Chelonian Conservation and Biology, 1995, 1(3):207–214

Habitat Use and Population Parameters of the Spotted Turtle, *Clemmys guttata*, a Species of Special Concern in Massachusetts

TERRY E. GRAHAM[1]

[1]*Department of Biology, Worcester State College, Worcester, Massachusetts 01602 USA*

ABSTRACT. – Demographic data and information on movement and habitat use are presented for spotted turtles, *Clemmys guttata*, for early May 1989 to June 1990 in central Massachusetts, USA. Density, home range, growth rate, and clutch size appear similar to those reported for other northeastern populations. Movements monitored by radiotelemetry indicate that spotted turtle habitat use varied seasonally with the general cycle including: 1) winter hibernation in red maple-sphagnum swamps within underwater passageways among masses of inundated sphagnum and roots of red maples, 2) overland migration (ca. 120 m) to upland vernal pools in late March, 3) feeding in and fidelity to these pools for 3–4 months, 4) departure from vernal pools in August followed by aestivation in terrestrial forms for 4-14 days, 5) completion of the overland migration back to the permanent swamps in August, 6) localized movement within these red maple swamps during September and October. Spring migration to vernal pools is apparently timed to take advantage of seasonally abundant foods there, but the rationale for terrestrial dormancy is unclear.

KEY WORDS. – Reptilia; Testudines; Emydidae; *Clemmys guttata*; turtle; ecology; habitat; demography; population status; home range; aestivation; growth; activity cycle; telemetry; Massachusetts; USA

The semiaquatic spotted turtle, *Clemmys guttata,* is a small eastern North American emydid which reaches the northeastern limit of its New England range in southern Quebec (Cook, 1984). It is distributed in suitable wetlands from central New England southward to Florida and westward through Pennsylvania, northern Ohio, southern Michigan, Indiana, and northeastern Illinois. Spotted turtles characteristically frequent unpolluted, shallow, mud-bottomed water bodies, e.g., marshes, bogs, swamps, small streams, drainage ditches, and vernal pools.

According to Mauger (1988), the spotted turtle is protected as endangered, threatened, or of special concern in ten of twenty-one states from which it is known, and in several other states where the species is not currently protected there have been concerns expressed over its rarity and declining populations. *Clemmys guttata* is listed by the Massachusetts Natural Heritage Program (Massachusetts Division of Fisheries and Wildlife) as a Species of Special Concern; as such, it is a rare vertebrate species.

In Massachusetts, *C. guttata* occurs virtually statewide, including the off-shore islands, wherever suitable habitat is present, but state range data are not complete (Mirick, in press). There are probably several hundred spotted turtle populations remaining in Massachusetts, but the species is becoming less common throughout most of its range in the state. Its relative rarity today contrasts alarmingly with the situation over a hundred years ago when it was considered to be one of the most common turtles in Massachusetts (Storer, 1840). Over-collecting, predation, road mortalities, habitat destruction, and natural habitat succession are among the probable causes of the decline in spotted turtle abundance.

This report presents demographic data for *C. guttata* at Cedar Swamp, Westboro, Worcester County, Massachusetts (Fig. 1). Field work was conducted from early May 1989 through June 1990. The objectives of the study were: 1) to estimate spotted turtle density in Cedar Swamp, and 2) to assess other parameters such as population structure, growth, habitat preference, home range, site fidelity, reproduction, recruitment, and the status of the population. This information will be useful to wildife biologists assessing the status of spotted turtles and implementing management measures to protect them.

MATERIALS AND METHODS

Cedar Swamp, about 607 ha of forest and wetlands, is bisected by a railroad right-of-way (Fig. 1). The north portion of the swamp consists of roughly 240 ha of wetlands and uplands, while the south part contains about 367 ha (values determined by map planimetry).

Spotted turtles were captured by hand and dip-net beginning on 3 May 1989. Experimental use of two floating basking traps was discontinued when they failed to capture any animals. Baited trapping commenced on 10 May and continued through 16 July 1989, when all traps were removed. A total of 100 traps were used during this phase of the trapping. They were not all installed at once, but were put out 3–14 at a time until 7 June; the last 40 were deployed on 10 June. These traps were checked every 48 hrs and normally re-baited with canned sardines in soybean oil. Each sardine can was punctured with an awl and suspended by a short length of copper wire from the roof of the trap. Other bait (fresh shrimp, scallops, and fish) was tried briefly to determine suitability, but proved less effective than the sardines. Traps were constructed of 2.5 cm^2 heavy vinyl coated wire mesh bent to provide a single arched top piece and flat

bottom (D-shape). One end of each trap contained an inward-pointing poultry mesh cone with a hole in it to admit turtles to the body of the trap. These low-profile traps were designed to be stable and effective in shallow water (Fig. 2).

