instead utilizing sphagnum-covered hummocks for aestivation.

Some of the turtles showed fidelity to hibernaculum sites. In the communal hibernaculum in the bog, turtles regrouped in the same location for the second year of the study. Communal hibernation may increase chances of early spring mating. All of the turtles demonstrated a seasonal pattern of movement which they repeated during two years of the study. Often turtles could be found in the same exact locations at the same general time of the year within the study time.

When giving consideration to spotted turtles' habitat requirements it should be noted that these turtles utilize a variety of interconnected habitat types within a certain range. Protecting wetlands is critical, but maintaining continuity among wetland sites is integral to preserving populations of spotted turtles. Providing buffer zones of at least 200 m around the wetlands is also necessary to provide adequate protection since turtles are migrating out to aestivate and nest during spring and summer months.

Future research should be focused on microhabitat selection and population studies in New England and throughout the spotted turtle's range. As this species is listed as threatened or of special concern in three of the six New England states where it occurs, documentation of where it occurs now and population abundance should be of high priority for future studies. Studies to determine habitat preferences will be helpful to predict where spotted turtles are apt to occur.

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Ecology and Natural History of the Wood Turtle (*Clemmys insculpta*) in Southern New Hampshire. Linnaeus Fund Research Report

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An intensive one-year ecological study of the wood turtle (*Clemmys insculpta*) was conducted in New Hampshire from April 1993 to June 1994 at a site where Carroll (1991) previously had observed *C. insculpta*. The wood turtle is distributed throughout New Hampshire (Oliver and Bailey, 1939; DeGraaf and Rudis, 1983), but the species does not appear to be common anywhere in the state (Taylor, 1993). Few population or ecological data have been published on any wood turtle population in northern New England, and quantitative field studies of the wood turtle in New England are scarce. Virtually nothing is known about the early life stages of this species throughout its range. A major goal of this field study was to provide basic life history data to expand our understanding of the wood turtle's ecological variation (Tuttle, 1996).

Materials and Methods. — Located in southern New Hampshire in the Merrimack River watershed, the immediate study site includes two converging brooks with a sandy to gravelly substrate and occasional muck-bottomed stretches. Separated by a hayfield, the brooks are bordered by scrub-shrub wetlands, forested wetlands, emergent wetlands, upland mixed forest, and white pine stands.

Sampling was chiefly by hand-capture; turtles were individually marked by carapacial marginal scute notching. Environmental and cloacal temperatures were recorded. Straight-line morphometric measurements of the shell (carapace length, carapace width, plastron length) were taken, and body mass was recorded. Sex was determined by using external features (Harding and Bloomer, 1979). Mean values of all measurement samples are followed by ± 1 standard deviation (SD).

Ten adult *C. insculpta* (five of each sex) and two juveniles were fitted with external radio transmitters (Model 16M, Advanced Telemetry Systems, Inc., Isanti, Minnesota) on the rear of the carapace using waterproof epoxy. Each turtle was located on alternate days with a portable receiver and hand-held directional antenna. Tracking took place between April 1993 and June 1994. Movements of radio-tagged turtles were mapped by noting their exact locations in the field and plotting them on an enlarged aerial photograph. Using a microcomputer program (McPAAL, National Zoological Park,

Smithsonian Institution), three measures of home range size were calculated.

Located nests were covered with hardware cloth to capture hatchling wood turtles upon emergence. Eggs were excavated, length and width measured, and then reburied. Late in incubation, nests were monitored several times during each day and emergent hatchlings were marked by shell notching. Hatchlings were powdered with fluorescent pigments and tracked nocturnally in August and September using longwave ultraviolet light (Butler and Graham, 1995). Hatchling turtles were monitored daily in their terrestrial forms from 0600–1300 hrs and tracked at night from 2030 hrs until the last hatchling was located.

Habitat was evaluated by plant composition in habitat units of approximately 500–2000 m^2 covering the areas most frequently used by radio-tagged wood turtles. Dominant cover types and species within cover types were noted. Plant species and vegetation density also were noted each time a turtle was located.

