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# Home Range and Seasonal Movements of the Wood Turtle (*Glyptemys insculpta*) in Southern New Hampshire

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**ABSTRACT. – An intensive one-year (April 1993 – June 1994) study of movements and home range of the wood turtle (*Glyptemys insculpta*) was conducted in southern New Hampshire. A total of 82 turtles in a study population were marked for individual identification. Based on 756 captures (61–88 recaptures per turtle) of 10 radio-tagged adults (5 of each sex), home ranges were calculated by three methods: minimum convex polygon, harmonic mean isopleths, and summed 20 m quadrats of locations. For adult male and female turtles, home ranges were most similar to those previously reported in central Pennsylvania based on a similar 20 m quadrat summation method. Home ranges in New Hampshire averaged 5.8 ± 3.3 ha for adult males and 3.9 ± 3.0 ha for adult females. The other methods yielded considerably larger estimates: 23.9 ± 26.2 ha (convex polygon) and 13.3 ± 9.9 ha (95% isopleth) for adult males, and 7.1 ± 7.3 ha (convex polygon) and 4.5 ± 2.2 ha (95% isopleth) for adult females. There was no significant difference in home range size between adult males and females, and no correlation between turtle body size or estimated age and home range size. Home ranges between sexes overlapped spatially and temporally throughout the study. Females were more terrestrial than were males throughout the active season, seldom being observed in a brook during the summer, whereas males were more frequently encountered in water. During the combined months of June, July, and August, females were located significantly farther from a brook (84.5 ± 61.0 m) than were males (31.0 ± 26.5 m). The home range information provided in this study expands our knowledge of geographical variation in this ecological parameter for *G. insculpta*, thus providing an important step toward developing conservation and management strategies for the species.**

**KEY WORDS. – Reptilia; Testudines; Emydidae; *Glyptemys insculpta*; turtle; home range; seasonal movements; radiotelemetry; New Hampshire**

The wood turtle (*Glyptemys insculpta*) is a semiaquatic emydid found from Nova Scotia south to northern Virginia and west to eastern Minnesota (Ernst et al., 1994). Based on evidence that *Clemmys* is a paraphyletic genus (Holman and Fritz, 2001; Feldman and Parham, 2002a, 2002b), *Clemmys insculpta* has recently been reassigned, along with *C. muhlenbergii*, to the genus *Glyptemys*; we follow that revision here. Researchers are increasingly noting that wood turtles have declined throughout their range (Harding and Bloomer, 1979; Saumure and Bider, 1998; Ernst, 2001; Compton et al., 2002); in Connecticut the extirpation of two populations has been documented (Garber and Burger, 1995) and in northern Virginia the disappearance of several populations has been reported (Ernst and McBreen, 1991). In New Hampshire, the wood turtle has been recorded from various localities (Oliver and Bailey, 1939; DeGraaf and Rudis, 1983; Taylor, 1993), but it has not been shown that the species is common anywhere in the state (Taylor, 1993). Although wood turtles may be sporadically common in local populations where suitable habitat exists, many of its habitats are being increasingly lost to human development (Tuttle and Carroll, 1997). Many occurrence records of wood turtles in New Hampshire are based on localities with marginalized habitats and thus may represent non-viable populations (Tuttle and Carroll, *unpubl. obs.*).

In various locations throughout the species' range, a number of investigators have reported home ranges or seasonal movements in wood turtles (Harding and Bloomer, 1979; Barzilay, 1980; Strang, 1983; Harding, 1991; Quinn and Tate, 1991; Ross et al., 1991; Farrell and Graham, 1991; Kaufmann, 1992, 1995; Foscarini, 1994; Foscarini and Brooks, 1997; Niederberger and Seidel, 1999; Ernst, 2001; Compton et al., 2002; Arvisais et al., 2002). Although movements and home range of *G. insculpta* in New Hampshire have been preliminarily described (Tuttle, 1996; Tuttle and Carroll, 1997), no detailed studies of home range and movements of wood turtles in New England have been published. This field study provides basic data on home range size using several methods of calculation, and reports seasonal occupancy of aquatic and terrestrial habitats in order to expand our understanding of the geographic variation of these spatial parameters in *G. insculpta*. In addition, our study indicates that spatial data are informative for developing objectives to conserve local populations of this species.