Areas for trapping were selected following a helicopter reconnaissance of the entire swamp. During this fly-over, water availability and habitat type were inspected and videotaped. Trap sites were chosen on the basis of: 1) water depth (20–35 cm); 2) habitat type; 3) accessibility; and 4) relationship to a proposed development site. Water depth had to be sufficient to allow turtles aquatic entry and to insure that the punctured sardine can was submerged. Because their height was about 35 cm, traps had to be set in less than 35 cm of water to prevent accidental drowning of entrapped animals. Aquatic habitats representative of those available in the swamp as a whole were trapped. These included vernal pools, shallow streams, and pools in shrub and red maple-sphagnum swamps. The total area effectively sampled by the trap array was calculated from the average of the longest diagonal drawn through the home ranges of turtles plotted from telemetry data collected 6 May–15 July 1989, and the amount of overlap between adjacent traps. The total trapped area in this study was adjusted (Table 1) from 20.365 ha to 14.720 ha to account for the proportion of days each trap was deployed out of the maximum of 66 trapping days for the sampling period.

Turtles were marked, measured, photographed, and released at their capture site. Females were palpated to determine the presence of eggs, and gravid specimens were radiographed (Fig. 3) to obtain egg counts. Several evening hours were spent searching for nesting turtles from 10–25 June 1989. Plastral annuli were counted (when complete and clear) to determine turtle age. Absolute and estimated growth data (Graham, 1979) were obtained for seven animals. Marking was accomplished by notching the marginal scutes with a rotary grinding tool. Turtles < 80 mm in plastron length (PL) were usually younger than 6–7 years of age and were classed as juveniles.

From May through October 1989, nine turtles were fitted with 15–20 g radio transmitters (49 MHz) attached just anterior to the rear carapacial margin with high-strength epoxy cement. The first five turtles so equipped also had two small nylon bolts attaching their transmitter to the shell via small holes drilled in the carapacial margin. The use of the bolts was later discontinued, as the epoxy without bolts proved more than adequate for secure attachment.

Movements and habitat utilization of spotted turtles were evaluated from standard radio fixes taken from early May 1989 through early June 1990. It was necessary to determine turtle location by triangulation in only a couple of trials during the early part of the radio-tracking program. At that time triangulation was necessitated by high water which made access to portions of the swamp difficult. Most turtle locations were determined from close range, but all fixes were taken from sufficient distance so as not to disturb turtle

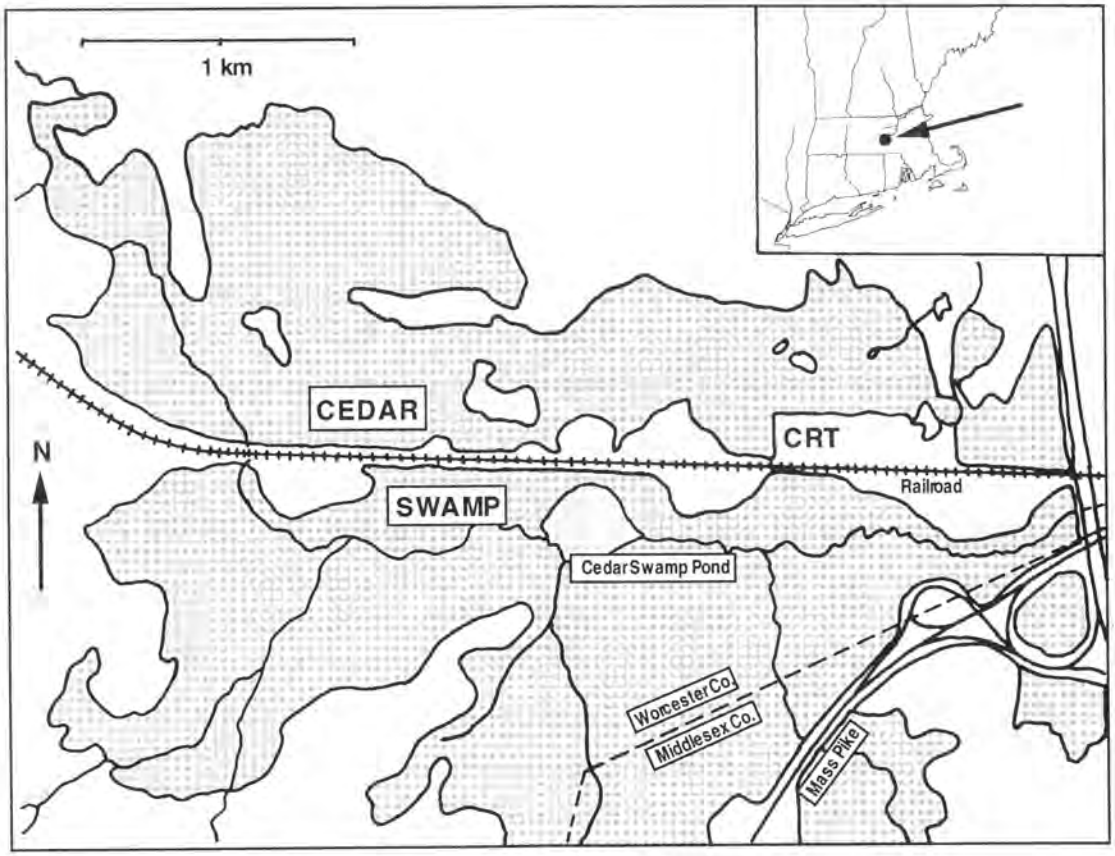

Figure 1. Map of Cedar Swamp, Westboro, Massachusetts showing the location of the railroad right-of-way and the Conrail Automotive Terminal (CRT); tracking studies (see Fig. 5) were conducted just west and north of CRT.

