

Natural history of the Queen Snake, *Regina septemvittata*, in southeastern Pennsylvania, U.S.A.

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ABSTRACT — The behaviour and ecology of the North American Queen Snake, *Regina septemvittata*, was studied in Lancaster County, Pennsylvania, from May 1965 through July 1967. Data were gathered on the snake's habitat, population dynamics, annual and daily activity cycles, hibernacula, thermal ecology, reproduction, diet and foraging behaviour, and predation, parasites and injuries.

THE Queen Snake, *Regina septemvittata*, ranges in North America from southeastern Pennsylvania, western New York, and southwestern Ontario west to southeastern Wisconsin and adjacent northeastern Illinois, and south to northern Georgia, Alabama, and eastern Mississippi (Ernst, 2002). A disjunct population occurred in the Ozark Mountains of northern Arkansas and southern Missouri, but Johnson (2000) reported that the Missouri population has been extirpated. Although widespread this snake is restricted in habitat to clean waters, usually shallow streams or brooks, where its crayfish prey are plentiful, and abundant hiding places are present along the banks (Ernst & Ernst, 2003). It has been mostly ignored, and knowledge of its life history parameters and population dynamics are generally lacking or anecdotal in nature. The only comprehensive study was in Kentucky by Branson & Baker (1973, 1974). Other reported studies were on growth (Raney & Roecker, 1974), aggregation and hibernation (Wood, 1944, 1949), various aspects of reproduction (Dunn, 1915; Tripplehorn, 1949; Dyrkacz, 1975; Ford, 1982; Minesky & Aldridge, 1982; Brown, 1992; Fontenot & Platt, 1996), and diet and feeding behaviour (Surface 1906; Uhler et al., 1939; Raney & Roecker, 1947; Judd 1955; Adler & Tilley, 1960; Burghardt, 1968; Brown 1979, 1992; Godley et al., 1984; Pinder, 1996).

Regina septemvittata was studied in Lancaster County, Pennsylvania from May 1965 through July 1967. Data gathered during that period are reported below.

METHODS

Study Site

Regina septemvittata were studied at the former White Oak Bird Sanctuary, approximately 1.6 km north of Manheim, Lancaster County, Pennsylvania. The site was privately owned and covered approximately 10 ha of woodland and marsh surrounding a 2.4 ha pond. The pond and marsh were originally formed by the damming of Big Chickies Creek, a tributary of the Susquehanna River, for a milling operation, which was still active at the time of the study. The original mill dam was supplemented by a paved stone road which crossed its top. The land surrounding the sanctuary included several boggy pastures crossed by clear, shallow brooks which were also examined during the study. The pond was shallow and slowly filling with silt. Its depth graded from 10 cm at the northern end to slightly less than 2 m at the dam at the southern end of the sanctuary. Beyond the northern shore of the pond was a > 5 ha marsh transversed by the creek and several 1-2 m wide tributary brooks, and including several shallow vernal pools. The more solid

portions of the marsh were filled either with peat or sand-loam soil. On the eastern and western shores of the pond were more than 2 ha of mixed woodlands, predominately of White Oak (*Quercus alba*), maples (*Acer ruber*, *A. saccharinum*, *A. saccarum*, *A. negundo*), and Hickory (*Carya cordiformis*), but also including Ash (*Fraxinus nigra*), American Elm (*Ulmus americanus*), Beech (*Fagus grandifolia*), Sassafras (*Sassafras albidum*), Gum (*Nyassa sylvatica*), Hackberry (*Celtis occidentalis*), and Willow (*Salix* sp.). The most common shrubs were sumacs (*Rhus copallina*, *R. vernix*). The most abundant ground plants were Poison Ivy and Poison Oak (*Rhus radicans*, *R. toxicodendron*), and Raspberries (*Rubus* sp.). Skunk Cabbage (*Symplocarpus foetidus*) was common in the damp parts bordering the marsh. The eastern side of the pond was 25-65 cm deep, and mostly shaded by large trees. The western side was more shallow, 5-30 cm, and had less dense woodlands along its banks making it more open to sunlight during the day. At the northeastern and southeastern corners of the pond were small areas of grass lawn (*Poa* sp.). Other amphibians and reptiles collected in the vicinity were the anurans *Acris crepitans*, *Bufo americanus*, *Rana catesbeiana*, *R. clamitans*, *R. palustris*, and *R. pipiens*; the salamanders *Eurycea bislineata*, *Plethodon cinereus*, and *Pseudotriton ruber*; the turtles *Chelydra serpentina*, *Chrysemys picta*, *Clemmys guttata*, *Glyptemys insculpta*, *G. muhlenbergii*, *Sternotherus odoratus*, and *Terrapene carolina*; and the snakes *Nerodia sipedon*, *Thamnophis sauritus*, and *T. sirtalis*.

