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## SEASONAL MOVEMENTS AND HABITAT PREFERENCES FOR THE SPOTTED TURTLE AND EASTERN BOX TURTLE IN MASSACHUSETTS

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**Abstract:** Seasonal habitat use and population dynamics of a spotted turtle (*Clemmys guttata*) population and an eastern box turtle (*Terrapene c. carolina*) population in southeastern Massachusetts are presented in this paper. The two-year study, conducted between March 1998 and December 1999, was part of a mitigation plan proposed by the Massachusetts Highway Department (MassHighway) and approved by the Massachusetts Natural Heritage and Endangered Species Program (NHESP) to mitigate for 1.0 hectares of direct rare species habitat loss and 1.6 hectares of indirect habitat loss associated with a highway relocation project in Carver, Kingston, and Plymouth, Massachusetts. Sixty individual spotted turtles were captured in a 29-hectare study area consisting of upland and wetland habitat in Carver. Of these, 11 spotted turtles were radio tracked. Thirty-seven box turtles were also captured and 7 were radio tracked. Spotted turtles were observed in wetlands 96 percent of the time, and box turtles 15 percent of the time. During the spring and nesting season, spotted turtles were found exclusively in wetlands. Most activity was observed in an open emergent wetland and a forested vernal pool, with movement between the two habitat types via a stream channel and secondarily via overland travel through the forested wetland. Most turtles estivated in the emergent or forested wetland; only one turtle consistently estivated in forested upland. Hibernacula were found in the forested vernal pool (3) and the emergent wetland (3). The southern ramp of new Route 44 alignment will bisect the spotted turtle population. A proposed 1.8-meter by 1.8-meter box culvert that will convey the stream channel under one of the highway entrance ramps may provide a passageway connecting the emergent wetland to the forested vernal pool; its use will be determined during a future study. Box turtles were generally found in forested upland in the spring, in open upland during the nesting season and summer, with some summer migration to wetlands. Five hibernacula were found, all in forested upland. The new alignment should have less impact on the box turtle population, but will likely result in some loss of nesting habitat and some shifts in home range. Use of nearby replacement nesting habitat will be monitored during a future study. Home ranges averaged 1.43 hectares for spotted turtles and 3.26 hectares for box turtles. For both species, home ranges were larger for males than for females. The population density for spotted turtles was estimated to be 18.8 turtles per hectare, and for box turtles was estimated to be 3.0 turtles per hectare.

### Introduction

Over 20 years ago, the Massachusetts Highway Department (MassHighway) undertook a highway relocation project in southeastern Massachusetts to address safety and capacity concerns of Route 44 between Route 58 in Carver and Route 3 in Plymouth. The proposed project involved construction of 12 kilometers of a new four-lane, limited access highway, and resulted in 1.0 hectares of direct habitat loss and 1.6 hectares of indirect habitat loss for three state-listed turtle species. On December 31, 1997, the Massachusetts Department of Environmental Protection (DEP) issued a combined Wetland Variance Decision and Water Quality Certification for the Route 44 Relocation Project, which found that MassHighway had avoided and minimized impacts to rare species to the greatest extent practicable, and that adverse impacts to rare species would be mitigated by a two-part mitigation plan developed by MassHighway and approved by the Massachusetts Natural Heritage and Endangered Species Program (NHESP). The mitigation plan required MassHighway to purchase approximately 11.25 hectares of upland and wetland habitat, and to conduct a two-year study to determine the seasonal movements and habitat preferences for wood turtles (*Clemmys insculpta*), spotted turtles (*C. guttata*), and eastern box turtles (*Terrapene c. carolina*).

### Methods

#### *Study Area Definition*

The 29.2-hectare, mostly wooded study area is bounded on the west by Route 58, a two-lane roadway, on the north by an upland field, on the east by the Winnetuxet River, and on the south by commercial and residential

properties (see Figure 1, end of paper). The study area includes the Winnetuxet River and associated wetlands and uplands in the vicinity of the new Route 44 alignment. Wetlands mapping from the Notice of Intent, aerial photographs, and field-verification were used to determine 11 different cover types.

Eight of the cover types are wetlands and the remaining three are upland. In the forested wetland, the vegetation is primarily a red maple (*Acer rubrum*) forested wetland, with smaller areas of forested wetland dominated by red maple and white pine (*Pinus strobus*) in the canopy, and highbush blueberry (*Vaccinium corymbosum*), sweet pepperbush (*Clethra alnifolia*), and spicebush (*Lindera benzoin*) in the understory. Wooded upland areas are characterized primarily by white pine and oak (*Quercus* spp.). The western portion of the study area adjacent to Route 58 is an emergent wetland characterized by soft rush (*Juncus effusus*) common cattail (*Typha latifolia*), common reed (*Phragmites australis*), steeplebush (*Spiraea tomentosa*), and tussock sedge (*Carex stricta*). Other open areas include disturbed upland in the MassHighway maintenance depot, a clearcut area in the southern portion of the study area, and two upland fields, one in the northwest corner and one in the southeastern portion of the study area. Two stream channels fed by roadway runoff converge in the emergent marsh in the western portion of the study area. To the east, the stream flows through forested upland and wetland and forms the main tributary to the Winnetuxet River. Several small channels in the forested wetland flow into the vernal pool labeled Turtle Pond during the study; one channel flows from Turtle Pond into the main tributary to the Winnetuxet River. Kettle Pond is a vernal pool in forested upland north of the new alignment.