Figure 2. A small vernal pool (BVP, Fig. 5) showing baited trap installation.

behavior. The locations of each tracked turtle were carefully plotted on a base map which was carefully constructed from surveyor's blueprints and recent infrared aerial photographs of the swamp. Range length for each turtle was measured directly from the plotted locations on the map and halved for use in the calculation of home range (Fitch, 1958).

A second search and mark-recapture program was conducted concurrently with the ongoing radio-tracking effort from 27 August through 30 September 1989. In this trapping effort 40 traps were set; 20 (four sites) on the north side of the railroad right-of-way, and 20 (five sites) on the south side. Trap locations were selected using the same criteria as for the first trapping period, but animals captured during this late summer trapping project were not included in population estimation procedures because of a distinct shift in habitat use by the turtles in early August.

The estimate of spotted turtle density derived from the May–July 1989 mark-recapture data was calculated by the computer program CAPTURE (White et al., 1982). This program formulated a series of models and then selected the most appropriate model based on the actual mark-release-recapture data. It then computed the most efficient estimate of n and the reliability of that estimate.

To evaluate turtle food resources in the vernal pools, macroinvertebrate samples were taken from mid-May to mid-August at six stations in vernal pool no. 2. During each trial a steel sampling drum (35 cm diam.,with its bottom removed) was set in place and the water inside was swept six times with a 13 x 20 cm nylon mesh net. In May, examination of stomach flushings (Legler, 1977) and fecal material from an adult male and female failed to provide any qualitative information on food habits.

RESULTS

A total of 38 spotted turtles were captured 58 times during the May–July 1989 trapping period; 26 captures were made by hand, and 32 by baited traps. Early in this study hand capture was more productive than trap capture until all of the traps were deployed. From that point on trapping was more productive. Trap capture efficiency throughout the May–July sampling period was only 0.7% (32 captures in 4424 trap days), but the overall effectiveness of the baited trapping effort was considerable due to the large number of traps deployed.

Population size structure for the 38 animals is presented in Fig. 4; eight new turtles obtained during the August 1989 to June 1990 period are not included. Five subadults were captured in the May–July period and two more in the August–November interval. These seven subadults constitute roughly 18% of all spotted turtles obtained in this study. Twelve males and 21 females were taken in the May–July sample of 38 animals, giving a sex ratio of 0.57 males per female, which is not significantly different from 1:1 (x^2= 1.94, df = 1, P = 0.1637).

Morphometric data for 40 adult spotted turtles taken between May 1989 and June 1990 were as follows: male carapace length (CL) ranged from 105.1–123.0 mm ($\bar{x}$ = 113.3 ± 1.3 [mean ± SE], n = 15); male plastron length (PL) ranged from 89.3–104.8 mm ($\bar{x}$ = 96.4 ± 1.2, n = 15); female CL ranged from 79.0–126.0 mm ($\bar{x}$ = 110.2 ± 2.0, n = 25); female PL ranged from 72.0–115.8 mm ($\bar{x}$ = 101.5 ± 2.0, n = 25). In the second trapping period (August–November 1989) a total of seven spotted turtles were obtained; none of these were taken or seen at the sites trapped on the south side of the railroad right-of-way. Four of the seven were recaptures, three of which were caught by hand while taking radio fixes. During the course of telemetry work in the spring of 1990, seven more spotted turtles were hand-captured, and five of these were previously not seen.

One gravid female found on land near a brook at 2000 hr on 10 June contained four eggs, and another captured by

Figure 3. Radiograph of gravid female spotted turtle (F13) showing the presence of five shelled eggs on 6 June 1989.

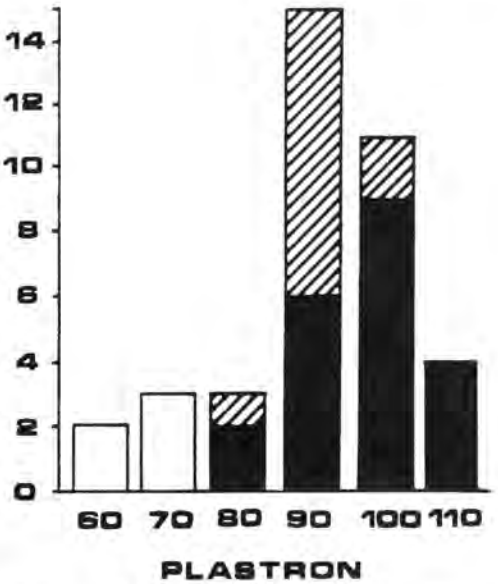

Figure 4. Population size structure of 38 *Clemmys guttata* from Cedar Swamp, Westboro, Massachusetts, compiled from 3 May through 16 July 1989. The clear portions represent juveniles, the shaded portions females, and the cross-hatched portions males. Plastral measurements are in 10 mm intervals, e.g., 60–69 mm, etc.

hand on 6 June contained five eggs (Fig. 3). A majority of the spotted turtles (22 of 38) were resident in four vernal pools but several were taken in shrub swamp and stream settings. The May–June capture of adults ($n = 54$) was 93% of the total.

