mitochondrial ND2 gene and 4 microsatellite loci were examined from 9 - 12 animals from 4 populations (Burghardt et al., 2001).

Adult *T. radix* samples were obtained from animals in Ohio, northeastern Indiana (adjacent to Cook County, IL and Lake Michigan), Dekalb County, IL, and Nebraska. *Thamnophis radix* tail tips were obtained from Ohio, Nebraska and Indiana populations. Blood samples were collected from those from Northern Illinois. Standard molecular and statistical methods were employed as detailed in the 2001 report ND2 data are also now available from other populations of *T. radix* throughout the country as well as the closely related, evolutionarily derived *T. butleri* (Rossman et al., 1996) from the Toledo area of Ohio, Michigan, and Wisconsin. Except as noted below, these new data do not alter the general conclusions reached in the 2001 report.

Results and Discussion

ND2 sequences showed little variation within and across populations, and there was none found at all in the 10 Ohio Plains gartersnakes analyzed. However, there was a fixed base pair (haplotype) difference that separated the Ohio animals from all other Plains gartersnakes. Based on comparing across all the populations, the Illinois population was most similar to the Ohio population as compared to Indiana and Nebraska. Furthermore, the only population specific fixed allele was found in the Ohio animals. Interestingly, our more recent work on Butler's gartersnake, which historically was found in the counties surrounding KPWA, showed that the fixed haplotype difference was also found in *T. butleri* from the Toledo area. These animals are larger and more *T. radix* like in color (but not pattern) than Michigan *T. butleri* from populations less than 50 miles away. Unfortunately, extensive surveys of areas around KPWA from which *T. butleri* were collected in the 1930s to 1970s have not yielded any animals and thus they must be considered extirpated. Given the close relationship between the two species, hybridization may have occurred between the species as has been amply documented in SE Wisconsin (Fitzpatrick et al., 2008).

The microsatellites, as expected, showed much more variability within and between populations. The number of alleles and genotypes differed by population. Although there is no significant pattern, the total number different genotypes and alleles across loci were both lowest among the Ohio animals, in spite the relatively large sample size. Without going into details, there was significant genic and genotype differentiation among the four populations at all four loci both individually and combined. At two loci, Ohio animals were statistically distinct from all others populations. Thus, even more so than the sequence data, the microsatellite results suggest that the Ohio population does differ genetically from the others.

In addition, low levels of inbreeding as measured by Fis values were found. Population differentiation is indicated by Fst scores. Comparing Ohio with each population and locus it was found that the combined Fst for the Ohio and Illinois comparison is the lowest, suggesting that Ohio snakes are more similar to Illinois than the Indiana population (which was, however, rather close to Lake Michigan and not inland as were the Ohio and Illinois populations). In short, the Ohio population is distinct from all the other three populations in both mitochondrial sequence and microsatellite genetic data.

NATURAL HISTORY

Conant et al. (1945) described the habitat where *T. radix* is found in Ohio as the single most extensive wet prairie area in this state. The original prairie has been converted to very productive farmland, restricting the former prairie vegetation to limited areas. Most of the original specimens noted in Conant et al. (1945) were not found in typical prairie land, but rather they were in close proximity to prairie swales and streams. At KPWA they are found in low-lying grassland areas often bordering ponds. In the spring these grassland areas are often inundated with water. By midsummer the water table often recedes as much as several meters below the surface and the soil becomes dry, cracked and very hard (Dalrymple and Reichenbach, 1981). Three adult *T. radix* implanted with transmitters that were tracked from mid-June to late August 2007 moved throughout grassland habitat and never entered the nearby forested areas (Wynn and Reichenbach, 2007). Terrestrial crayfish, *Falicambarus fodiens*, burrows and cracks in the soil are used for daily refuges (Dalrymple and Reichenbach, 1984; Reichenbach and Dalrymple, 1986; Wynn and Reichenbach 2007). Crayfish burrows are also used as hibernacula at KPWA (Dalrymple and Reichenbach, 1984; Reichenbach and Dalrymple, 1986) and in Manitoba, juvenile *T. radix* used an ant hill as a hibernaculum (Criddle, 1937).

The activity pattern for *T. radix* in Ohio spans primarily from April through October (Dalrymple and Reichenbach, 1981; Reichenbach and Dalrymple, 1986). This pattern is seen generally for this species (Wright and Wright, 1957). The Plains gartersnake is almost exclusively diurnal. Dalrymple and Reichenbach (1984) and Reichenbach and Dalrymple (1986) found most of the gartersnakes between 1100-1600 hours during the spring and autumn while in the summer, the activity pattern was bimodal with one peak in the morning and one in late afternoon. During the summer midday temperatures often exceeded 34^{o}C which forced the snakes to retreat to crayfish burrows.

Distances moved between recaptures were generally less than 76 m for time intervals from several months to over a year (Reichenbach and Dalrymple, 1986). In KPWA, three adult snakes implanted with transmitters and tracked from mid-June to last August, 2007 showed a home range style of movement throughout an area that averaged 3626 m^2 (range 1499 to 5717 m^2). These same snakes moved on average 5.6 m/day (range 2.8 to 9.1 m/day) (Wynn and Reichenbach, 2008). Siebert and Hagen (1947) found that most individuals moved less than 2 m/day. One snake, captured 4 times, was last seen only 11 m from its original capture location. It had apparently traveled a semicircular arc.

Mating activity occurs primarily in April and May (Reichenbach and Dalrymple, 1986; Ernst and Barbour, 1989, and Stanford and King, 2004) though fall mating may occur (Pope, 1944, Stanford and King, 2004). Sexual maturity appears to be reached at 350 to 370 mm SVL for males and 380-400 mm SVL for females (Stanford and King, 2004) which would correspond to snakes that are 2 years old (Seibert and Hagen, 1947; Gregory, 1977 and Stanford and King, 2004). Spermiogenesis is pronounced in late summer and early fall. The sperm are stored in the ductus deferens during hibernation and are used the following spring (Cieslak, 1945).

Males find females by following their sex pheromone (Kubie et al., 1978b; Ford and Schofield, 1984). In Y-maze experiments, where male *T. radix* were offered a choice between *T. radix* and *T. sirtalis* pheromone trails, the males discriminated and preferred those of their own females (Ford and Schofield, 1984). It is thought that shedding potentiates the release of a sexual pheromone from the dorsal skin of the female (Kubie et al., 1978a). One or more males may court a female (Ernst and Barbour, 1989) and in Missouri small mating balls of 4-6 males per female have been seen (Rossman et al., 1996). After a male mates with a female a copulatory plug may be deposited in the female's cloaca which exerts an inhibitory effect on the courtship activity of other males (Ross and Crews, 1977).