## METHODS

*Study Site.* — The study site is located in southern New Hampshire where wood turtles have been observed since 1988 (Carroll, 1991, 1999). Because wood turtles are often a target of illegal collecting for the pet trade, the exact locality of our study site is not revealed. The site is characterized by gently hilly terrain consisting of predominantly forested habitat scattered with streams, wetlands, and agricultural fields; human residences and farmhouses are sparsely distributed along most paved roadways. In addition to sand and loam soils largely formed in glacial till and outwash, the study site consists of soils developed in small areas of glacial lake sediments, stream sediments, and depressions (USDA, 1961).

The immediate study area includes two streams (Streams A and B) separated by an approximately 120 m wide hayfield, and bordered by scrub-shrub wetlands, forested and emergent wetlands, upland mixed forests, and white pine (*Pinus strobus*) groves. Dense woody vines, upland shrubs, and herbaceous vegetation border two dirt roads leading to a disturbed sandpit area that is used by wood turtles for nesting. Maintenance of the habitat can be attributed, in part, to an active beaver (*Castor canadensis*) population, and to the mowing and haying operations of an agricultural landowner. A 2.4 km longitudinal section along the streams shows elevation gradients of 36 m (Stream B) and 12 m (Stream A). Along Stream A where beaver impoundments had previously inundated the stream borders, wet meadows provide cover for wood turtles. Active beaver impoundments with numerous scrub-shrub islands and beaver backwaters and channels define sections of both streams. The streams are generally flanked by dense tangles of shrub and emergent vegetation or steep banks. The substrate of both streams consists primarily of sand and gravel with occasional muck-bottomed stretches. Other chelonians were occasionally found at the site, but *G. insculpta* was by far the dominant turtle species based on the number of turtles observed. Other species (*Clemmys guttata, Sternotherus odoratus, Chrysemys picta, Chelydra serpentina*) presumably represented transient individuals.

*Field Procedures.* — From 4 April 1993 to 14 May 1994, 82 wood turtles were captured and marked; sampling efforts were chiefly by hand-capture throughout the study. Turtles were given a unique number by notching marginal scutes of the carapace with a triangular file, using a numbering system similar to that of Cagle (1939). Carapace length was measured along a straight line using dial calipers accurate to 0.1 mm, and body mass was measured using a 2 kg Pesola spring scale accurate to ± 5 g. Sex was determined using external features enumerated by Harding and Bloomer (1979) and Ernst et al. (1994). Age estimates were determined by counting growth annuli on the right abdominal scute; counts of 15 or greater were considered to represent minimal ages only (Harding and Bloomer, 1979).

The first 10 adult individuals captured (5 males, 5 females) were fitted with 30 g transmitters (Advanced Telemetry Systems, Inc., Isanti, MN) affixed externally to the rear of the carapace using a waterproof epoxy. A portable telemetry receiver (Model LA12-DS, AVM Instrument Company, Livermore, CA) and hand-held directional antenna were used to locate turtles from a maximum distance of about 0.8 km; all turtles were then approached and physically located. Neither dense vegetation nor intervening topography appeared to limit reception within this range. Ten turtles (five from each stream) were located on alternate days throughout the 1993 active season (1 April – 1 November) and less frequently (4–16 times per individual, $\bar{x} = 9.3$) during the 1993–94 hibernation season (from late September to late March). When found after spring emergence in 1994, transmitters were removed. In this study, movements and home range data were analyzed for the 10 radio-tagged turtles only.

Movements were mapped by plotting the specific locations of turtles located in the field on an approximately 500% enlargement tracing of an aerial photograph (scale: 2.5 cm = 122 m). The accuracy of daily plotted locations was improved by careful attention to detail, including the use of landmarks such as brook meanders, beaver dams, islands, vernal pools, boulders, sandpits, and trees that could be located on the aerial photograph. When necessary, precision was further improved by measuring distances from the stream to a landmark using a 300 m tape.