Spotted turtle population density calculations are provided in Table 1. The point estimator ($n = 98$) and its 95% confidence limits (n = 42–154) were used to compute density for the sampled area of the north swamp only, since spotted turtles were not seen or trapped in the south portion of the swamp. The density of *Clemmys guttata* in the sampled area of the north swamp was 98 ± 56 for 20.365 ha = 4.8/ha (unadjusted), and 98 ± 56 for 14.720 ha = 6.7/ha (adjusted).

Growth data for seven *Clemmys* are given in Table 2. Plastron length at the end of each growing season was estimated by summation of median border lengths of plastral annuli (Graham, 1979). Absolute plastral growth was measured for one 12 yr old adult male (M6) at Cedar Swamp. This individual was originally measured on 29 May 1989 with a PL of 103.0 mm and subsequently remeasured on 11 November 1989; its growth increment (3.8 mm) was 3.7%.

Home range estimates determined by the method of Fitch (1958) for three animals radio-tracked during the May–July sampling interval are: M2 = 0.7884 ha, M1000 = 0.8901 ha, and F2000 = 0.5649 ha [M = males, F = females]. This admittedly small sample may suggest that males have larger home ranges than females. The longest excursion made by any of our radio-tracked turtles was that of a male (M2) which moved 442 m overland in early August.

As shown in the plotted locations in Fig. 5, aquatic habitats were used almost exclusively during early May through July. The only exception was a short excursion made between VP1 and VP2 by F2000. Most of the abrupt shifts in home range and habitat type shown in Fig. 5 occurred during the first two weeks of August. Once turtles left the vernal pools, some spent periods of 4–14 days on land burrowed into shallow "forms" in open grassland or in woodland leaf litter (Fig. 6).

Invertebrate survey data collected for one vernal pool (VP2) are given in Table 3. Invertebrate taxa were identified as follows: beetle adults and larvae (Dytiscidae) *Acilius* sp.; dipteran pupae (Culicidae); damselfly naiads (Lestidae) *Lestes* sp.; caddisfly larvae (Limnephilidae) *Limnephilus* sp.; isopods (Asellidae) *Caecidotea* sp.

Water level in VP2 dropped in July and August so that both depth and surface area of the pool were reduced. By 10 August the water was restricted to one circular pool roughly 0.7 m deep and 7 m in diameter. Due to the declining water level, the July sample was obtained from four of the six sampling stations and the August sample from only three. Bottom temperature in this pool increased from 10°C in early May to 18°C in July; temperature was not taken in August.

Table 1. Spotted turtle total population size estimates (n) and density calculations for Cedar Swamp, Westboro, Worcester Co., Massachusetts; minimum to maximum = 95% confidence interval.

	Point Estimator	Minimum	Maximum
n for trapped area	98	42	154
Density in unmodified sample area (20.365 ha)	4.812/ha	2.062/ha	7.562/ha
Density in adjusted sample area (14.720 ha)	6.658/ha	2.853/ha	10.462/ha
North swamp, wetlands only (180.83 ha): total adult pop. size (n)			
Unmodified	870	373	1367
Adjusted	1204	516	1892

DISCUSSION

The estimated number of adult spotted turtles in Cedar Swamp (north part only) may be conservative for two reasons: 1) density figures only include turtles > 60 mm in PL, and 2) sightings of a few adult spotted turtles occurred in locations where traps failed to catch them. The adjusted adult population estimate for Cedar Swamp (1204 ± 688) is quite high; the only population of spotted turtles as large as this was reported by Ward et al. (1976), who obtained 1205 captures over four years on a 346 ha island in Chesapeake Bay, Maryland. The vast and heterogeneous wetland habitats sampled in both studies obviously provide the carrying capacity needed to support such large populations of *C. guttata*.

Home range shifts, which included excursions on land between water bodies, took place during the first two weeks of August (Fig. 5). This discovery was supported by concur-