The south side of the dam was over 3 m deep at a 20% grade. Its walls contained numerous shallow, 10-55 cm, cracks between the rocks, or under the asphalt paved surface on top. Two sluice gates drained the pond into the creek below. At their bases were erosion pools 1-3 m deep. Downstream from the dam, Big Chickies Creek was 5-8 m wide, shallow, rocky, bordered with woods of the same vegetation as above, and contained many crayfish (*Cambarus* sp.). Large rocks and logs were present along the banks, and were used for retreats by the Queen Snakes.

Procedures

Snakes were hand collected. Each snake was marked by the scale clipping method of Blanchard & Finster (1933) and Fitch (1949). At each capture, the total body length (TBL), snout-vent length (SVL), and tail length (TL) were recorded with a metric tape measure accurate to 1.0 mm, and the snake was weighed with a spring scale accurate to 1 g. Each snake was sexed using the methods of Conant & Collins (1998) and Palmer & Braswell (1995). The following data were also recorded: date, military time, type of activity (activity was defined in terms of thermal dormancy; snakes were considered active if responsive to disturbance, dormant if not responsive), air temperature (AT), surface temperature (ST), water temperature (WT), cloacal temperature (BT), presence or absence of a food bolus, and any signs of injury or parasites. BT was taken with a quick reading Schultheis cloacal thermometer, and AT, ST and WT were recorded with a standard laboratory mercury thermometer. Snakes swollen with food were gently palpitated to force regurgitation of the prey. These prey and others from natural observations of feeding were recorded.

RESULTS AND DISCUSSION

A total of 205 individual *Regina septemvittata* were captured 290 times during the study; 280 of these were of active snakes. Capture data allowed the following conclusions to be drawn.

Habitat

Habitat characteristics were recorded at each capture. Five different habitats were occupied. Four individuals were captured once each (1.4%) in the clear brooks flowing through the boggy pastures to the north of the marsh. Water depth in the brooks was 15-61 cm, but the Queen Snakes were captured in areas of 15-20 cm depth. The bottoms of the brooks consisted of sandy-loam to gravel, with a few larger rocks scattered along them. Crayfish were common throughout the brooks. Few surface retreats were present, and it is thought that the snakes used Muskrat (*Ondatra zibethicus*) bank burrows for retreats, as 10 captures were made at or near the entrance of such

burrows. Three Queen Snakes were captured once each (1.1%) in the shallow pools or drainage channels of the marsh where crayfish occurred. These sites had mucky sandy-loam bottoms and water depths of 10-15 cm. Four captures (1.4%) were made in the western shallows of the pond at depths of 15-25 cm. The bottom there was of sandy-loam, and some crayfish were present.

Sixty-five captures (22.4%) were made on the rocky south-facing wall or in the numerous shallow cracks in the wall of the dam above the water line. The dam site was not considered a foraging area, instead it served as a basking site and one of nighttime and winter retreat. It also served as a refuge during frequent spring and summer flooding of Big Chickies Creek. The dam was the major aggregation site for snakes at the southern portion of the Sanctuary; in addition to the Queen Snakes, 25 Northern Water Snakes (*Nerodia sipedon*) and 5 Common Garter Snakes (*Thamnophis sirtalis*) were also captured there.

Most captures (216, 74.5%) of *R. septemvittata* occurred in the 100 m stretch of the Big Chickies Creek below the dam. No *R. septemvittata* were found in the two deep pools at the base of the dam, although *Nerodia sipedon* was occasionally seen there. The bottom of the creek consisted of alternating stretches of sandy-loam, gravel, or rocky areas, and water depths along the 100 m stretch were 3-20 cm. Most crayfish were observed and most foraging by the snakes in all areas occurred in the gravel and rock areas, where 216 captures were made.