Using the program McPAAL (Micro-computer Programs for the Analysis of Animal Locations, Version 1.2.2; Stuwe and Blohowiak, 1985), the following three methods were used to measure home range size: 1) minimum convex polygon (Mohr, 1947) in which the outermost data points were connected; 2) 20 m grid summation calculated using McPAAL's concave polygon routine with an observational grid size set at 20 m and in which any recapture within a quadrat qualified the quadrat to be included in the additive area sampled; and 3) harmonic mean transformation analysis (Dixon and Chapman, 1980) computed by McPAAL for areas used most heavily within the home range. These are defined here by 50 and 95% isopleths for turtle locations throughout the active season showing areas of the densest array of locations enclosed by lines of these occurrence dimensions. For each of the three methods, turtle locations were plotted on a clear acetate sheet which was overlain onto base maps of the study site and then converted to scaled X and Y coordinates for use in McPAAL. Because overwintering locations were included in the analysis only if a turtle changed position during hibernation, and as only 7 movements (< 1% of the total) were recorded during hibernation, isopleths heavily reflect locations for wood turtles throughout the active season rather than during the winter season of dormancy.

Statistical analyses were performed using SigmaStat statistical software (Jandel Scientific, San Rafael, CA) and methods generally followed Zar (1984). Mann-Whitney rank-sum tests analyzed differences between distance-to-water measurements of males and females and a chi-square goodness-of-fit test was used for differences in the frequency of use of terrestrial vs. aquatic locations under an

**Table 1.** Selected biological data of 5 adult female and 5 adult male *G. insculpta* radio-tracked in New Hampshire. Ages (determined by counting visible plastral annuli) represent minimum estimated ages for turtles aged 15 years and older; CL = carapace length.

| | Age (yrs) | | Mass (g) | | CL (mm) | |
|---|---|---|---|---|---|---|
| Sex | Mean | Range | Mean ± SD | Range | Mean ± SD | Range |
| Males | 20 ± 1.6 | 18–20 | 817 ± 87.4 | 730–920 | 186 ± 5.4 | 177–192 |
| Females | 18 ± 4.4 | 15–26 | 658 ± 32.5 | 610–700 | 169 ± 20.3 | 165–174 |

assumption of 50:50 use for both sexes. Percentage data for differences between areas of highest usage of the home range between males and females were tested using a Student's t-test with arcsine transformation, whereas differences between male and female distances to water were t-tested using nontransformed data. Pearson product-moment correlation coefficients tested for comparisons of home range by body size (carapace length, mass), and estimated age. All sample mean values reported are followed by ± one standard deviation (SD), and range in parentheses.

## RESULTS

*Main Activity Center.* — Most radio-tracked turtles' home ranges were located within a 31.2 ha area of diverse wetland and upland habitats (including suitable nesting and overwintering areas) defined as a main activity center. In this activity center, 93% of the 82 wood turtles were captured initially and the home ranges of 4 radio-tagged females and 4 radio-taggged males were located; one male and one female occupied areas well outside the main activity center. Morphometric data for the ten individuals radiotracked are presented in Table 1.

*Home Range Size.* — Using the 20 m grid summation method, mean home range size for 5 adult males was 5.8 ± 3.3 (1.60–10.04) ha and for 5 adult females mean home range was 3.9 ± 3.0 (2.1–9.2) ha (Table 2). There was no significant difference in home range size between adult males and females using both the 20 m grid summation method ($t = 0.98, p = 0.36$) or the minimum convex polygon method: males = 23.9 ± 26.2 (3.2–67.9) ha, females = 7.1 ± 7.3 (2.4–19.9) ha ($t = 1.37, p = 0.21$). There was no correlation between home range size (20 m grid and convex polygon, respectively) and body mass ($r = 0.04, 0.31; p > 0.05$), carapace length ($r = 0.06, 0.14; p > 0.05$), or estimated age ($r = 0.17, 0.15; p > 0.05$).

A harmonic mean transformation analysis computed home range areas used heavily by wood turtles (Table 2). Smaller regions show areas used by turtles 50% of the time and larger ones depict areas used 95% of the time (Fig. 1). Areas of highest usage (95% isopleths) averaged 73% (range 31–99%) of the convex polygon areas in males, and 92% (range 37–193%) in females; these percentages were not significantly different between the sexes ($t = 0.52, p = 0.62$). Isopleths at 95% yielded considerably larger mean home range estimates (males, 13.3 ± 9.9 [2.8–25.0] ha; females, 4.5 ± 2.2 [2.0–7.4] ha) than did the 20 m quadrat summation method (Table 2).