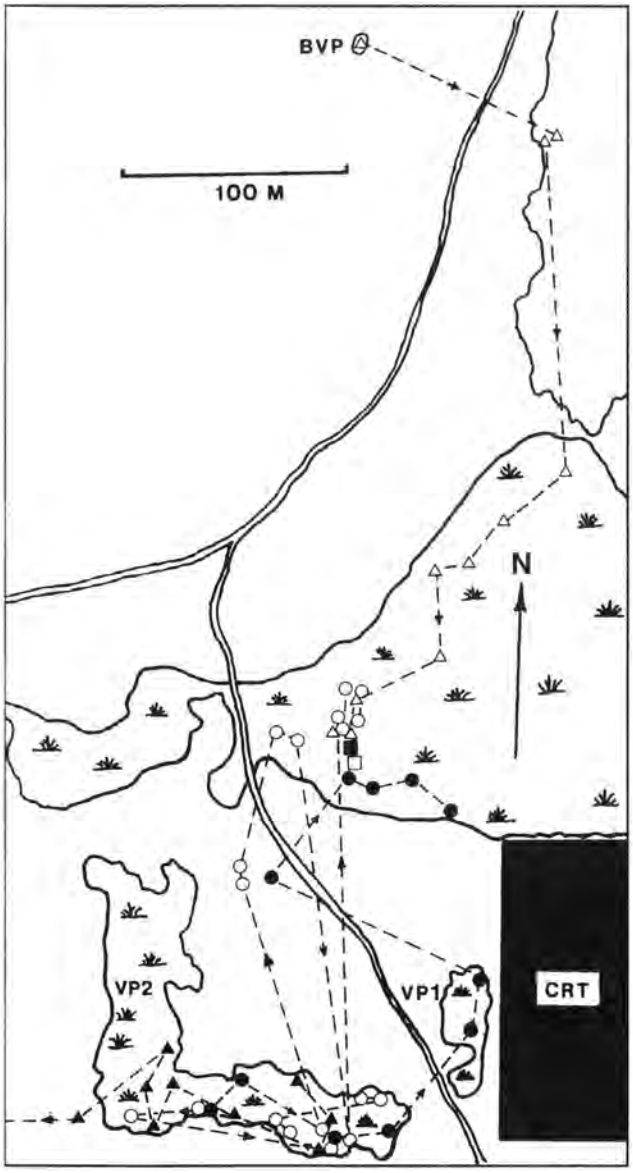

Figure 5. Plotted locations of M2 (▲) from 10 May to 19 August; F2000 (●) from 7 May to 27 November; M1000 (○) from 7 May–27 November; and F3000 (△) captured and released in the Banyan vernal pool (BVP) and tracked from 16 July–27 November 1989. The direction of major movements are indicated by arrows. The solid square represents the site of capture of M6 on 23 October 1989 (originally captured in VP2 on 29 May), and the open square the site of capture of M133 on 23 October 1989. All verified locations are not included because sometimes turtles had not moved or had moved only slightly from their previous site. CRT = Conrail automotive terminal, VP1 and VP2 = vernal pools 1 and 2.

rent telemetry work by P. Auger (*pers. comm.*) who also found that spotted turtles left their May–July habitat in early August to move into more open and inundated portions of the swamp. Coincidental with the overland migrations at Cedar Swamp, a road-killed female was found in nearby Northboro on 7 August. This animal had left a low-lying wetland adjacent to the highway and climbed a very steep embankment before attempting to cross the road. The same cues which triggered overland travel at Cedar Swamp apparently were operating elsewhere in the area.

Because *C. guttata* was restricted to aquatic habitats during the May–July sampling period, and was never seen or trapped on the south side of the railroad tracks, density extrapolations were only made for suitable wetland habitat (180.83 ha) in the north portion of Cedar Swamp. The adjusted density (6.7 turtles/ha) is similar to spotted turtle densities from other studies (Table 4). At the same time, it is quite a bit lower than any of the four yearly values obtained by Ernst (1976), and a good deal higher than the density reported by Capler and Moll (1988).

The Pennsylvania population studied by Ernst (1976) apparently resides in a more homogeneous habitat than Cedar Swamp (C. Ernst, *pers. comm.*). It would appear that on a per unit area basis, his small wetland has a much higher spotted turtle carrying capacity than Cedar Swamp. Perhaps "edge effect" gives small wetlands greater *C. guttata* density.

Capler and Moll (1988) acknowledged that their extremely low density estimate may have been caused by prevailing drought and high temperature conditions or by the failure of their baited traps to capture *Clemmys* during their final three sampling periods in June. The bait they used (chicken liver and fish entrails) was probably unsuitable and the irregular nature of their trap deployment may also have hindered capture. Aside from the present study, the only other report of successful spotted turtle capture in baited traps was by Dunson (1986) in tidal creeks on the eastern shore of Virginia, who also used canned sardines in soybean oil as bait (*pers. comm.*).

Hand capture was most effective during the early part of the sampling period, while trap capture was greater and more uniform from week to week during the time it was employed. It is probable that hand captures diminished over time owing to the increase in vegetative cover with season, and also due to a reduction in the time spent searching for animals once all traps were deployed. Although trap capture in this study was not very efficient, if we had not employed such a large baited trap array, sufficient data for population estimation might never have been gathered.

Home range estimates derived for the three adults tracked during the May–July interval in VP1 and VP2 (Fig. 5) agree closely with the average home range of 0.7881 ha reported for spotted turtles in Illinois by McGee et al. (1989). Those authors also noted no significant sexual difference in home range or range length although they did mention that male *C. guttata* exhibited greater variation in these parameters. Of the three animals used here for home range measurement, the female utilized a distinctly smaller area. One male (M2) made the longest foray of any turtle tracked. Perhaps the suggestion of Kiester et al. (1982) that transient male turtles may act as agents of genetic exchange between adjacent populations is correct. Lovich's (1990) telemetry study of two male spotted turtles during spring in South Carolina showed their movements to be extensive; 24-hr displacements were as great as 423 m.

Because spotted turtles had previously been found

Table 2. Early plastral growth in spotted turtles from Cedar Swamp, Westboro, Worcester Co., Massachusetts.

		Plastral Length (mm)		
Age (yrs)	n	$\bar{x}$	Range	% Increase
0 (hatchling)	7	26.5	25.2–29.0	—
1	6	42.2	38.2–47.3	59.2
2	6	54.2	49.8–60.0	28.4

chusetts Natural Heritage Program (MNHP) personnel, initial searching was conducted there. For that reason most early captures came from vernal pools. The best search time prevailed during the first few weeks of the study when the vegetative cover was not yet full and walking through vernal pools was easy. In contrast, travel through the swamp at that time was difficult and the cover was already obscuring animals. So it was easier to see and capture *Clemmys* in the vernal pools, particularly on cloudless days, and return per unit capture effort was much higher there than in the swamp.