Parturition occurs in late July through early September (Wright and Wright, 1957) after a nine week gestation period (Cieslak, 1945). Average clutch size ranges from 9 to 29.5 (Smith, 1961; Gregory, 1977; Seigel and Fitch, 1985; Stanford and King, 2004). In Ohio, the average clutch size in 1980 from eight clutches was 15.2 (Reichenbach and Dalrymple, 1986) and more recently 12.5 from 17 clutches from females collected between 1999 and 2001 (Badgley, Quinn and Reichenbach, unpublished data). Clutch size is dependent upon female SVL (Reichenbach and Dalrymple, 1986; Stanford and King, 2004) with average female fertility increasing from 6.4 in one year olds to 21 in six year olds (Stanford and King, 2004). Mean neonate size and mass were recorded as 142 mm SVL (n=51) and 1.9 g (n=199) respectively for females collected in KPWA from 1999-2001 (Badgley, Quinn and Reichenbach, unpublished data). Neonate mass was the same (1.9 g) as that found previously in 1980 at KPWA (Reichenbach and Dalrymple, 1986). In Illinois the average neonate SVL was 138 mm (n=557) (Stanford, 2002).

Growth has been accurately described using the von Bertalanffy growth model for *T. radix* in Illinois (Stanford and King, 2004). They found that males differed from females in asymptotic size (male and female asymptotes were 502 and 582 mm SVL, respectively) but not in the rate at which they approached this size. In Illinois, year class SVLs from males were as follows (average SVL in mm followed by year class in parentheses): 171.1 (0, newborn snakes during the August to October time period), 289.1 (1), 397.4 (2), 442.2 (3), 466.4 (4), 490.3 (5) and 495 (6) and for females: 196.6 (0), 315.8 (1), 460.9 (2), 513.5 (3), 543.3 (4), 596.2 (5) and 605.2 (6) (Stanford, 2002). Seibert and Hagan (1947) found that *T. radix* grew at a rate of 1.6 mm/day to 406-457 mm TL during their first year (20 May to 9 September) and 559-610 mm TL during their second year (1.3 mm/day). In Ohio, growth rates for snake age classes 1+ averaged 0.65 mm/day in 1978-79 and 0.52 mm/day in 1980.

Longevity, based upon the von Bertalanffy growth model, was estimated to be from 6-7 years (Stanford and King, 2004). Captive born *T. radix* in colonies at the Columbus Zoo and Aquarium (CZA) and Cleveland Metroparks Zoo (CMZ) have lived up to 9 years for males (this male is still alive as of August 2009) and 9 years 11 months for females. Longevity for captive born *T. radix* which died from a variety of causes other than accidental death averaged 5 years (n=6) and 4 years (n=4) for males and females, respectively (Johantgen, Becka and Reichenbach, unpublished data).

Population sizes for *T. radix* are some of the highest recorded for gartersnakes. Seibert (1950) using the Hayne method estimated 845/ha (342/acre) in a disturbed site near Chicago. In Illinois, Stanford and King (2004) estimates ranged from 24 to 65/ha using the Schumacher-Eschmeyer and Jolly-Seber methods, respectively. Bauerle (1972) estimated 320/ha in Colorado. In Ohio, estimates from 1978-1980 ranged from 52-123/ha for one site at KPWA (Reichenbach and Dalrymple, 1986; using the Schumacher-Eschmeyer method).

In Ohio, the diet of the Plains gartersnake consisted primarily of earthworms and frogs and occasionally toads and leeches (Dalrymple and Reichenbach, 1981). Elsewhere, Plains gartersnakes have been found to eat similar items as noted for Ohio snakes as well as slugs, fish, salamanders, shrews and mice (Rossman et al. 1996). In Missouri, *T. radix* showed strong seasonal variation with snakes primarily eating frogs in the summer and worms in the spring and fall (Rossman et al., 1996). Ballinger et al (1979) saw 30-40 adult *T. radix* feeding on tiger salamander larvae in a pond. Cebula (1983) recorded a *T. radix* regurgitating a nestling bird, possibly an eastern meadowlark. Neonate *T. radix* ate earthworms, fish and frogs but rejected grasshoppers (Reichenbach and Dalrymple, 1986). Neonatal Plains gartersnakes from Illinois and Ohio responded to prey chemical cues for earthworms, amphibians and fish (Burghardt, 1967, 1969; Burghardt and Williams, in prep.). Young snakes can also learn to capture different prey types including fish (Halloy and Burghardt, 1990; Burghardt and Krause, 1999) and thus predatory experience during headstarting may be a factor in survival of released snakes.

Chemical prey trails are followed primarily by use of the tongue which brings odorant molecules to the vomeronasal system (Kubie and Halpern, 1979). Visual cues are also used to detect prey (Chiszar et al., 1981).

Predators of the Plains gartersnake include red-shouldered hawks and other birds of prey, predatory mammals (foxes, coyotes, skunks, minks and domestic cats) and ophiophagous snakes (Ernst and Barbour, 1989). In addition to predators, cars and mowing may also be substantial forms of mortality. Of 56 snakes found dead on the roads at KPWA during a six hour period in fall, 1979, 10 were *T. radix* and of 39 snakes found dead after mowing operations, 17 were *T. radix* (Dalrymple and Reichenbach, 1984). Yaussy (2003) found four dead and one injured *T. radix* out of 469 snakes found on roads at KPWA during the fall, 2003. In addition to road mortality, improperly timed and duration of management activities such as prescribed burning are also potential threats. In many cases the actual management outcomes are compatible with the habitat requirements of herpetofauna, however large field burning or mowing activities may be deleterious if they occur during the animal's active season (generally mid-March through October). Wynn (1995, 1996, 1997) found one dead *T.*

radix as well as dead smooth green snakes, brown snakes and a massasauga after a prescribed burn at KPWA. Since management practices such as short grass cutting (mower decks <6 inches off the ground) and burning are considered mortality factors for the Plains gartersnake, the Division of Wildlife modified or stopped plowing, mowing and burning at selected sites (see Management Practices).

Mortality was estimated to be from 8 to 12% per month for newborns and 1.4 to 2.9% for adults (Reichenbach and Dalrymple, 1986). Survival estimated for *T. radix* in Illinois increased from 0.17 and 0.16 for male and female neonates (age-class 0) to 0.42 and 0.41 for male and female age-class 1 snakes. Survival for age-class 2+ snakes ranged from 0.35 to 0.52 (survival estimates are weighted averages from the 12 best-fit models from the program MARK) (Stanford and King, 2004).

The Plains gartersnake is one of the more mild tempered members of the genus *Thamnophis* (Rossman et al. 1996). Its first defense mechanism is to flee when encountered which is a common strategy used by striped snakes (Jackson et al., 1976). Fitch (1941) noted for *T. sirtalis* that the longitudinally striped pattern disguises motion as the snake moves through grass or brush with only part of its body visible. It may seem to shrink and vanish before the eyes of the observer, who may not be aware that it is in motion or at least may not detect the direction and rate of motion, as he would if there were transverse markings. The longitudinally striped pattern on *T. radix* has a similar effect at KPWA where *T. radix* can simply vanished in the tall grass. Its most common defense mechanism up capture is secretion of musk or defecation though some individuals will bite (personal observation; Rossman et al, 1996; Ernst and Barbour, 1989).

Newborn *T. radix* that were subjected to a variety of threatening stimuli in the lab would first attempt to crawl away from the investigator until high levels of lactate were attained (i.e. they were exhausted). Thereafter they would adopt one of a variety of antipredator displays including hiding their head under one or more loops of the body, tail waving and closed- or open-open mouth attacks (Arnold and Bennett, 1984). Developmental factors are also involved in these antipredator responses (Herzog et al., 1992).