Results. — In an area of 31.2 ha of primary habitat, consisting of diverse wetland and upland communities, an estimated density of male, female, and juvenile wood turtles was 2.6 turtles/ha. The study population consisted of 82 adults that were captured and marked (29 females, 17 males, 36 juveniles). The adult male-to-female sex ratio was 1.0:1.8, which did not differ statistically from a 1:1 ratio. There were significant differences in carapace length between the sexes, with males averaging 181.5 ± 11.2 mm and females 171.5 ± 6.1 mm, but no significant differences in body mass between adult males (750.3 ± 134.0 g) and adult females (711.4 ± 85.9 g).

There were no significant differences in intrapopulational home ranges. Mean home range sizes were: adult males, 5.8 ± 3.3 ha (n = 5); adult females, 3.9 ± 3.0 ha (n = 5); juveniles, 6.0 ± 6.8 ha (n = 2). There were no correlations between home range size and body mass, carapace length, or estimated age. Home ranges overlapped spatially and temporally between sexes and age classes throughout the study. Females were seldom observed in a brook during the summer, whereas males were more frequently encountered in water. Throughout the active season females were terrestrial 80% of the time and males were terrestrial 64% of the time.

Fifteen of 28 (54%) habitat units evaluated were wetland habitat, 13 (46%) were upland. Of 5 cover types recognized, shrub cover (42%) was represented most frequently. An interesting foraging behavior was observed in shrub wetland habitat. One adult male and one adult female wood turtle were each observed stomping for earthworms on several occasions. This foraging technique has previously been observed in the wild in this species only in central Pennsylvania (Kaufmann, 1986).

Between April and December, various activity categories were recorded: basking, dormant in water, swimming, courtship, foraging (Fig. 1), walking, and quiescent in terrestrial forms. Cloacal temperatures were positively correlated with environmental temperatures. Wood turtles showed peak activity periods during May and June, although this may be correlated with an increased number of females observed nesting in June.

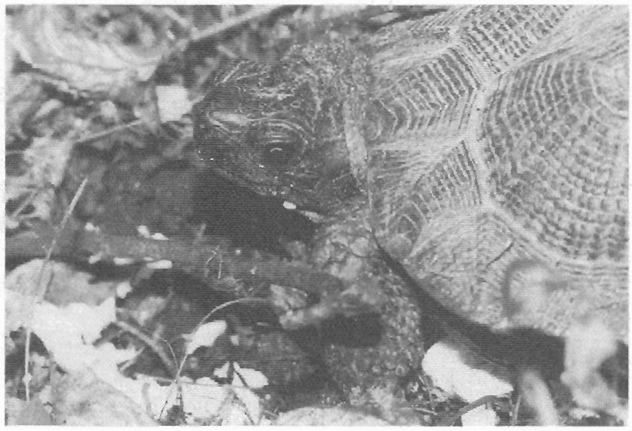

Figure 1. Adult female wood turtle (*Clemmys insculpta*) foraging on mushrooms (*Russula* sp.) in a southern New Hampshire pine forest (photo by Sheila E. Tuttle).

The first nest was discovered on 2 June 1993 and was followed by observations of nesting behavior between 5 and 13 June. Nests excavated by females were in sandpits located 60.3 ± 18.4 m (n = 9) from a brook. Mean clutch size was 7.8 ± 1.0 (range 6–9) eggs per clutch (n = 9). Egg width averaged 22.5 ± 1.0 mm and egg length averaged 35.3 ± 2.5 mm (n = 70). The natural incubation (to emergence) period for eight of nine protected nests ranged from 66 to 82 days (mean = 76.0 ± 6.2 days). Overall hatching success (n = 70 eggs) was 77%. Four additional unprotected nests observed during the nesting season were destroyed by predators.