One uniform characteristic of *C. guttata* studies in different habitats is the high frequency of captures in the spring. Conant (1951) found 89% of his Ohio spotted turtles from March to May, Ernst and Barbour (1972) reported 95% of Pennsylvania spotted turtles taken from March to June, Ward et al. (1976) obtained 97% of their Maryland captures from March through June, and during the present study in Massachusetts the May–June capture was 93% of the total.

Figure 6. Male spotted turtle (M2) with anterior hidden in woodland leaf litter on 7 August 1989.

If sampling had also been done in March and April, it is likely the figure would have been even higher.

The few growth data presented in Table 2 are similar to records collected by Ernst (1975) and Graham (1970). Massachusetts hatchlings increased their plastron length by 59.2%, Ernst's Pennsylvania animals increased by 55.8% during their first year, and Rhode Island hatchlings increased by 42.98%. During their second year, Massachusetts *C. guttata* also outgrew Pennsylvania animals (Ernst, 1975) and Rhode Island specimens (Graham, 1970). This suggests that early growth of the Cedar Swamp spotted turtles is excellent and is probably fueled by more than ample available food resources in the swamp. One might expect that turtle growth for Massachusetts would be slower than that for *C. guttata* from the more southern Pennsylvania and Rhode Island locations. But in Ernst's population, the rate of growth may have been reduced somewhat by greater competition for food in a denser population. His marsh was only about 3.2 ha and he found high densities of roughly 40–80 turtles/ha.

The absolute plastral growth of M6 is close to the mean increment Ernst (1975) estimated for 12 year olds (3.66%). The movements of M6 are also of interest in that it was originally captured and recaptured in VP2, then it moved into VP1, and finally it was hand captured out in the maple-sphagnum swamp in late fall. Its movements were very similar to those of the radio-tracked animals, supporting the observation that at Cedar Swamp spotted turtles shifted their home ranges dramatically in midsummer.

The annual cycle of spotted turtle habitat utilization at Cedar Swamp can be summarized as follows: 1) winter hibernation (November–March) in permanent red maple-sphagnum swamps within underwater passageways between roots of red maples and through the dense elevated mats of sphagnum at their bases, 2) overland migration (ca. 120 m) to upland vernal pools in late March, 3) feeding and residence in these pools for 3–4 months, 4) departure from vernal pools in August followed by brief (1–3 week) aestivation in terrestrial forms, 5) completion of the overland migration back to the permanent swamp in September, 6) localized movement within the swamp during September and October. The spring migration to vernal pools is apparently timed to take advantage of seasonally abundant foods there, and the later decline in caddisfly larvae, isopods, and odonate naiads, combined with falling water levels and rising temperatures, may cue the exodus of spotted turtles in August. In wet summers the departure of the turtles from the vernal pools might be expected to occur later, while in exceptionally dry years it could take place earlier. The terrestrial aestivation of adults after leaving the vernal pools in August is peculiar in that animals could have traveled directly to the red maple-sphagnum swamps (which they ultimately reached) without first entering terrestrial "forms" (Ward et al., 1976). Forms are shallow excavations made in earth beneath accumulated organic debris. P. Auger (*pers. comm.*) also noted similar terrestrial behavior at Cedar Swamp. Creighton and Graham (1993) radio-tracked three

Table 3. Aquatic invertebrates available by date in vernal pool 2 (VP2) from May 14 to August 10: all values are rounded numbers of individuals/m^2.

Date	Caddisfly larvae	Isopods	Diptera pupae	Beetle adults	Beetle larvae	Odonate naiads	Ranid tadpoles
5-14	29	9	2	0	2	0	0
5-21	49	9	14	0	0	0	1
5-28	33	7	2	2	2	10	5
6-14	10	0	100+	14	2	17	0
7-06	0	0	100+	62	5	0	0
8-10	0	0	100+	45	10	0	0

female spotted turtles at Squam Swamp, Nantucket, Massachusetts, that entered terrestrial forms beneath leaf litter at the swamp edge and/or used forms in relatively dry fields of dense goldenrod (*Solidago* sp.) for periods up to three weeks in late August to early September. K. Perillo (*pers. comm.*) tracked spotted turtles in Connecticut in 1993 (notably a dry year) and found that as the wetlands dried up in July, the turtles left them, and in some cases aestivated on land for as much as nine weeks.