The stone dam was a focus of activity for the *R. septemvittata* in the southern end of the Sanctuary. All but seven (2.4%) of the total Queen Snake captures were made at the dam or downstream from it. Only those snakes taken to the north in the marsh or boggy pastures were not originally captured or recaptured there. The number of captures in the Big Chickies Creek below the dam indicates that it was the principal foraging habitat for the population at the dam site. Of the four Queen Snakes caught foraging above the dam in the pond, two were also captured at the dam. The importance of the dam and downstream habitat is even more important when it is considered that

most research time in 1965-1967 was centered on the capture of turtles, the prime research subjects then, in the pond, marsh and boggy pastures above the dam.

From the above data, prime habitat for *Regina septemvittata* can be described as gravel or rocky bottomed, clear waters, with depths of 10-25 cm, an abundance of crayfish, good daily refuges in the form of fallen logs or large stones on the banks, and a suitable hibernation site nearby. This description essentially fits those reported by Branson & Baker (1974), Judd (1955), LeRay (1928), Neill (1948), and Wood (1949).

Population

A total of 205 *R. septemvittata* were captured 290 times at White Oak from May 1965 through July 1967. Eighty-five individuals (41.5%) were recaptured one or more times. The number of captured individuals per day averaged 1.8 (0-5); and the overall proportion of recaptures of marked individuals did not increase significantly as more individuals were marked after 1965 (Spearman's coefficient of rank correlation; $r_s = 0.388$, $p > 0.05$). Only 16 (7.8%) of the marked snakes were recaptured more than once: one adult female and two adult males were recaptured four times, and eight adult males and five adult females were recaptured twice each. No neonates were recaptured.

The population size was calculated using the 'weighted least squares' procedure of Schumacher & Eschmeyer (1943) recommended by Turner (1977). This method has the advantage of eliminating bias caused by unequal recapture rates, as it is based on a series of collecting periods rather than only two, as in the Peterson Estimate (Begon, 1979). Data from a series composed of the last 100 collections of *R. septemvittata* in 1966-1967 were used to calculate the population size, and the population size limits were determined by adding and subtracting two standard errors (S.E., 95% confidence level) from the population size estimate (Schumacher & Eschmeyer, 1943). The overall population size was estimated to be 216 (S.E. 19) *R. septemvittata*, with a possible range of 178-254 individuals.

Time (hrs)	Months								Total
	A	M	J	J	A	S	O	N	
0600	0	0	0	1	0	0	0	0	1
0700	0	1	1	1	1	4	0	0	8
0800	0	8	6	5	7	5	0	0	31
0900	0	9	9	14	9	6	1	0	48
1000	1	15	8	10	9	12	1	0	56
1100	2	5	4	6	5	10	3	0	35
1200	1	7	1	0	1	3	0	0	13
1300	0	3	2	0	2	2	1	1	11
1400	3	4	4	4	6	8	2	2	33
1500	1	2	6	5	5	1	2	1	23
1600	1	0	6	4	4	1	0	0	16
1700	0	0	2	2	1	0	0	0	5
Total	9	54	49	52	50	52	10	4	280

Table 1. Frequency of capture of active *Regina septemvittata* by months and hours.

The total area of available crayfish-bearing waterways at White Oak in 1965-1967 was estimated to be 3 ha, and the total density of *R. septemvittata* was estimated to be 68.3/ha. However, 178 of the Queen Snakes were captured at the dam site or within 300 m downstream from it, clearly indicating the aggregation area for the White Oak population. That estimated waterway area was approximately 1 ha; a density of 178/ha, or 59.3 snakes per 100 m of stream.

Males were considered mature at a SVL greater than 30 cm; females at a SVL greater than 34 cm (Ernst & Ernst, 2003). Based on these estimated lengths of maturity, the combined White Oak population was composed of 68 juveniles (31.7%, including neonates), 81 mature males (37.6%), and 66 mature females (30.7%). The mature male to female ratio was 1.23:1; not significantly different from 1:1 (Chi square test, 1 d.f.). The juvenile to adult ratio was 46.3:1, significantly different from 1:1.