STATE STATUS

The Plains gartersnake has been a state endangered species since being designated as such on August 31, 1974.

CONSERVATION

Population Monitoring

The first surveys began with studies on the Plains gartersnake in 1978 (Dalrymple and Reichenbach 1981, 1984, and Reichenbach and Dalrymple, 1986). Weekly trips were made to one particular site at KPWA from March through September from 1978-80. Snakes were hand collected by walking throughout the 20 ha grassland site. All *T. radix* and *T. sirtalis* collected were marked (ventral scale marking technique; Brown and Parker, 1976), measured (snout-vent length, SVL) and classified as males, females, juveniles or neonates. The densities estimated during those years ranged from 52 to123 and 45 to 89/ha for *T. radix* and *T. sirtalis*, respectively (using the Schumacher Eschmeyer (1943) mark-recapture methodology) (Reichenbach and Dalrymple, 1986).

From 1981-1993 monitoring of *T. radix* at KPWA was not conducted. Then from 1994-1997 herpetofauna surveys were conducted at KPWA. Cover sheets placed in various locations throughout KPWA was the primary method used to find reptiles. In over 60 trips, only six *T. radix* were seen (Davis et al., 1994; Wynn 1995, 1996, and 1997). Earlier, during the 1978-80 study, five or more *T. radix* would typically be found per trip. In 1998, Reichenbach duplicated his earlier survey methods on the Plains gartersnake and found five Plains gartersnakes in 10 trips to the same site he studied 17 years earlier. It was determined that the *T. radix* population at this one site had declined by 94% (Reichenbach, 1998).

An intensive survey for the Plains gartersnake began during the 1999 season. Combined efforts by the Columbus Zoo and Aquarium (CZA), the Ohio Division of Wildlife (ODW), Norm Reichenbach and a research class from Westerville North High School resulted in 41 Plains gartersnakes being found. Snakes were found by walking the grasslands similar to what was done during the 1978-80 study in addition to using the cover sheets placed during the KPWA herpetofauna studies from 1994-1997. Seven of 41 *T. radix* found prior to 27 May 1999 were not marked. After 27 May 1999, 34 individuals were found and PIT tagged. Thirty-one of the 41 snakes found in 1999 were taken to the CZA since at that time it was unknown how many *T. radix* still existed in Ohio. Of the 31 individuals taken to CZA, four gave birth to 45 neonates. All 31 adult snakes were subsequently released at their capture sites as well as 17 neonates. The rest of the neonates were retained by the CZA in order to establish a captive breeding colony (Wynn and Reichenbach, 1999). In the seasons following 1999 only a few additional adult Plains gartersnakes were permanently retained in captivity in order to augment the captive breeding colonies. In addition, some gravid females where temporarily held in captivity until they gave birth in order to gain a better knowledge of their reproductive biology.

Since 1999, 10 sites around KPWA have been used to determine the range of *T. radix* at KPWA. Two other sites, where the highest numbers of *T.* radix were recorded, were used to determine population demographics. One site was designated as the reference site and the other as an experimental site where headstarted *T. radix* were to be added and where *T. sirtalis* were removed (*T. sirtalis* were removed from this site from 2003 to 2008). Findings from these sites are detailed in annual reports to ODW (Wynn and Reichenbach, 2001, 2002, 2003, 2004, 2005, 2006, 2007 and 2008).

In addition to field surveys, extensive surveys of the roads throughout KPWA were conducted in the fall and spring of 2003 and 2004 (Yaussy, 2003). These data along with the information collected on the sites used to assess the range of *T. radix* at KPWA indicated that relative to the range in 1978-80, the north to south range (3.2 km or 2 mi) remained the same and the east to west range (6.8 km or 4.2 mi) contracted eastward by about 3.2 km (2 miles) (Fig. 1).

At the reference site, 91 *T. radix* (82 with PIT tags) were collected over eight years (2001 to 2008). At this site, 21% of snakes marked were recaptured during the same year they were marked (17 out of 82) and then between years the recapture rate declined to

3.7% (3 out of 82). The average number of *T. radix* found annually at the reference site was 11 and ranged from 2 to 28. The ratios of *T. sirtalis* to *T. radix* from 2002 to 2008 were between 1.3:1 to 12.7:1 except in 2006 where the ratio was 34.5:1.

At the experimental site 107 *T. radix* were collected including 44 females, 60 males and 3 snakes of unknown gender captured over a period of 10 years (1999 to 2008). Of these snakes, 10 have been recaptured at least once during the year they were tagged (9.3%) and nine have been recaptured in the years beyond the year they were tagged (8.4%).

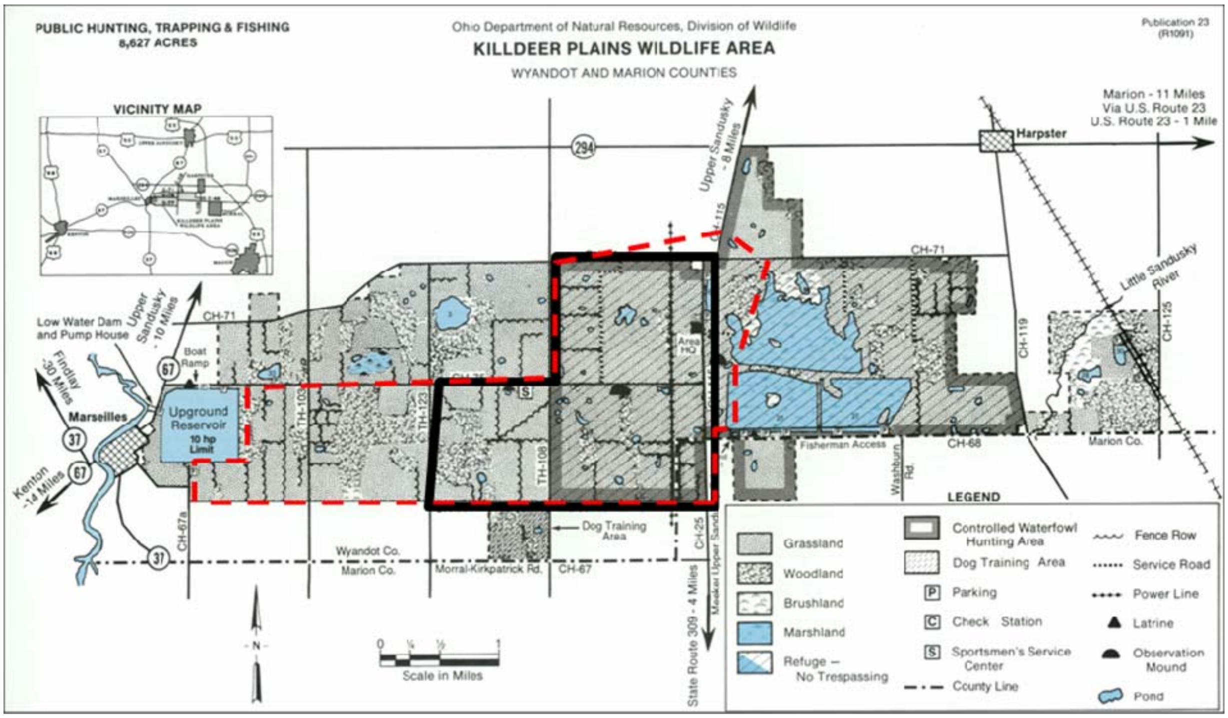

Figure 1. Range of Thamnophis radix at KPWA (dashed line polygon represents the distribution in 1978-80 and the solid line polygon represents the current distribution.