**Table 2.** Home range comparisons from populations of wood turtles (*G. insculpta*) investigated by methods comparable to those of this study. Total area is reported as mean area ± SD unless a single individual is listed. *n* = number of individuals; R = number of total recaptures; n.s. = not stated.

| Study Locality | *n* | R | Total Area (ha) | Method | Authority |
|---|---|---|---|---|---|
| Males | | | | | |
| New Hampshire | 5 | 384 | 5.8 ± 3.3 | quadrat summation | Present study |
| | | | 13.3 ± 9.9 | harmonic mean | Present study |
| | | | 23.9 ± 26.2 | convex polygon | Present study |
| Pennsylvania | 6 | 5401 | 5.0 ± 1.4 | quadrat summation | Kaufmann, 1995 |
| Wisconsin | 3 | 19 | 0.3 ± 0.2 | convex polygon | Ross et al., 1991 |
| Quebec | 6 | 232 | 30.3 ± 26.9 | convex polygon | Arvisais et al., 2002 |
| Ontario | 6 | n.s. | 1.1 ± 0.3 | quadrat summation | Foscarini, 1994 |
| | 6 | n.s. | 5.0 ± 2.9 | convex polygon | Foscarini, 1994 |
| Females | | | | | |
| New Hampshire | 5 | 372 | 3.9 ± 3.0 | quadrat summation | Present study |
| | | | 4.5 ± 2.2 | harmonic mean | Present study |
| | | | 7.1 ± 7.3 | convex polygon | Present study |
| Pennsylvania | 4 | 2134 | 3.3 ± 0.5 | quadrat summation | Kaufmann, 1995 |
| Wisconsin | 4 | 81 | 0.5 ± 0.3 | convex polygon | Ross et al., 1991 |
| | 1 | 32 | 2.2 | convex polygon | Ross et al., 1991 |
| | 1 | 10 | 0.6 | convex polygon | Ross et al., 1991 |
| Quebec | 14 | 610 | 27.6 ± 34.8 | convex polygon | Arvisais et al., 2002 |
| Ontario | 4 | n.s. | 0.9 ± 0.3 | quadrat summation | Foscarini, 1994 |
| | 4 | n.s. | 6.4 ± 3.7 | convex polygon | Foscarini, 1994 |
| Sex not differentiated | | | | | |
| Ontario | 8 | n.s.[a] | 24.3[b] | convex polygon | Quinn and Tate, 1991 |

[a] mean number of recaptures per turtle = 14

[b] described as "activity areas" rather than home ranges

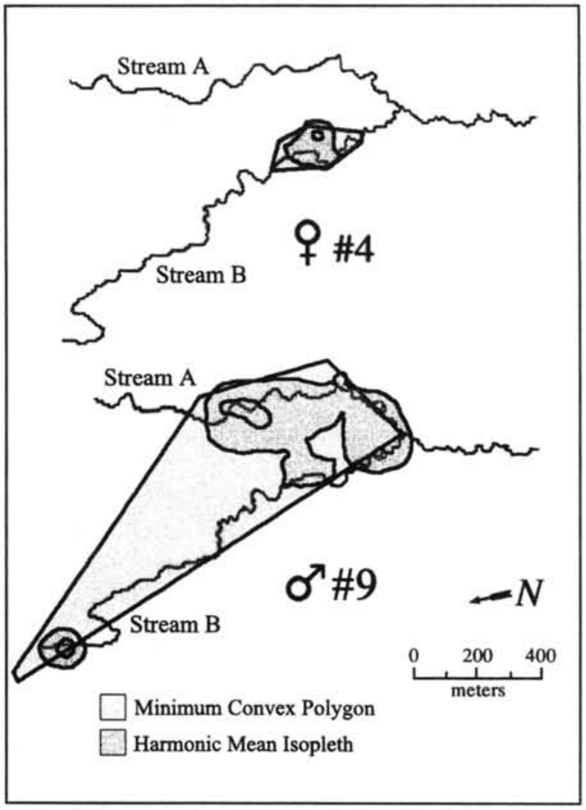


**Figure 1.** Home range maps for one adult male and one adult female *G. insculpta* in southern New Hampshire. Maps show two main streams (Streams A and B) in the study area and the computed home ranges. For each individual, the darker areas show harmonic mean isopleths (contour lines) of areas that encompassed 50% of the turtle's locations as an inner line and 95% of the turtle's locations as an outer line. Lighter areas represent the turtles' home ranges calculated by the minimum convex polygon method.