The *R. septemvittata* were measured and weighed at each capture. The mean SVLs and masses of captured Queen Snakes were as follows

(ranges in parentheses): adult males (97 captures) had a mean SVL of 39.6 cm (34.5-48.0 cm) and a mean mass of 10.8 g (9.5-12.0 g), adult females (75 captures) had a mean SVL of 48.2 cm (36.0-66.9 cm) and a mean mass of 13.5 g (10.3-14.9 g), yearling or older juveniles (65 captures) had a mean SVL of 25.6 cm (20.5-28.0 cm) and a mean mass of 4.8 g (3.2-6.83 g), and 53 neonates averaged 15.6 cm (12.5-18.1 cm) in SVL and 2.9 g (2.7-3.1 g) in mass. Ernst (2002) reported that the average SVLs of adult males and adult females are 39.5 cm and 45.1 cm, respectively. *Regina septemvittata* is a naturally slender snake, so, while the masses recorded at White Oak seemed somewhat low, they were probably within normal ranges for the species. The total biomass *R. septemvittata* at White Oak was 2.29 kg, with 2.10 kg centered at the dam and stream below it.

Only limited data have been published on the population dynamics of *R. septemvittata*. The Kentucky Queen Snakes studied by Branson & Baker (1974) had a 1:1 sex ratio (113 males, 116 females), and the sex ratio of 128 neonates born in captivity during their study was also 1:1 (65

Activity (N)	Body	Temperatures		
		Air	Surface	Water
Hibernate (10)	2.8(2.0-4.1)	3.0(2.0-4.0) r=0.92	26(2.0-4.0) r=0.95	--
Under Shelter, active (41)	17.5(14.0-20.5)	19.3(12.2-24.5) r=0.89	18.0(12.2-24.5) r=0.98	20.1(8.5-22.4) r=0.63
Basking (59)	26.3(18.5-31.6)	25.0(17.5-33.0) r=0.92	26.1(17.0-33.0) r=0.95	19.3(7.5-22.5) r=0.75
Moving on Land (8)	20.8(19.3-28.7)	23.0(20.0-29.5) r=0.92	21.5(20.0-29.5) r=0.94	19.7(18.0-22.0) r=0.78
Foraging in Water (115)	24.2(16.3-26.8)	26.1(18.0-34.0) r=0.89	--	24.0(17.0-26.8) r=0.99
Mating on Land (4)	24.6(22.8-26.8)	25.1(22.5-28.2) r=0.95	25.4(23.0-30.0) r=0.90	21.3(19.0-23.5) r=0.86

Table 2. Body and environmental temperatures (°C) of *Regina septemvittata* by activities.

males, 63 females). The sex ratio of adult Queen Snakes at White Oak was slightly skewed toward males 1.23:1, and if the estimated sexes of the juveniles and neonates are included in the calculations, 115 males and 90 females were present at White Oak; a 1.27:1 sex ratio. Neither ratio is significantly removed from equality. Branson & Baker (1974) found Queen Snake densities of 35 per 192 m and 62 per 237 m along two Kentucky waterways, and Wood (1949) collected 124 individuals within 92 m in Ohio. At White Oak, 178 of these snakes were collected in the 300 m below the dam, a density of 59/100 m; in addition, four others were collected in the mill pond within 100 m above the dam, and 16 individuals were first caught at the dam. The number of first captured individuals using the dam area was 198, 96.6% of the total 205 *R. septemvittata* captured at White Oak. The stream below the dam apparently offered the best foraging opportunities in the area, and the dam served as the principle hibernation site for the population.

Annual Activity Cycle

During the three years of study, responsive *R. septemvittata* were found from 3rd April to 6th November, a maximum annual period of activity of 217 days. In the only complete year of study, 1966, active queen snakes were observed from 10th April to 6th November, 210 days. In 1965, the latest capture of an active individual was on 4th November; in 1967, the first spring capture occurred on 5th April. There was no indication of a bimodal activity pattern, as the snakes were active throughout the summer. Once the snakes became active in the spring, about equal numbers of individuals were observed or captured in every month from May through September (Table 1). Fewer snakes were seen or captured in October, so some may have entered hibernacula earlier than others. Nighttime temperatures in southeastern Pennsylvania normally drop below 4°C by late October, and generally continue to drop to below freezing by late November.