For the experimental site, during the years where recaptures were available between years, survival and recapture rates as well as population sizes were estimated. The survival and recapture rates ranged from 0.36 to 0.41 and 0.24 to 0.42, respectively, using a model in Program MARK that assumes constant survival and recapture rates. The recapture rate was 0.24 (0.05, 0.66, 95% confidence intervals). Using the same model as noted for Program Mark (Jolly-Seber Model D), the population estimates for the adult *T. radix* are 100, 145, 44 and 45 snakes (estimates for 2000, 2001, 2002 and 2003, respectively) with an average of 84 (0, 204, 95% confidence intervals). The average number of *T. radix* found annually at the experimental site was 12 and ranged from 1 to 35.

While reducing the number of *T. sirtalis* at this site was successful (initial numbers of *T. sirtalis* removed were 93 and 88 in 2003 and 2004, respectively and then they ranged from 26 to 42 from 2005 to 2008), the number of *T. radix* did not increase. This is even with the augmentation of the *T. radix* population at this site which included the release of 98 headstarted snakes in an area near this site starting in 2005. Removal of *T. sirtalis* at this site was stopped in 2009.

As noted above, the number of *T. radix* recaptured the year subsequent to when it was marked was low (3.7% and 8.4% at the reference and experimental site, respectively). This probability was examined in relationship to the number of snakes collected in a given year for data collected from 1999 to 2008. When 11-15 snakes were marked, recaptures in the subsequent year occurred 25% of the time. If 16 or more snakes were marked, recaptures in the subsequent year occurred 100% of the time. When 10 or fewer snakes were marked in a given year, there was never a recapture in the subsequent year. Considering that the annual survival rates for *T. radix* ranged from 0.36 to 0.41 at KPWA, if 10 or fewer snakes were marked in a given year, then in the subsequent year only four snakes might still be available for recapture. As seen above, a recapture would be very unlikely.

In addition to field surveys of *T. radix* at various locations throughout KPWA, reproductive output was monitored primarily from 1999 to 2001. Gravid females were taken to both the CZA and CMZ until they gave birth. Neonate masses were then recorded along with % alive and stillborns. In 2001, both gravid *T. radix* and *T. sirtalis* were evaluated as noted above for reproductive output. Total mass of neonates produced per female were compared to that collected in 1980 using analysis of covariance.

The average number of neonates from 17 clutches from females collected between 1999 and 2001 was 12.5 (Badgley, Quinn and Reichenbach, unpublished data). The % neonates born alive was similar for the two species in 2001 with *T. radix* averaging $95\pm6\%$ and *T. sirtalis* $79\pm31\%$. Comparison of *T. sirtalis* reproductive output (total grams of neonates produced) from 2001 to 1980 indicated a statistically significant drop of about 8.5 g for females of comparable SVL ($F=24.1$, d.f.=1,21, $P<0.001$). For *T. radix*, there were no statistically significant annual differences (1999-2001) for the reproductive output of snakes found recently (1999-2001; $F=0.4$, d.f.=2, 10, $P=0.6$). Comparing the reproductive output (total grams of neonates produced) from these recent years to snakes collected in 1980 indicated a significant drop of 13.3 g for females of comparable SVL ($F=10.1$, d.f.=1,21, $P=0.005$). If an average neonate has a mass of 1.9 g then these decreases would translate into a reduction of approximately five neonates for *T. sirtalis* and seven for *T. radix*.

Comparison of the two species in the recent years (*T. radix* data for 1999 to 2001 and *T. sirtalis* data only for 2001) indicated no significant difference in their reproductive output ($F=0.4$, d.f.=1,22, $P=0.5$). This was similar to that noted in 1980 by Reichenbach and Dalrymple (1986) where both species showed no statistically significant differences in their reproductive output. This reduced reproductive output in the recent years likely reflects natural variation since it was noted in both species (Seigel and Fitch, 1985).

In addition to comparing the reproductive output of *T. radix* and *T. sirtalis*, laboratory studies on neonates of both species were conducted. *Thamnophis radix* and *T. sirtalis* from KPWA showed no competitive differences in food competition not explained by body size. However, *T. sirtalis* were considerably more prone to strike in antipredator contexts (Burghardt and

Williams, in prep.). Earlier studies also showed that young *T. radix* learned to avoid snakes that they lost encounters with (Yeager and Burghardt, 1991).

Population augmentation

Captive *T. radix* Colonies at Cleveland Metroparks Zoo and Columbus Zoo and Aquarium

Garter snake colonies at each zoo are maintained in states of permanent quarantine to prevent pathogen transfer between the colony and the cosmopolitan animal collection. This is achieved through the use of small dedicated isolation buildings and standard quarantine protocols.

Housing

Adult snakes are housed together in standard 20-gallon aquaria at Cleveland Metroparks Zoo (CMZ) and/or Vision® brand reptile enclosures (CMZ: 36"x 28"x 18" CZA: 48"x 28"x 28"). Substrate consists of newspaper or unbleached paper towels (CMZ) or several inches of shredded aspen bedding at CZA. Cage furnishings include hide-boxes (with/without moist sheet moss), flat rocks, large water bowls, and cork bark slabs. Soiled substrate is removed twice weekly, at which time clean water bowls with fresh water are provided. Total replacement of substrate and disinfection of the enclosure is performed every 6 to 8 weeks.

Neonate and juvenile snakes are housed individually in clear plastic storage boxes (7" x 13" x 3.5"). The boxes fit into a multi-tier storage rack that is specially designed for housing reptiles. The bottom of each box is lined with newspaper or paper towels. At one end, sheet moss or crumpled paper towel is provided for cover along with a shallow water bowl (Syracuse watch glasses are ideal for this application). Small holes in the side of each box provide ventilation. The young snakes are transferred from soiled to freshly prepared boxes three to four times per week (after each feeding and on one or two intervening days).

Temperature & Photoperiod

Temperature and humidity within the garter snake buildings tend to fluctuate with outdoor conditions daily and seasonally. For normal maintenance of adult and juvenile snakes, ambient daytime temperature is kept at a range of 70-80^{o}F and allowed to drop to around 65^{o}F at night. During daylight hours, a 50W UVA heat lamp warms a region of the adult enclosure(s) to 85^{o}F.

Fluorescent strip lights with standard and/or specialty reptile bulbs provide lighting for aquarium and Vision® enclosures. Because the plastic neonate/juvenile boxes are enclosed by a walled rack that is open on one side only, they are illuminated only by ambient room light. Electronic timers are utilized on enclosure and building interior lights to approximate the natural outdoor photoperiod.