The 95% isopleth shown for adult female #4 (Fig. 1) reflects 72% of her home range and represents capture locations between 28 April and 3 August when she traveled back and forth from Stream B and its shrub swamp borders to the densely vegetated banks bordering a sandpit nesting area. This female remained as long as 14 days in the sandpit area and up to 10 days along Stream B at any one period. The 95% isopleth also includes the area of her hibernaculum. The 50% isopleth reflects areas of use in the sandpit only, and represents only 4% of her total home range. For adult male #9, the 95% isopleth represents 31% of his home range (Fig. 1), including his hibernaculum. The male (who was missing his left forefoot) occupied both brooks throughout the year, as well as an upstream area along Stream B located approximately 0.8 km from the main activity center. The 50% isopleth represents this upstream section of the stream where he remained for 51 days, and comprises only 2% of his total home range.

*Distances Moved.* — Movement data reflect distances traveled over a two-day period between successive location points during the active season months of 1 April to 1 November. Movement distances are straight-line measurements between capture locations rather than actual distances traveled on a daily basis. Distances traveled by males during the active season ranged from as little as 2.6 m in May and October to as much as 978 m in July. The greatest distance traveled by any female over a two-day period during the active season was 436 m in June. Mean distance traveled by all females ($\bar{x} = 50.1 \pm 59.5$ m, range 0.1–436 m; $n = 315$) was significantly less ($t = 6.2$, $p < 0.01$) than that for all males ($\bar{x} = 109.6 \pm 159.9$ m, range 1.3–978 m; $n = 353$) throughout the active season. Differences in mean movement distances over the six-month period diverged in the latter portion of the active season, with males showing prominently greater movement distances in July, August, and September (Fig. 2). In October, the longest distance traveled by a male (615 m) reflected the distance to his hibernaculum. By October, most females were already situated in or near their aquatic hibernacula. During hibernation, 3 females and 2 males moved a minimum of 2.0–11.0 m between 8 December and 1 February when the brook was frozen on the surface; none of the other turtles were observed to change position during that period. No movements occurred for 8 of the 10 turtles between 1 February and 2 April, and during this period movements of two males were minimal (2 m, 3 m).

*Distances from Streams.* — Females consistently were located farther away from a waterway than were males during the summer (Fig. 3). Females were located as far as 231 m from a stream but were within 188 m from a stream in 95% of the locations. Although one male was found as far as 198 m from a stream in June, 95% of captures of males were within 61 m of the water. There was a significant difference between the distances that males and females where found from a stream during the combined months of June, July, and August (Mann-Whitney rank sum test, $p < 0.001$; males $\bar{x} = 31.0 \pm 26.5$ m, range 0.1–198 m, $n = 120$; females $\bar{x} = 84.5 \pm 61.0$ m, range 0.9–231 m, $n = 171$). Females were captured closer to a stream in May ($\bar{x} = 23.5 \pm 26.0$ m, range 0.3–98.7 m; $n = 59$) and September ($\bar{x} = 58.5 \pm 49.8$ m, range 5.3–181.9 m; $n = 32$) than during other times during the active season. Combined data for all male and female recaptures showed that adult *G. insculpta* occupied

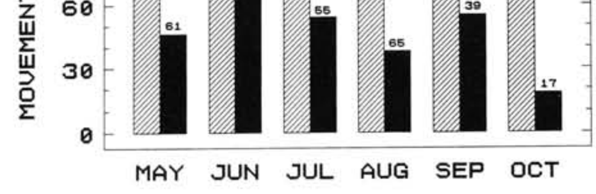


**Figure 2.** Mean distance moved by *G. insculpta* in southern New Hampshire. Distances were measured over successive location points at two-day intervals over six months of the active season. Sample size (number of locations) indicated above each bar.