Juveniles (>35 cm SVL) appeared later in the spring and disappeared earlier in the fall than did adults. The earliest juvenile was found on 22

April, and the latest on 1st October (163 days). No significant difference occurred in adult males or females in either the length of the annual activity period or the dates of spring emergence or final fall entrance into hibernacula. However, gravid females basked more often and for longer periods in the spring than did adult males. Thirty females were found basking on the dam in April and May; only 11 males were observed basking during the same period. Individual, undisturbed females basked an average of 2.3 hrs (1.2-3.0 hrs); males basked for an average of only 1.5 hrs (1.0-2.2 hrs). The difference of the basking duration is significant at the 0.05 level (one-way ANOVA, $F = 2.75, p = .05$).

Cracks or other openings in the dam which led to below frost depth were used as communal hibernacula, and 10 *R. septemvittata* were found in such places during the winters of 1966 and 1967. All had been previously captured and marked when active, but none of the hibernating snakes were recaptured the next winter. Fall aggregations of 10-25 snakes were observed basking on the downstream slope of the dam in late September and during October. All were positioned near the openings to suspected hibernation sites. Aggregated dormant Queen Snakes were found on 20th (2 snakes) and 28th (5 snakes) January 1966 and on 4th February 1967 (3 snakes) at a mean depth of 18.3 cm (16-21 cm). The two snakes found on 20th January and the five found on 28th January were in cracks on the side of the dam at depths of 16 cm and 18 cm, respectively. The three snakes found on 4th February were in an opening which extended from the side of the road about 18 cm beneath the asphalt. Undoubtedly, other Queen Snakes had retreated to greater depths within the dam.

White Oak *R. septemvittata* were surface active over 200 days from early April to early November. In the more southern parts of its range, *R. septemvittata* is active for longer periods, possibly in every month (Ernst & Ernst, 2003). North Carolina Queen Snakes are surface active from late March to late October (Palmer & Braswell, 1995), and those in Virginia from late February to early October (Mitchell, 1994). In Kentucky,

active Queen Snakes were found from 5th April to 15th November (225 days) by Branson & Baker (1974). Farther north, Conant (1938) reported them active from 6th May to October, over 149 days in Ohio, and this species was found active for 136 days from 10th May to 23rd September in western New York (Raney & Roecker, 1947).

In southeastern Pennsylvania, *R. septemvittata* is forced to hibernate during the winter. Queen Snakes gathered at the entrances to cavities in the dam in late September and October, where they basked during the day. Such pre-hibernation aggregations have also been noted by Neill (1948) in Georgia, and by Wood (1944) and Wood & Duellman (1950) in Ohio, but not by Branson & Baker (1974) in Kentucky. By the end of the first week of November, all of the White Oak *R. septemvittata* had retreated into the dam for the winter. Occasionally, *R. septemvittata* may be active later in the season in southeastern Pennsylvania; Reinert (1975) found a sluggish one basking at 13:30 hrs on 5th December in Berks County, Pennsylvania. So some may possibly emerge on warm winter days to bask, even as far north as Pennsylvania. Conant (1951) found one in Ohio lying on ice in January.

At White Oak, adult snakes emerged in the spring earlier than juveniles, but the juveniles entered hibernation earlier in the fall. This pattern is typical of most hibernating snakes in North America (Ernst & Ernst, 2003). Gravid females were less active than males and nongravid females, and spent more time basking than foraging; only two were found foraging.

Daily Activity Period

Although the dam site and the creek below it were examined for nocturnal activity, no Queen Snakes were found active after dusk (Table 1). The earliest snake was observed at 06:30 hrs, and the latest at 17:49 hrs. Activity was bimodal, with most activity in the period 08:00-11:00 hrs and another period, although of somewhat reduced activity, from 14:00 hrs to about 18:00 hrs. Surface activity included foraging (159, 56.8% of captures of active snakes; while foraging, the snakes crawled or swam along the bottom of the waterway and



Regina septemvittata from Central Kentucky.
Photograph by author.

explored possible crayfish retreats, such as beneath or on the downstream side of rocks), basking (59, 21.1%), hiding under cover of large stones or logs (41, 14.6%), or crawling along the bank (8, 2.9%) (Table 2).

Branson & Baker (1974) also found *R. septemvittata* active only during the daylight hours, but did not report bimodal activity. In contrast with this study, they reported that 95.6% of their captures were of snakes found beneath rocks, and that only 1.8% of their snakes were basking. Aquatic versus land captures were in a 1.26:1 ratio. At White Oak, 172 (59.3%) captures occurred in water, and 118 (40.7%) were terrestrial; a 1.46:1 ratio.