Diet

Adult snakes are individually offered food twice weekly, with two to three days between feedings. Food items may be offered on a glass Petri dish in the snake's enclosure or the snake may be placed into a lidded, ten-gallon Rubbermaid® waste receptacle for feeding. Food items offered include neonate mice & adult mice (freshly sacrificed and/or frozen), earthworms, and chopped smelt. Generally an adult radix will consume 4 to 6 earthworms, 2 pieces of smelt, or 2 to 4 neonate mice per feeding. Gravid females however are often ravenous and will readily consume as many as 15 neonate mice per feeding. Adult snakes show a preference for earthworms.

Juvenile snakes are offered food twice weekly, with two to three days between feedings. Food items regularly offered include chopped earthworms, chopped neonate mice, and chopped smelt. Juvenile snakes at CZA are fed a mixture of chopped earthworm and mouse (approximately 1:1 by volume) which they consume readily (to satiation). Guppies and tadpoles may be offered as they are available.

Neonate snakes are offered food three times a week, with one to two days in between feedings. Food items include chopped trout worms or diced night crawlers, guppy fry, and small tadpoles. Some neonates will initially refuse to consume earthworm but will readily accept a diet of guppy fry, chopped smelt and/or tadpoles. Once they have begun eating reliably, earthworm and eventually mouse may be incorporated into their diet. Most neonates will be eating consistently and putting on mass by two to three months of age, at which time feedings may be reduced to twice a week.

Brumation & Breeding

During the winter months, captive adult snakes are put through a period of brumation in order to induce reproductive behavior in the spring. Beginning in the early fall, use of heat lamps is discontinued and the photoperiod is gradually shortened to approximately nine hours of light. During this time the adult snakes often reduce food consumption or stop feeding all together. Any snakes that have continued to feed are fasted for at least ten days to allow their digestive tracts to clear. Adult snakes are usually moved into brumation enclosures in mid to late November (2-5 snakes/enclosure). At this time a veterinarian performs a brief physical exam on each snake to verify that it is in good health.

Brumation enclosures consist of standard 15-gallon glass aquariums with latching screen lids or Rubbermaid® containers with holes drilled in the lids. A thick layer of moistened sheet moss is provided as substrate. This may overlay a 3-inch base of cypress mulch which helps to maintain humidity. Light-weight water bowls are placed on top of the moss. The brumation enclosures are place inside a household refrigerator or biological incubator (Percival Scientific) at an initial temperature of 65-70 ^{o}F. The temperature is subsequently lowered 2.5 to 5 degrees per day until 55 ^{o}F is achieved.

Morbidity and Mortality

Plains gartersnakes are generally hardy in captivity. Mortality factors observed include bacterial infections and neoplasia, failure to thrive, and stillborns. Gout has occurred in several cases and it is unknown if this was from primary renal disease, or dehydration. Many deaths are associated with brumation, or leaving brumation. Also, death or illness has been associated with husbandry events such as heat failure. Commonly affected organs include liver, lung, gastrointestinal tract, skin and kidney.

The causes of mortality are relatively consistent between the Cleveland Zoo and the Columbus Zoo. In 2006 there was a cluster of deaths (eight captive born *T. radix*) due to mycobacteria. These were generally neonates. Guppy feeder fish were examined and were also found to have mycobacteriosis. Of the few mycobacteria samples that were cultured and speciated (snakes and fish), there was not a consistent culprit. The cause of this outbreak is still undetermined. To date, unaffected snakes housed in the same enclosure have not developed mycobacteriosis.

Population Viability Analysis for *Thamnophis Radix* at KPWA

In 2003, a Population Viability Analysis was conducted on the population of *T. radix* at KPWA (Stanford, 2003). Population Viability Analysis (PVA) is a broadly defined term that utilizes a variety of quantitative methods to assess the future status of a population. Over the past 20 years, the methods encompassing PVA have helped to provide insight into population dynamics, refine management strategies and direct future research (Mills and Lindberg, 2002). Many types of PVA modeling techniques require knowledge about age specific survival, fecundity and initial distributions of each age-class. Fortunately, mean adult survival and fecundity for the KPWA *T. radix* had previously been determined. However, since survivorship estimates for both the neonate and juvenile age-classes of snakes in this population were unable to be calculated from the available data, values previously calculated for a Northern Illinois population of *T. radix* were substituted and utilized in a Leslie matrix model (Stanford, 2002, 2003).

Methods

<u>Preliminary Population Assessment</u>

Initial age class distributions were extrapolated using data from the experimental site at KPWA and supplemented with data from the Northern Illinois population (Stanford, 2003). These distributions along with the estimates of survival and fecundity (Table 1) were entered into a Leslie matrix and modeled for 10 generations to obtain a population projection model of *T. radix* at KPWA. The corresponding elasticity and sensitivity values, along with the population growth rate (λ) and other population characteristics, were then determined from this initial matrix.

An extinction/decline risk curve was also generated for the current population of *T. radix* at KPWA based on this initial matrix. These curves show the probability that the population will fall below a threshold abundance during the duration of the simulation (Akcakaya et al., 1999).

Table 1. Age specific distributions, fecundities and survivorships that were used to model the KPWA population of *Thamnophis radix*. Values in ***bold italics*** were supplemented with data from Stanford 2002.

Age-Class	***Initial Distribution***	***Fecundity***	***Survival***
Age 0 (Neonate)	151	0	***0.16***
Age 1 (Juvenile)	***5***	0	***0.41***
Age 2+ (Adult)	24	2.63	0.42[1]

[1 data from KPWA, 0.42 survival values differs from the 0.41 noted under population monitoring since the 0.41 was for all size classes of *T. radix* at the experimental site at KPWA]

Demographic Perturbation Analysis

Elasticities and sensitivities indicate the parameters that are most likely affecting the current population growth rate (λ). To test whether these "sensitive" parameters actually induced an effect on λ, a Sensitivity Analysis (Mills and Lindberg, 2002; Caswell 2000a, 2000b; Akcakaya et al., 1999) was conducted following the methods described in Stanford 2002. Analyses were conducted in two ways. First, λ was examined after parameter estimates were individually adjusted according to their 95% confidence intervals. Second, λ was examined after each initial parameter estimate was either increased or decreased by 10%. A result was considered significant if λ changed by more than 10% from the initial model.

Management Strategies

Although sensitivities and elasticities are useful tools for determining which parameters have the most effect on the population growth rate, modeling potential management strategies can show the possible effects to the population size itself. Several management strategies were examined that involved the introduction of individuals from each age class or a combination of age classes. The average abundance after 10 generations following the implementation of each management strategy was compared to the average abundance of the population with no management in place. The percent change in population size was then determined. A cost rank (1-5) was also placed on each management strategy for comparative purposes. Risk curves were also generated for each of the management simulations to determine the subsequent change in the population size as it relates to the risk of decline/extinction.

Results/Discussion

Preliminary Population Assessment

Using the most current data available, the population models indicated that *T. radix* was in decline at KPWA (λ = 0.7373). The predicted average female abundance after 10 generations was only 5.41 snakes (Figure 2). The extinction risk curves showed that the population had an 18.5% chance of going extinct within the next 10 years if no management occurred.