According to Gibbons (1986), turtles move overland for several reasons, e.g., in response to seasonal cues or declining habitat quality. Aquatic habitats may become unfavorable as water levels fall during droughts (Gibbons et al., 1983) or when food availability decreases (Parker, 1984). The Australian chelid turtle, *Chelodina longicollis*, in coastal New South Wales inhabits permanent but relatively unproductive dune lakes during protracted periods of low rainfall, in some cases for up to 7 yrs (A. Georges, *pers. comm.*). In response to rainfall the turtles move overland to newly formed ephemeral wetlands rich in macroinvertebrates, and they subsequently grow faster and reproduce better there than in the dune lakes (Kennett and Georges, 1990). Later, when these transitory swamps dry up, *C. longicollis* retreats overland to the dune lakes. Although this behavior does not occur annually in *C. longicollis*, the parallel between it and the behavior of *Clemmys guttata* is striking. Both species are opportunists, poised to avail themselves of the periodic bounty which ephemeral waters can offer. In the northeastern United States this opportunity comes each spring when vernal pools of all sizes are full and teeming with life, but in Australia *C. longicollis* may get such a chance only once every several years. The advantages of such opportunism are obviously important to the success and persistence of both species. Another behavioral trait which these two species share is terrestrial aestivation, which in the case of *C. longicollis* may last for as much as 2.5 mo (Chessman, 1983). The functional role of terrestrial aestivation in hot and dry environments is obvious, but under cooler and more mesic circumstances, like those prevailing in the wooded uplands between water bodies at Cedar Swamp, the utility of this mechanism is questionable. Seidel (1978) found that experimentally-induced terrestrial dormancy in the mud turtle, *Kinosternon flavescens*, resulted in lowered rates of gas exchange which apparently reduced water loss from the respiratory tract. While this response might enable turtles to resist severe dehydration in more xeric settings, its usefulness in more mesic circumstances seems questionable. A. Georges (*pers. comm.*) has suggested that while aestivation behavior may have dubious value to some species at the present time, it could represent an adaptation that was of greater importance in the past.

In light of findings in the present study, Netting's (1936) report of four spotted turtles migrating across a rural New York roadway at 1000 hr on 1 April should perhaps be reinterpreted. He was informed that spotted turtles left a farm woodland on the south side of the road and crossed to a shallow swamp on the north side of the road. He speculated that these animals had hibernated in the woodland, either in mud or dry soil. Since he apparently did not inspect the woodland or locate the hibernaculum, it is altogether likely that they actually emerged from a permanent swamp in the woods and were heading to a transient shallow swamp when found. The likelihood of their overwintering on land seems very remote considering the severity of winters in the area. None of my fall telemetry data (October and November) indicate that those *Clemmys* originally resident in vernal pools return to them for overwintering, nor that they return to terrestrial uplands for that purpose.

Because spotted turtles in Massachusetts are near the northeastern limit of their range, recruitment is probably adversely affected in some years by cool or otherwise inclement weather, which can delay egg laying and/or negatively impact development within terrestrial nests. Although habitat destruction is usually mentioned as the principal cause of spotted turtle decline, another serious and often overlooked problem involves habitat succession which gradually "destroys" prime spotted turtle habitat. From the man-

Table 4. Spotted turtle densities from other field studies.

Location	Total suitable habitat (ha)	Total numbers estimated	Total numbers obtained	Density/ha	Year	Reference
Dutchess Co., New York	15.59	—	155	9.35	1974-89	J. Behler (*pers. comm.*)
Will Co., Illinois	44.00	41	32	0.94	1988	Capler and Moll, 1988
Cayuga Co., New York	2.83	30	26	10.60	1988	D. Collins (*pers. comm.*)
Lancaster Co., Pennsylvania	3.24	127	96	39.20	1967	Ernst, 1976
	3.24	233	155	71.91	1972	Ernst, 1976
	3.24	222	162	68.52	1973	Ernst, 1976
	3.24	258	180	79.63	1974	Ernst, 1976
Carroll Island, Maryland	207.80[1]	—	1205	5.80	1970-73	Ward et al., 1976

[1] My calculation

agement standpoint, a protocol could be implemented (e.g., controlled burning) to help maintain habitat diversity.

Acknowledgments

Financial support of this work was provided by the Consolidated Rail Corporation whose legal counsel, Phil Boxell, and terminal manager, Bob Coggins, facilitated the project in various ways. I would like to thank the following individuals who contributed pertinent information or provided commentary on the project: John Behler, Dave Collins, Jay Copeland, Carl Ernst, Ray Farrell, Tom French, Whit Gibbons, Jeff Lovich, Dave Mauger, Paul Metcalf, Pete Mirick, Steve Roblie, Steve Santella, and Tom Tyning. I am grateful to Robert M. Nuzzo for his help with the identification of vernal pool invertebrates. The dedicated field assistance of Judy Forsberg Santella with trapping and telemetry was vital to the success of this project, as was the help of Andy Graham with trap construction, deployment, and inspection. I appreciate the collaboration of Peter Auger and P. Giovanonne in the May–July 1989 trapping program, and thank Peter for subsequent discussions and comparison of my findings with data he gathered concurrently. Preparation of this report was supported during my recent sabbatical by the Applied Ecology Research Group, University of Canberra, A.C.T., Australia. I thank Arthur Georges for critically reading a draft of the manuscript and for suggestions that helped improve it.

LITERATURE CITED

CAPLER, J.M., AND MOLL, E.O. 1988. Survey of a spotted turtle population (*Clemmys guttata*) at Lockport Prairie Nature Preserve, Will Co., Illinois. Unpublished report to the Will County Forest Preserve District, 34 pp.