Thermal Ecology

Body (cloacal) temperatures and environmental temperatures were recorded at the time of capture of all adults and juveniles, resulting in 237 records, of which 227 were of snakes considered active (Table 2). Because of their smaller size, body temperatures were not recorded for neonates. Active snakes had BTs ranging from 14.0°C to 31.6°C, and averaged 25.1°C; BTs of the 10 hibernating snakes averaged 2.8°C (2.0-4.1°C) (Table 2).

BTs of active White Oak *R. septemvittata* were similar to those reported in Kentucky by Branson & Baker (1974), who recorded mean 25.6°C (12.2-30.4°C) BTs. They also reported that the CTmax of their adult snakes varied from 43.4 °C and 44.5°C, and that of juveniles were 39.5-41.5°C. The CTmax was not determined for White Oak *R. septemvittata*, but no BT approached the critical limits reported by Branson & Baker (1974). Hibernating White Oak Queen Snakes had BTs averaging 2.8°C (2.0-4.1°C). BTs of all White Oak Queen Snakes were highly correlated with environmental temperatures, although the highest correlation varied by activity and collection site (Table 2).

Movements

The greatest straight-line distance moved between captures was by a 53.0 SVL male which was recaptured two days later 101 m from its last capture point. The greatest straight-line distance moved between captures by a female was 60 m by one nongravid with a 43.3 cm SVL. Eleven recaptures of gravid females indicated that they moved only short distances, 0-12 m (mean, 4.0 m); four were recaptured at the same place as their last capture. Juveniles moved 0-30 m (mean, 12.0 m) between recaptures. Of those snakes first captured at the dam, the greatest recapture distance from the dam was 55 m by a 40.0 cm SVL male, and 80% of the 75 recaptures of snakes at the dam were within 25 m of it. No significant difference was found between the distances moved by adults of either sex (t-test, 4.04, $p > 0.5$), and most juveniles were found no more than 10 m from their last capture point.

Based on the limited recapture data, White Oak *R. septemvittata* seemed to occupy small home ranges, as no individual was captured over 101 m from its last collection point. The home ranges seemed essentially linear, extending along the bank of the stream below the dam. No Queen

Snake was collected inland farther than 6 m from the stream. Of 13 Kentucky recaptures by Branson & Baker (1974), the straight-line distances from point of release to that of recapture were 3-137 m (mean 22.6 m). Most activity at White Oak centered around the stone dam which was used both as a summer and winter retreat.

Reproduction

Mating *R. septemvittata* were found on 6th May 1966 and 30th April 1967. The males had SVLs of 36.5 cm and 39.2 cm, and the females were 55.8 cm and 66.9 cm in SVL. Temperature data for these matings are presented in Table 2. Unambiguously gravid females were captured or observed basking from 1st July to 28th August. The first neonates were found on 2nd September. The 53 neonates captured had TBLs of 16.6-23.1 cm (mean, 20.5 cm), SVLs of 12.5-18.1 cm (mean, 15.6 cm), and weighed 2.7-3.1 g (mean, 2.9 g). Gravid females averaged 3.9 g (3.2-4.8 g) more than nongravid females.

The main breeding period of *R. septemvittata* is the months of April and May, although Branson & Baker (1974) thought that some matings possibly occur in the fall. Ford (1982) reported spring courtship activity by recently captured snakes, and Ashton & Ashton (1981) thought mating occurred in the spring in Florida, possibly as late as June. Observations of mating activity by wild *R. septemvittata* have only occurred on 30th April and 6th May (this study), and 28th May in Indiana (Minton, 1972). Reported births have occurred from 6th July to 1st October, but most take place from mid-August to mid-September (Ernst & Ernst, 2003). White Oak Queen Snakes followed this pattern.

Diet and Foraging Behaviour

Although crayfish were abundant in all four foraging habitats, the shallow, rocky stretches of the creek below the dam were clearly preferred by the Queen Snakes. The greater number of foraging and feeding observations there corresponds to this area supporting the largest number of snakes, due largely to the various retreats in the dam.