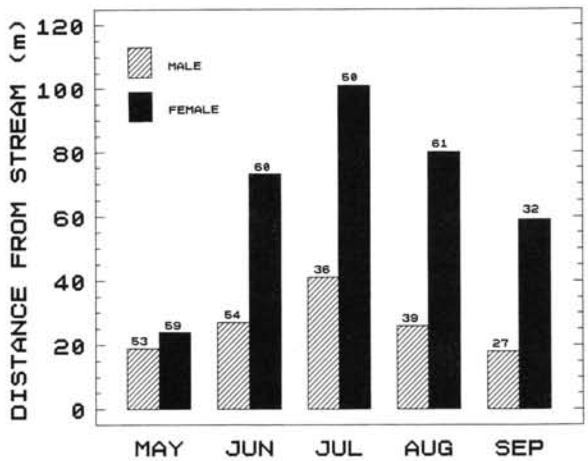


**Figure 3.** Mean distance away from a stream for *G. insculpta* locations over five months of the active season in New Hampshire. Sample size (number of locations) indicated above each bar.

terrestrial habitat a mean distance of 47 m from a stream, with 95% of the captures recorded within 175 m of water ($n = 489$).

After the nesting season (determined by the discovery of nests or observation of nesting females from 2–13 June), most females soon traveled to their terrestrial summer ranges. Females occupied terrestrial habitats for longer lengths of time than did males and were seldom observed in a stream during the summer, whereas males were more frequently encountered in water. The mating season was observed in the fall as well as in the spring in New Hampshire (Carroll, 1991, 1999; Tuttle, 1996). One male was captured in a stream during the entire month of September; this was possibly a reflection of mate-seeking behavior. Throughout the active season females were terrestrial 83% of the time ($n = 270$ of 327 locations) whereas males were terrestrial 64% of the time ($n = 219$ of 343 locations). The selection of terrestrial over aquatic locations by males and females was tested by a two-way (sex x location) goodness-of-fit test; there was a significant difference between the sexes ($\chi^2 = 165$, $p < 0.01$).

*Home Range Overlap.* — Overlap in home ranges occurred spatially and temporally between turtles of the same sex, as well as between males and females. There was extensive overlap between radio-tagged females from the same stream. There was little overlap, however, between turtles of the two streams, including females radio-tracked during nest-site selection. No females were found crossing the hayfield between the two streams, or swimming downstream from their home stream to the confluence of the two streams. Although radio-tagged females did not cross the hayfield, during the summer they routinely utilized hayfield edge habitats on both sides of their home stream.

There was overlap between males of the same stream as well as between males from the two streams. Observations of overlap between males include a male who traveled downstream in Stream B to the confluence of the two streams, and then moved upstream in Stream A where an agonistic encounter took place with a second radio-tagged male. Another observation of two males (one from each stream as determined by their spring emergence locations) later showed them to be hibernating within 5 m of each other in the confluence of the two streams. None of the radio-tagged turtles were observed using the same hibernaculum; the closest distance that any of the turtles were found from each other while overwintering was 5 m. Except for a female who was located under the bank in a hemlock (*Tsuga canadensis*) root system, all of the telemetered turtles hibernated on the stream bottom at water depths of 0.5–1.2 m within 1.0–1.5 m of the stream's edge.

## DISCUSSION

Because most vertebrates are not nomadic, home range has been defined as a fairly confined area where animals perform their day-to-day activities (Powell, 2000). Much of the recent home range literature is concerned with evaluation of methods for measuring an animal's home range. Additional to the methods used in this study (quadrat summation, harmonic mean isopleths, minimum convex polygon) is the adaptive kernel method as recently used for spotted turtles (*Clemmys guttata*) (Lewis and Faulhaber, 1999). Although kernel methods are becoming widely accepted by ecologists, these estimators share shortcomings with most other home range methods (Powell, 2000) and there appears to be a discrepancy over which kernel estimator (fixed or adaptive) performs in the most robust fashion, i.e., fixed kernels as suggested by Seaman and Powell (1996) or adaptive kernels as suggested by Whorton (1989). This study was not intended to be an exhaustive comparison of home range estimators; rather we have presented herein three methods for calculating home range sizes in *G. insculpta* that may be considered in understanding and managing populations of this species.