Elasticity values were all fairly close, but indicated that adult survival was contributing the most to the observed growth rate. Sensitivities also revealed that a change in neonate survival would have the most effect on changing the population growth rate (Figure 3).

Demographic Perturbation Analysis
Results of the perturbation analyses conducted showed that the majority of the significant effects to the vital statistics occurred when a survival value was changed by the 95% confidence interval (see Tables 4 & 5, Stanford, 2003). Both neonate and adult 95% confidence intervals had significant effects on the population growth rate. Additionally, the upper limit of adult survival had significant effects on all of the vital statistics. Since both neonate and adult survival induced an effect on the growth rate, it was suggested that both of them would be potential candidates for the focus of management strategies. However, the large confidence intervals of both of these parameters indicated that the estimates themselves were not that reliable.

Management Strategies
Implementation of each of the eight initial management strategies all significantly increased the size of the population in the simulations. A trajectory summary and an extinction/decline curve were also generated for each management strategy in order to visualize the changes to the overall population size from the original model (see Appendix in Stanford, 2003). A cost rank of 1-5 was placed on each strategy based on how "costly" it might be to complete. The strategy that induced the largest change in population size was the release of 20 adult female snakes (N = 194.42 after 10 generations; 3493% increase, Table 7 Stanford, 2003). The strategy that had the smallest increase in population size was the release of 10 female neonates (N = 23.73 after 10 generations; 339% increase, Table 7 Stanford, 2003).

Conclusions
The results of the analyses indicated that the current adult survival rate was contributing the most to the observed population growth rate, but that a change in this growth rate would most likely be accomplished by changing the neonate survival rate. Management simulations showed that the release of any age class of animals caused an increase to the population size. However, the release of juvenile or adult animals caused larger increases in overall population size after 10 years, than the release of neonates. However, these strategies would also be more costly to implement. The release of larger numbers of neonates would equally increase the overall population size at less of a cost.

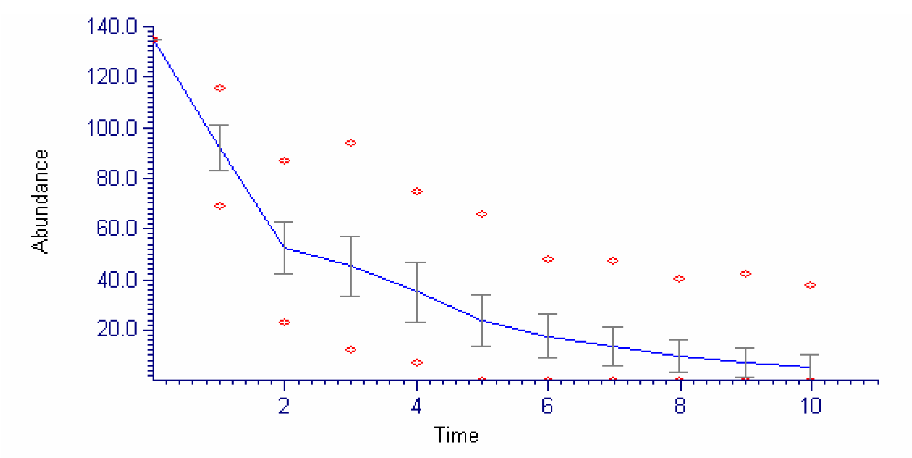

Figure 2. Population projection for *Thamnophis radix* at Killdeer Plains Wildlife Area based on the demographic data available in 2002 (λ = 0.7373). The population was modeled for 10 generations using the initial distributions, survivorships and fecundities in Table 1. The line represents the abundance mean with ±1 standard error bars. Symbols appearing below and above the abundance means represent the minimum and maximum abundances, respectively.

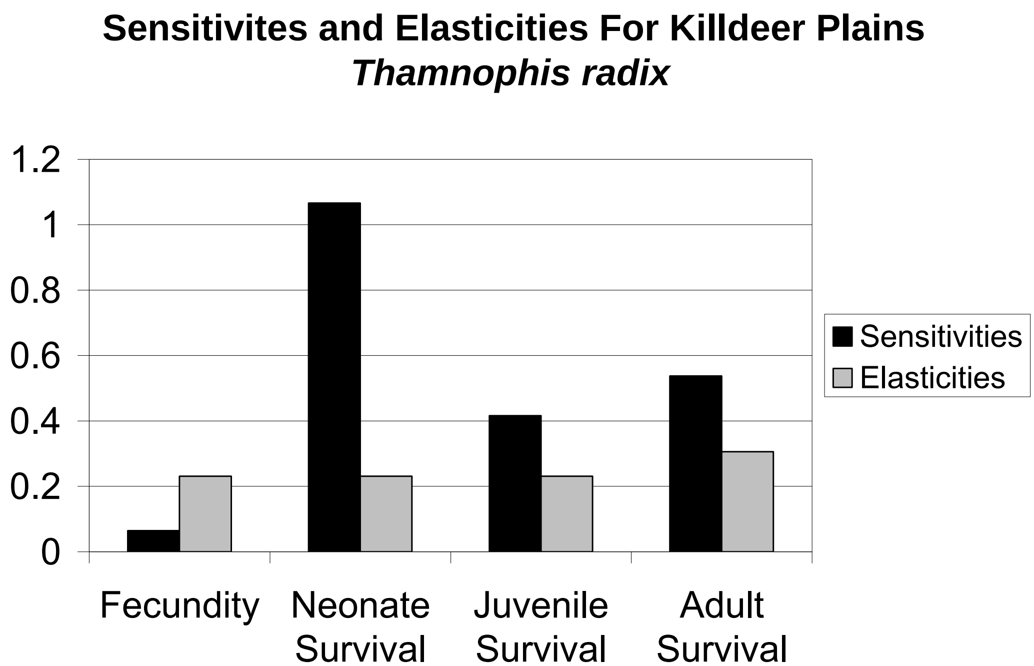

Figure 3. Elasticity and sensitivity values for the Killdeer Plains Wildlife Area population of *Thamnophis radix* based on a Leslie matrix model generated in RAMAS Ecolab using Table 1.

Reproductive output of captive breeding colonies and assessment of released neonates and head-started snakes

A captive breeding colony was established in 1999 at the CZA. Thirty-one *T. radix* captured at KPWA were taken to the CZA since at that time it was unknown how many *T. radix* still existed in Ohio. Of the 31 individuals taken to the zoo, four gave birth to 45 neonates. All 31 adult snakes were then released at their capture sites as well as 17 neonates. The rest of the neonates were retained by the CZA with plans that half would be headstarted and the other half would be used to establish a captive breeding colony (Wynn and Reichenbach, 1999). Because 50% of the retained neonates died during their first year in captivity, all the surviving snakes were retained for the captive breeding program and none were released as headstarted snakes.

In August 2000, the CMZ retained thirty-five neonates produced from wild caught *T. radix* from Ohio in order start a second captive breeding colony and to evaluate a new marking method, binary coded wire tags (CWT, Northwest Marine Technology, Inc.), planned for use with neonates produced by the captive breeding program. Mortality for all retained neonates was high (60%) from August through December 2000. Of the remaining snakes, six had CWT and five were controls. Retention of the CWT was 100% and the tag appeared to be safe for use with *T. radix* neonates since it did not increase mortality or decrease growth rates relative to control snakes (Wynn and Reichenbach, 2002). Some of the snakes used in the CWT study along with other neonates produced from wild *T. radix* collected from KPWA in 2001 were used to start a second captive breeding colony at the CMZ.