CHESSMAN, BRUCE C. 1983. A note on aestivation in the snake-necked turtle, *Chelodina longicollis* (Shaw) (Testudines: Chelidae). Herpetofauna 14(1/2):96-97.

CONANT, ROGER. 1951. The Reptiles of Ohio. Notre Dame, Indiana: Notre Dame Press, 284 pp.

COOK, FRANCIS R. 1984. Introduction to Canadian Amphibians and Reptiles. National Museums of Canada, 200 pp.

CREIGHTON, C.A., AND GRAHAM, TERRY E. 1993. Population status and habitat use patterns of the spotted turtle in Squam Swamp, Nantucket Island, Massachusetts. Unpublished report to the Nantucket Land Council, Inc. and Natural Heritage and Endangered Species Program, Massachusetts Division of Fisheries and Wildlife, 14 pp.

DUNSON, WILLIAM A. 1986. Estuarine populations of the snapping turtle (*Chelydra*) as a model for the evolution of marine adaptations in reptiles. Copeia 1986(3):741-756.

ERNST, CARL H. 1975. Growth of the spotted turtle, *Clemmys guttata*. J. Herpetol. 9(3):313-318.

ERNST, CARL H. 1976. Ecology of the spotted turtle, *Clemmys guttata* (Reptilia, Testudines, Testudinidae), in southeastern Pennsylvania. J. Herpetol. 10(1):25-33.

ERNST, CARL H., AND BARBOUR, ROGER W. 1972. Turtles of the United States. Lexington: University Press of Kentucky, 347 pp.

FITCH, H.S. 1958. Home range, territories, and seasonal movements of vertebrates of the University of Kansas Natural History Reservation. U. Kansas Publ. Mus. Nat. Hist. 11:63-326.

GIBBONS, J. WHITFIELD. 1986. Movement patterns among turtle populations: applicability to management of the desert tortoise. Herpetologica 42(1):104-113.

GIBBONS, J. WHITFIELD, GREENE, J.L., AND CONGDON, J.D. 1983. Drought-related responses of aquatic turtle populations. J. Herpetol. 17(3):242-246.

GRAHAM, TERRY E. 1970. Growth rate of the spotted turtle, *Clemmys guttata*, in southern Rhode Island. J. Herpetol. 4(1/2):87-88.

GRAHAM, TERRY E. 1979. Life history techniques. In: Harless, M., and Morlock, H. (Eds.). Turtles: Perspectives and Research. New York: Wiley and Sons, pp. 73-95.

KENNETT, RODNEY M., AND GEORGES, ARTHUR. 1990. Habitat utilization and its relationship to growth and reproduction of the eastern long-necked turtle, *Chelodina longicollis* (Testudinata: Chelidae), from Australia. Herpetologica 46(1):22-33.

KIESTER, A. ROSS, SCHWARTZ, C.W., AND SCHWARTZ, E.R. 1982. Promotion of gene flow by transient individuals in an otherwise sedentary population of box turtles (*Terrapene carolina triunguis*). Evolution 36:617-619.

LEGLER, JOHN M. 1977. Stomach flushing: a technique for chelonian dietary studies. Herpetologica 33:281-284.

LOVICH, JEFFREY E. 1990. Spring movement patterns of two radio-tagged male spotted turtles. Brimleyana 16:67-71.

MAUGER, D. 1988. Conservation of the spotted turtle (*Clemmys guttata* Schneider) in Illinois: a preliminary plan. Unpublished graduate research project. Governors State University.

MCGEE, E., MOLL, E.O., AND MAUGER, D. 1989. Baseline survey of a spotted turtle (*Clemmys guttata*) population at Romeoville Prairie Nature Reserve, Will Co., Illinois. Unpublished report to the Will County Forest Preserve District.

MIRICK, P.G. In press. Special concern, spotted turtle, *Clemmys guttata* (Schneider), Family: Emydidae, Order: Testudines. In: French, T., and Cardoza, J.E. (Eds.). Rare and Endangered Vertebrates of Massachusetts. Lincoln: Massachusetts Audubon Society.

NETTING, M.G. 1936. Hibernation and migration of the spotted turtle, *Clemmys guttata* (Schneider). Copeia 1936:112.

PARKER, W.S. 1984. Immigration and dispersal of slider turtles *Pseudemys scripta* in Mississippi farm ponds. Amer. Midl. Nat. 112:280-293.

SEIDEL, MICHAEL E. 1978. Terrestrial dormancy in the turtle *Kinosternon flavescens*: respiratory metabolism and dehydration. Comp. Biochem. Physiol. A. 61:1-4.

STORER, D. HUMPHREYS. 1840. A report on the reptiles of Massachusetts. Boston J. Nat. Hist. 3:1-64.

WARD, F. PRESCOTT, HOHMANN, C.J., ULRICH, J.F., AND HILL, S.E. 1976. Seasonal microhabitat selections of spotted turtles (*Clemmys guttata*) in Maryland elucidated by radioisotope tracking. Herpetologica 32:60-64.

WHITE, G.C., ANDERSON, D.R., BURNHAM, K.P., AND OTIS, D.L. 1982. Capture, recapture, and removal methods for sampling closed populations. Los Alamos, New Mexico: Los Alamos National Laboratory, LA 8787-NERP.

Accepted: 11 October 1994