The quadrat summation method resulted in home range size estimates that were somewhat smaller than both the harmonic mean and minimum convex polygon estimates. Although the latter method usually tends to overestimate home range size (Kaufmann, 1995; Powell, 2000), it was retained here primarily because in several earlier studies it was a widely used method. Studies reporting limited movements and small home range sizes may be a result of either short-term sampling, lack of radiotelemetric tracking, or habitat constraints at a particular locality. Apparently small sample sizes (10–32 locations per turtle) produced small home range estimates (0.08–2.2 ha) in Wisconsin (Ross et al., 1991). Although several researchers have reported limited movements or small home range sizes for *G. insculpta* (Ernst, 1968; Harding and Bloomer, 1979; Strang, 1983; Harding, 1991; Ross et al., 1991), others have observed wood turtles traveling much farther: 1.0 to 1.6 km in Virginia (Ernst and McBreen, 1991; J. McBreen, *pers. comm.*), up to 1 km by nesting females in Pennsylvania (Ernst, 2001), and up to 3.6 km in Ontario (Quinn and Tate, 1991).

From a management perspective, an important consideration when selecting an estimator is that methods which tend to underestimate home range (e.g., quadrat summation) should be used with caution. Harmonic mean estimators, which tend to overestimate home range, were widely used into the 1990s (Powell, 2000) and include home range studies of ornate box turtles (*Terrapene ornata*) (Doroff and Keith, 1990; Nieuwolt, 1996) and other reptiles (e.g., timber rattlesnakes, *Crotalus horridus*; Reinert and Rupert, 1999). In this study, our calculations of harmonic mean isopleths which show concentrations of locations as observed in the field, provide "close approximations of the true activity center" (Dixon and Chapman, 1980).

Measurements of home range and seasonal movements reported here for New Hampshire allow a more complete survey of geographic variation in the spatial biology of *G. insculpta*. Of the home range sizes reported for *G. insculpta*, those in Pennsylvania (Kaufmann, 1995) are closely comparable to our results using a similarly scaled quadrat summation method. Home range areas in Quebec (Arvisais et al., 2002) and Ontario (Quinn and Tate, 1991) are comparable to our results using the convex polygon method. As suggested by our results, if a single active season study is intense in relocation effort and involves an adequate sample size of individuals, one full season (including knowledge of the hibernacula and nesting sites), is minimally necessary in order to obtain a general home range estimate in this species. Based on observations by one of the authors (DMC) over a 15-year period, there were no anomalous weather patterns or land-use activities during the 1993–94 study period as compared to other years, and measurements of ambient temperatures recorded between April and December 1993 were typical. We observed all 10 of the radio-tagged turtles within their reported home ranges both before and after the 1993–94 study period. These observations confirm strong site fidelity in *G. insculpta*, as have observations in other studies (Carroll and Ehrenfeld, 1978; Harding and Bloomer, 1979; Quinn and Tate, 1991; Walde, 1998; Arvisais et al., 2002). Following our study, one female (#4) has been found within her reported home range in every year since 1994. Longer studies would, however, yield additional useful data and "smooth out" differences in behavior, including differences due to climatic variation, changes in land-use patterns, or habitat changes brought about by natural causes such as beaver activity. Although longer studies are valuable in order to portray a more complete temporal picture of home range in this species, we are confident that our study, together with observations both before and after the year of investigation, provides the information needed for delineating wood turtle habitat required for the persistence of *G. insculpta* at this site.

A home range method should offer some level of predictability of an animal's location (Powell, 2000). In this study, the harmonic mean and convex polygon home range estimators provided the most reasonable levels of predictability of the spatial characteristics of *G. insculpta*. In particular, these estimators are indicative of the kinds of information on movement distances and occupancy of specific local habitats by individual turtles that can be used to focus attention on important habitat-use areas. Although harmonic mean estimators produced home ranges that were consistently smaller than minimum convex polygons, overlays of the two methods show closely corresponding occupancy of habitat. Male #9 used the stream between his separated isopleths of activity as a travel corridor; this turtle was rarely observed in the intermediate stream segment (thus its exclusion as a heavy use area). Knowledge of a turtle's habits correlated with the harmonic mean estimator would, in this case, provide the data necessary for managing the turtle's habitat. A key issue in home range analysis is our ability to understand a species' cognitive assessment of its habitat which, in turn, influences its selection of a home range (Powell, 2000). Further research is needed to measure behavioral factors that influence home range and habitat selection in order to determine which of the available estimators are most suitable for *G. insculpta*.