One hundred sixty-eight captures (57.9%) were of snakes either foraging for ($n = 159$, 94.6%) or ingesting ($n = 9$, 5.4%) crayfish (*Cambarus* sp.). All feeding observations occurred downstream from the Sanctuary dam. Of those foraging, 148 (93.1%) were in the rocky creek below the dam, 4 (2.5%) were in the shallow brooks flowing through the pastures to the north of the Sanctuary, 4 (2.5%) were in the western shallows of the pond, and 3 (1.8%) were in the marsh. The observations occurred at 07:50-11:04 hrs and at 15:09-17:49 hrs; with 149 (88.7%) observations in the morning, and 19 (11.3%) in the late afternoon.

When a crayfish was discovered, it was seized and was swallowed tail first. All of the prey ingested were small and appeared to have recently molted. Vomodor was probably an important cue to finding prey, as the snakes frequently tongue-flicked. Pinder (1996) observed that much tongue flicking is done while these snakes forage underwater; and Burghardt (1968) tested the response of naive neonate *R. septemvittata* to water extracts of several small animals, but the snakes only responded to extracts of crayfish, particularly those that had recently molted.

Predation, Parasites and Injuries

Predation, ectoparasitism and natural injuries were relatively rare among adults ($n = 27$, 13.2% of the population). These consisted of 14 *R. septemvittata* (6.8%) with bobtails; 10 individuals (4.9%) with healed or fresh scars on their head or body; 1 (0.5%) apparently predated by a Red-shouldered Hawk (*Buteo lineatus*), which was found feeding on its freshly killed carcass; and 1 (0.5%) parasitised by a leech, *Placobdella parasitica*, which was attached to the snake's cloacal wall with about 33% of its body protruding from the vent. Although all of the scars and 5 (45.4%) of the bobtails appeared to have been caused by predators, or possibly by crayfish during feeding bouts, 6 (54.5%) of the tail injuries were probably the result of winter frostbite.

The amount of recorded predation, parasitism and injuries in the White Oak population was not particularly high. However, these records were only from adults and larger subadults. None of the

neonates or small juveniles captured during the study showed evidence of predation or parasitism, but individuals of these age classes were small enough to be swallowed whole by a predator. Recorded predators of *R. septemvittata* include mice and other snakes during hibernation (Huheey & Stupka, 1967), the Racer (*Coluber constrictor*) (Palmer & Braswell, 1995), and the Hellbender (*Cryptobranchus alleganiensis*) (Branson & Baker, 1974). Branson & Baker (1974) had several captive neonates trapped underwater and killed by crayfish. They also reported that a male captured in mud had three leeches (*Placobdella rugosa*) attached to it. In addition, many of their Kentucky *R. septemvittata* had white blisters on their bodies caused by fungus (*Verticellium*); no White Oak Queen Snake had such an infection.

Human damage to White Oak queen snakes was more severe, and involved 53.6% of the individuals. Unfortunately, the Queen Snakes residing at the dam site and below it in the creek were extirpated due to multiple causes. During the summer months of 1966, local teenage boys shot and killed 107 adult and subadult *R. septemvittata* (52.2% of the entire population), 32 *Nerodia sipedon* and 6 *Thamnophis sirtalis* while the snakes basked on the sides of the dam or on the bank of the creek. In addition, from May 1965 through July 1967, 3 *R. septemvittata* (1.5% of the population), 12 *N. sipedon*, and 4 *T. sirtalis* were killed by motorised vehicles on the road crossing the dam. Still, some *R. septemvittata* survived, and the species was seen there into June 1972. In that month an approximately 3 m wall of flood water resulting from the torrential rains of Hurricane Agnes swept through the valley and over the dam (Ernst, 1974). Since then no Queen Snakes have been found at either the dam or along the creek below it. In addition, in the mid-1970s the Pennsylvania Department of Transportation repaved the road crossing the dam, filling many of the cracks used as hibernacula by snakes. While this was being done, asphalt was also spilled into the frames of the dam's sluice gates, making it impossible to close the gates completely. By 1980, the pond and marsh had been drained, resulting in less water flowing downstream from the dam, and

greatly reducing the available crayfish habitat. Crayfish were restricted to a narrow channel flowing through what was the old pond and over the dam, and several small brooks flowing through the marsh and pastures which still supported a reduced crayfish population. A few *R. septemvittata* still occur along the brooks in the pastures, as evidenced by a shed skin found in July 2001. In contrast, the populations of *N. sipedon* and *T. sirtalis* at and below the dam survived and grew in numbers until they appeared near pre-flood numbers by 1988.

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