Of the 53 hatchlings marked, 36 were recaptured at least once and 24 were recaptured more than once. Twelve individuals were successfully tracked to nearby brooks. Habitats selected by hatchlings usually were in herbaceous vegetative cover on hayfield banks and in dense woody and herbaceous ecotones along dirt roads. Mean distance traveled per movement was 26.2 ± 25.0 m (range 0.2–109.0 m, n = 134). The mean total distance traveled to a brook was 131.7 ± 119.7 m (27.8–445.4 m) and the mean rate of movement was 23.4 ± 9.5 m/day (14.5–40.0 m/day). The mean time taken to reach the brooks was 6.2 (1–24) days (Tuttle and Carroll, 1995).

Discussion. — Life history and reproductive data as well as home range and habitat use observations of the current study should allow a more complete survey of geographic variation in *Clemmys insculpta*. Wood turtles at the New Hampshire study site appeared to represent a viable population, as 44% of the population was represented by juveniles (excluding hatchlings). Based on a one-year study, population size and density recorded may be somewhat conservative. Using population estimates of other studies, the study area's 31.2 ha of diverse habitats may provide a higher carrying capacity than observed. Densities elsewhere averaged 10.7 turtles/ha (Farrell and Graham, 1991, all size and age classes), 12.5 turtles/ha (Harding and Bloomer, 1979, adults only), and 0.24 turtles/ha (Brooks et al., 1992, adults only).

Home range sizes of wood turtles in central Pennsylvania averaged 5.0 ± 1.4 ha for adult males and 3.3 ± 0.5 ha for adult females (Kaufmann, 1995). Using the same method (summed

locations in 20 m quadrats), the home ranges determined in this study were comparable (5.8 ± 3.3 ha for adult males, 3.9 ± 3.0 ha for adult females). Other studies have reported much smaller home range sizes (0.08–0.41 ha for males, 0.27-2.2 ha for females; Ross et al., 1991), or much larger home range sizes (mean 24.3, range < 1–115 ha; Quinn and Tate, 1991), both using a minimum convex polygon method. In Connecticut, wood turtle habitat was similar to that at the New Hampshire site (S.D. Garber, *pers. comm.*), as was habitat in central Pennsylvania (Kaufmann, 1992). But habitat in northern Virginia, the southernmost limit of the species' range, is comparatively more upland than wetland in character (C.H. Ernst, *pers. comm.*).

As in other studies of temperature and activity relationships in wood turtles, New Hampshire data showed positive correlations between cloacal and environmental temperatures. However, *C. insculpta* in southeastern Pennsylvania differ in the time of day of their main activity. In New Hampshire, most were active in early afternoon (1400–1500 hrs), whereas in Pennsylvania activity occurred in the morning and late afternoon (Ernst, 1986). This difference may be attributed to climatic variation between the wood turtle's more southern range vs. the comparatively cooler mid-day temperatures of the more northern locality.

Prior to the current study, little was known of the post-hatching life of young *C. insculpta*, and particularly about the behavior of hatchlings during migration from nest to water (Ernst et al., 1994). Fluorescent trails of hatchlings at night revealed that both siblings and non-siblings often were found to overlap one another precisely, suggesting that the hatchlings may have followed conspecific olfactory cues. Similar behavior was observed in hatchling *Emydoidea blandingii* (Butler and Graham, 1995). Based on field observations, olfaction, vision, positive geotaxis, and auditory cues of rushing water in brooks may be employed as orientation mechanisms.

Wood turtle populations have declined in many areas throughout the species' range (Harding and Bloomer, 1979); in some regions, *C. insculpta* has been locally extirpated by humans (Garber and Burger, 1995). Although wood turtles may be sporadically common in local populations where suitable habitat exists, in southern New Hampshire many of its habitats are being lost to human development. Because the species is highly vulnerable to habitat fragmentation, has a low reproductive potential, is vulnerable to nest predation, and is susceptible to incidental and commercial collecting, it is critical to protect the wood turtle. Recently adopted regulations in New Hampshire prohibiting the collection of four species of native chelonians, including *C. insculpta*, is a positive conservation step.

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