In many vertebrates, conspecifics often show extensive overlap in home ranges (Powell, 2000). In *G. insculpta*, overlap was recorded in both males and females in the present study. In Pennsylvania, Kaufmann (1995) found no exclusive use of any part of the home range by adult wood turtles during any year or season. In New Hampshire, after nesting, radio-tagged females traveled upstream as far as 450 m in their home stream, and from there moved out to terrestrial summer habitats. A few occurrences of overlap of the turtles' home ranges were noted in areas between the two streams where males and females from both streams traveled to terrestrial summer ranges with similar habitat characteristics. Hayfields on opposite sides of each stream, and between the two streams, were mowed within days of each other; vegetative composition in the hayfields was virtually the same, providing wood turtles with cover and seasonally abundant food resources (e.g., wild strawberries, *Fragaria virginiana*). In several instances, the opposite stream apparently was located outside the limits of each turtle's home range, and an individual not crossing to the other stream may simply have been a function of distance.

Various movement patterns among turtle populations suggest that numerous turtle species travel significant distances in response to seasonal changes, and that movements of males are generally longer and occur more often during the mating season than those of females (Gibbons, 1986). Similar patterns hold for *G. insculpta* in New Hampshire, i.e., increased movements and activity of males presumably increase the probability for mating encounters as in other emydids. In Ontario, Quinn and Tate (1991) observed that abrupt movements to summer ranges occurred from 18 June to 10 July. In New Hampshire, females in mid-June made similar movements after they had nested. Even though we recorded some females traveling long distances in order to find a suitable nest site, we include nesting movements in the females' calculated home range. We consider this a valid treatment of these reproductive sojourns in the spatial-seasonal biology of *G. insculpta*. In males, such distinctly recognizable movements were less obvious. Most males wandered farther and more frequently, however, and used a higher proportion of available aquatic habitats.

Our New Hampshire study showed that adult *G. insculpta* occupied terrestrial habitat a mean distance of 47 m from a stream, with 95% of the captures recorded within 175 m of water. Other studies also have reported that wood turtles select terrestrial habitats somewhat distant from a waterway. In Ontario, wood turtles were observed up to 500 m from a stream (Foscarini and Brooks, 1997), but in southern Quebec, wood turtles were usually observed in open grassy areas only several meters from a river (Saumure and Bider, 1998). In a Pennsylvania locality, wood turtles were found a mean distance of 15.7 m from a stream, with 95% of the captures occurring within 40 m of the stream (Ernst, 2001). In Michigan, the animals remained near streams throughout the active months, most staying within 150 m of water, but in New Jersey wood turtles assumed a terrestrial existence from late June to late August, only being found in the water during periods of drought (Harding and Bloomer, 1979). Farrell and Graham (1991) and Niederberger and Seidel (1999) also observed a prevalence of terrestrial activity during the summer. Knowledge of terrestrial occupancy of specific habitats and measurements of the distance wood turtles occupy from a waterway is emphasized here because the inclusion of these areas is critical to the development of conservation plans for the species.

An area we term the "main activity center" of the New Hampshire study population is a component of an extended continuum of wood turtle populations. In Stream A, wood turtles have been observed 3.2 km upstream as well as 2.4 km downstream from the confluence to a larger river, and then upriver for another 12.8 km. In Stream B, *G. insculpta* has been observed 2.6 km upstream from the confluence. We found wood turtles repeatedly using sections of Streams A and B that did not appear to provide them with suitable habitat (e.g., stretches of shallow water unsuitable for hibernation and with limited cover along the stream edges). However, these sections are nonetheless important for management of nearby wetland systems as well as population corridors used by wood turtles. Corridors—defined as "strips of habitat that facilitate movements of organisms between local populations" (Lidicker and Koenig, 1996)—for wood turtles may include stretches of seemingly unsuitable stream habitat that provide connections among suitable stretches. We often observed wood turtles swimming upstream in less than 30 cm of water to deeper, more suitable stream stretches. In a region of New Hampshire already suffering from irreparable habitat fragmentation and isolation of critical ecosystem elements, all stretches of Streams A and B could provide a significant conduit for wood turtle dispersal. Landscape-level management plans for this species in New Hampshire and elsewhere must include both adequate terrestrial buffers and connecting aquatic corridors. Recognition of both the size of individual home ranges and the seasonal habitat shifts made by moving turtles is critical if we are to maintain a diversity of our native turtle fauna that includes *G. insculpta*.

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