In 2001, the first neonates born from the captive breeding colony at the CZA (three from one female) were released at KPWA. In 2002, 47 neonates produced from the captive breeding colony in Columbus were released. All 50 neonates released in 2001 and 2002 were marked with the CWT tagging method and none were ever recaptured.

In 2003 the captive breeding colony did not produce any neonates. The one large female that produced 30 of the 47 neonates produced in 2002 died. In 2003, based upon a population viability analysis (see Population Viability Analysis for *Thamnophis radix* at KPWA), neonates produced by the captive breeding colonies were headstarted before release in order to improve their chances of survival. Hard releases of headstarted *T. radix* were done from 2004 through 2008 (Table 2). During the years where neonates were headstarted, mortality of neonates had declined from 50-60%, during the first few years of study, to an average of 26%.

Table 2. Summary reproductive output of the *Thamnophis radix* breeding colony at zoos in Columbus and Cleveland.

Year	# alive	#stillborn	total	% live neonates	# Females producing live neonates	# released[a]
2001	3	3	6	50.0	1	3
2002	47	5	52	90.4	4	47
2003	0	0	0	0	0	0
2004	38	21	59	64.4	4	24
2005	67	9	76	88.2	4	35[b]
2006	65	3	68	95.6	3	36[c,d]
2007	0	2	2	0	0	--
2008	37	15	52	71.2	2	3[d]&35[e]
Total	257	58	315			183

[a in 2001 and 2002 neonates were released during the year they were born while in subsequent years all snakes released were headstarted over the winter and then released during the following year. The difference between # alive and # released reflects mortality during headstarting.
b 14 headstarted snakes retained at the CZA due to potential infection with mycobacteria, one headstarted snake was retained by Doug Wynn since the transmitter implanted in the snake failed before release. Ten of these snakes were donated to Rich King in the summer of 2007 for research on mycobacteria transmission from adults to neonates and four were retained by the CZA for display at the zoo.
c eight additional snakes born in 2006 were retained by the Columbus and Cleveland Zoos. Six of these will be used for telemetry in 2008 and two were too small to be PIT tagged for release in 2007. These last two are with the Cleveland Zoo.
d of the eight snakes retained from the 2006 births, two died and six were implanted with transmitters. Two snakes died shortly after implantation. One of the other four snakes implanted had a nonfunctional transmitter. So a total of three headstarted snakes with transmitters were released near the experimental site on 10 July 2008 and the one with the nonfunctional transmitter was retained by the CZA. In summary, for snakes born in 2006, 36 were released in 2007 and 3 were released in 2008 for a total release of 39 snakes from the 2006 births.
e 35 snakes alive as of May 2009 and the plan to release all of these in 2009]

The focus since 2005 has been to augment the wild *T. radix* population near the experimental site with headstarted snakes. As headstarted snakes were released, methods to assess the effectiveness of this type of population augmentation were developed and implemented. Initially, released headstarted snakes were only PIT tagged and then the release location was surveyed in order to recapture released animals so that survival rates as well as movement patterns and growth rates could be evaluated. Only one headstarted snake was recaptured (snakes without transmitters) out of 98 that were released starting in 2005. This one snake was found about one month after it was released in 2005. It would have been expected with releases of 24, 35 and 36 headstarted snakes in 2005, 2006 and 2007, respectively (Table 2), to recapture some of these snakes. This expectation is based upon mark/recapture data on wild *T. radix* at KPWA where if 16 or more snakes were marked in a given year then there was a 100% success rate in recapturing one or more of these snakes in the subsequent year (see Population Monitoring). So either the survival rates for headstarted snakes are lower than those noted for *T. radix* (0.36 to 0.41 for adult *T. radix* at the experimental site, Wynn and Reichenbach, 2002, 2003, or 0.4 for "best-case" scenario for second year headstarted *T. radix* in Illinois, King and Stanford, 2006) or some other factor was adversely affecting recapture rates of headstarted snakes at KPWA.

Because of the low recapture rate noted above, some headstarted snakes were implanted with transmitters in 2006 to directly estimate mortality as well as movement patterns. As of July 2009, telemetry data are available for 13 headstarted snakes (6 in 2006, 4 in 2007 and 3 in 2008). Overall these data indicate that the snakes survived over the lifespan of the transmitter (average of 7.3 days; range 2-24 days) and that many randomly dispersed to distances of up to 294 m from the release site. Because many were dispersing randomly, it was difficult to find them once the transmitters ceased to function since many were moving outside of the monitoring sites where cover sheets were available to find snakes.

The high rate of movement of the headstarted snakes and the lack of recaptures from annual releases of 16 or more snakes in 2005, 2006 and 2007 (where recaptures were expected), caused reconsideration, in 2009, of the hard release protocol used for headstarted snakes. The current plan is to do soft releases so that the headstarted snakes can gradually adjust to KPWA. The hope is that this will increase site fidelity as well as survival rates. The soft release protocol involves retaining headstarted snakes in cages at KPWA for three to six weeks. The cages would include simulated crayfish burrow structures which are known to be used as refuges by *T. radix* at KPWA. Earthworms would be placed in the enclosures weekly where the snakes would have an opportunity to prey upon them. Prior to release the snakes would be measured (SVL and mass) to determine whether growth has occurred during the time the snakes were in the cages. A subset of snakes used in the soft release protocol would be implanted with transmitters and then tracked for the life of the transmitter (Wynn and Reichenbach, 2008). In addition, several hard released snakes will be released at the same time to compare survival, movement patterns and growth rates for hard and soft released snakes.

MANAGEMENT PRACTICES

Current Knowledge & Understanding

From the 1970's to the mid 1990's, Killdeer Plains Wildlife Area was managed to benefit the reintroduction of Canada geese in Ohio. During this time period, extensive areas of the wildlife area were mowed for goose pasture or placed into row crop agriculture to benefit resident and migratory Canada geese. Beginning in the mid 1990's, management strategy within the Division of Wildlife shifted to more of a habitat management strategy. Killdeer Plains was designated as a grassland management area. In addition, the number of Canada geese had increased dramatically in the state which greatly decreased the need for goose management areas. Also our knowledge of Plains gartersnakes and Eastern massassauga rattlesnakes increased greatly during this time period. Thus beginning in the mid 1990's the amount of mowing greatly decreased and is now conducted to maintain open habitats. In addition, guidelines for mowing were established to minimize effects on Plains gartersnakes and Eastern massassauga rattlesnakes since mowing was implicated as a mortality factor for the Plains gartersnake (see Natural History).

Based upon recommendations from Dalrymple and Reichenbach (1984), mowing operations have been modified as follows: 1) mowers at KPWA are set between 6 - 8 inches and 2) mowing conducted from June - August is done during the heat of the day (11am – 3pm) to coincide with the snake's period of inactivity and mowing done before June and after August is usually done in the mornings before 11am again to coincide with the snake's period of inactivity (see Natural History).

Controlled burning, which was also implicated as a mortality factor for the Plains gartersnake and Eastern massassauga rattlesnake, is used to prepare, enhance and maintain cool and warm season grass fields. Burning in snake sensitive areas is done as early as possible to coincide with the time period when snakes are hibernating. Burnings are typically done before the end of March though this may vary some depending on the actual weather conditions for a particular year. If there is concern that the snakes might be above ground, then the burn rate is slowed to give the snakes an opportunity to move to safety.

OHIO CONSERVATION PARTNERS ROLES & RESPONSIBILITIES

Division of Wildlife, Ohio Department of Natural Resources

The primary role of the Division of Wildlife has been to facilitate ongoing survey, inventory, captive-rearing, release, and outreach efforts by the conservation team. In addition, the Division owns the Killdeer Plains Wildlife Area and actively manages the site for the benefit of this and other grassland-dependent species which inhabit in the 9,170 acre area. Utilizing revenues from the Wildlife Diversity and Endangered Species Fund, the Division subsidizes the population survey work and some of the captive-rearing efforts.

Westerville North High School Field Studies Class

Surveys and mark-recapture studies at selected sites were initiated in 1999 to determine the current range and population size of *T. radix* at KPWA. Telemetry has also been used extensively to assess the effectiveness of using headstarted snakes to augment *T. radix* populations at KPWA. All components of the field work have been coordinated by herpetologist Doug Wynn with the help of students from his Westerville North High School Field Studies Class.

Columbus Zoo & Aquarium and the Cleveland MetroParks Zoo

The Columbus Zoo and Aquarium initially developed the protocols for breeding and rearing Plains gartersnakes in captivity with input and assistance from the Cleveland MetroParks Zoo and Northern Illinois University. This information has been used to produce captive-born snakes with sufficient genetic diversity for head-starting and release back into the wild. The zoos have been active members of the conservation team and have undertaken much of the captive rearing and implantation of transmitters in headstarted snakes with little or no financial support from the Division.

Liberty University

Norman Reichenbach, Professor at Liberty University in Virginia, did research on the population biology of the Plains gartersnake in the late 1970s at KPWA. He returned to his KPWA study site in 1998 and determined that the Plains gartersnake population had declined significantly. He works extensively with Doug Wynn on the study design and analysis of the field and captive snake data and remains an active partner in the project.

Northern Illinois University

A population viability analysis conducted by Northern Illinois University Research Associate Kristin Stanford suggested that holding neonates (newborn) snakes in captivity for their first year (referred to as “headstarting”) would improve their survival rate when released into the wild. This new approach was then implemented at the zoos in 2004. Ms. Stanford remains active in the conservation team.

University of Tennessee

Ecologist and evolutionary biologist, Professor Gordon M. Burghardt at The University of Tennessee has worked to examine the genetic diversity of the Ohio garters compared to the diversity found in the robust Midwestern population. In addition, Dr. Burghardt also conducted comparative developmental studies of neonatal plains gartersnakes and their potential competitor, the common gartersnake, in his laboratory to help determine the nature of any competition that does occur among young snakes, which are very hard to study in the field.

THE ROLE OF PRIVATE LANDOWNERS

While it is believed the entire population of the plains gartersnake is on the state-owned Killdeer Plains Wildlife Area, if snakes are discovered on privately-owned lands the Division of Wildlife will work with the landowners to alleviate any concerns they may have and encourage measures to conserve the species on their property.

OUTREACH AND EDUCATIONAL OPPORTUNITIES

In 1951, noted Ohio herpetologist Roger Conant stated, “We have learned only recently that this snake is a part of Ohio fauna. The presence of this western snake in the prairies of Ohio, so far east of any other known colony, would seem to constitute one of the most remarkable examples of prairie relict yet recorded." Even today while this species may not be well-known by the general public, it has garnered support from herpetologists and others interested in its conservation. As a result, media interest in the species remains high. The snake has been the subject of several WildOhio magazine and video program segments and has been featured in several newspaper articles. The Columbus and Cleveland Zoos have spotlighted the species in outreach programs and educational materials and the Division of Wildlife has materials available on their website. The snake and its conservation has been part of the curriculum for students who participate in the Westerville North High School Field Studies Class as well as the Ohio State University Stone Lab Herpetology Class. As additional opportunities to showcase this species arise the conservation partners will do so.

RESEARCH NEEDS

1) Comparison of site fidelity and survival of soft and hard released head started snakes including soft released snakes retained for variable lengths of time.
2) Behavioral evaluation of head started snakes with regard to their antipredator response and foraging efficiency.
3) Telemetry of adult male and female *T. radix* to determine
   a. their movement patterns and habitat use at KPWA
   b. use of underground structures like crayfish burrows. Cameras fitted with optic fiber lights could be used to examine crayfish burrows to confirm use of burrows by the snakes.
   c. overwintering mortality
4) Determination of the effects of illegal collecting on *T. radix* populations. This could be done through the use of "game cameras" set up at monitoring sites to determine if people are illegally collecting *T. radix*.
5) Evaluation of mower height on the mortality of snakes. Dead *T. sirtalis* could be placed in front of a mower set at various heights to determine if the currently used 6-8" height is adequate to prevent snakes from getting injured or killed by mowing operations.
6) Intensive survey of the Crawford and Marion County Historical Sites
7) Comparison of *T. radix* and *T. sirtalis* demographics (survival rates, recapture rates, population size)
8) Establishment of a second population of *T. radix* in Ohio, potentially at the Big Island Wildlife Area.

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PLAN DEVELOPMENT AND SECTION AUTHORS

This plan was developed and written by the following partners for this conservation endeavor:

Division of Wildlife, Ohio Department of Natural Resources

Carolyn Caldwell authored the following sections: Introduction/Purpose of the Plan, State Status, Ohio Conservation Partners Roles & Responsibilities, The Role of Private Landowners, and Outreach and Educational Opportunities.

Fred Dierkes and Scott Butterworth coauthored the Management Practices section.

Westerville North High School Field Studies Class

Doug Wynn coauthored the following sections: Historical & Current Ohio Distribution, Population Monitoring, Reproductive output of captive breeding colonies and assessment of released neonates and head-started snakes and Management Practices.

Columbus Zoo & Aquarium and the Cleveland MetroParks Zoo

Michael Barrie, Kristy Becka, and Peter Johantgen coauthored the section on Captive *T. radix* Colonies at Cleveland Metroparks Zoo and Columbus Zoo and Aquarium. Others who have contributed to the captive breeding program at these zoos include two recently retired curators, Dan Badgley and Hugh Quinn.

Liberty University

Norm Reichenbach was the editor of this plan and authored the following sections: Description/Taxonomy, U.S. Distribution, and Natural History. He also coauthored the following sections: Historical & Current Ohio Distribution, Population Monitoring, Reproductive output of captive breeding colonies and assessment of released neonates and head-started snakes and Management Practices.

Northern Illinois University

Kristin Stanford authored the section on Population Viability Analysis for *Thamnophis radix* at Killdeer Plains.

University of Tennessee

Gordon Burghardt authored the section on the Genetic Distinctiveness of *T. radix* in Ohio.

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