### *Turtle Capture and Characterization*

Turtle capture was initiated on March 24, 1998, during the first year of the study and on March 29, 1999, during the second year of the study. Turtles were caught by hand by visually searching the stream channels and vernal pools, and were trapped in hoop nets and minnow-style traps. Captured turtles were aged, sexed, measured, weighed, photographed, and notched for individual identification as described in Cagle (1939). A triangular metal file was used instead of the square file described by Cagle because the triangular file is less intrusive and produced equivalent notches. Age was determined by counting annuli on each right plastral plate, which is a reasonable estimate of age for many turtle species (Sexton 1959). Turtles were sexed based on eye color, jaw color, vent location, and plastral concavity.

### *Monitoring*

Ten spotted turtles and five box turtles were fitted with radio transmitters (AVM model SM 1-H; 165 MHz) between March and October 1998. Ten spotted and five box turtles were monitored in 1999, using the same transmitter model. Radio transmitters were glued to the right rear side of each turtle's carapace with a slow-setting epoxy (PC-7) as described in Belzer and Reese (1995). Turtles were released at their point of capture within 24 hours. Each turtle fitted with a radio transmitter was also numbered with a bright orange non-toxic paint pen on its carapace for easier visual observation. Spotted turtles were tracked three times per week in the spring and summer, every 48 hours during the nesting season, and once per month in the fall/winter season. Nine of the ten spotted turtles tracked in 1998 were also tracked in 1999, and three of the five box turtles monitored in 1998 were also tracked in 1999. The tenth spotted turtle was found dead in 1998. Eight turtles were analyzed in 1998; the ninth had fewer than 20 data points and was not included in home range analyses. The two 1998 tagged box turtles, both females, were not found in 1999. Each turtle was tracked to within one meter of its location, and notes were taken on the time, location, behavior, habitat, and, where applicable, the water depth and water temperature where the turtle was seen.

Seasonal habitat use was determined by counting the number of observations recorded in each cover type during each season. For the purpose of this study, seasons were classified as follows: spring (March 15 through May 21); nesting (May 22 through June 30); summer (July 1 through September 30); and fall/winter (October 1 through December 31).

Based on radio tracking data gathered over both field seasons, maps were generated for turtles that had at least 20 observations each year. Home ranges were determined by the minimum convex polygon method in *Animal Movement Analysis Arcview Extension* (Hooge and Eichenlaub 1997). Population estimates for spotted turtles and box turtles were derived using standard mark-recapture study techniques. The following formula was used to estimate population size:

$$N = C_1C_2/r$$

where  $N$  = population size

$C_1$  = number captured during first sample (first year)

$C_2$  = number captured during second sample (second year)

$r$  = number of recaptures

### *Macroinvertebrate sampling*

On April 30, 1999, a macroinvertebrate sampling was conducted at five sites in the study area: the north channel, south channel, and their confluence in the emergent wetland, Turtle Pond, and the main tributary to the Winnetuxet River approximately 150 meters east of the access path.

## Results and Discussion

### *Wood Turtles*

Two juvenile wood turtles were observed in the study area on three separate occasions in April 1990. Although wood turtles were searched for throughout the study site during the two-year study, both in upland and wetland habitats, none were found. Although there is some habitat in the study area that may support wood turtles, it is likely that the two juveniles observed in 1990 were transients, and did not have established home ranges in the study area.

### *Spotted Turtles*

Sixty individual spotted turtles were captured during the two-year study. Including 1998 recaptures, 81 spotted turtles were captured. Table 1 provides new capture frequencies by month, sex, and age. The majority of the captures (82 percent) occurred in open emergent wetland, and 12 percent were captured in a vernal pool in a forested wetland. Two turtles were captured in the main tributary to the Winnetuxet River (3 percent), one adult female was captured as she traveled through upland forest to the open emergent wetland and one turtle hatchling was captured in the MassHighway maintenance depot.

Table 1  
New Spotted Turtle Capture Frequencies

Month	Juveniles			Adults						Total		
	1998	1999	Total	Males			Females			1998	1999	Total
				1998	1999	Total	1998	1999	Total			
March	10	1	<b>11</b>	8	2	<b>10</b>	6	3	<b>9</b>	24 (60%)	6 (30%)	<b>30</b> <b>(50.0%)</b>
April	4	6	<b>10</b>	6	3	<b>9</b>	4	3	<b>7</b>	14 (35%)	12 (60%)	<b>26</b> <b>(43.3%)</b>
May	1	1	<b>2</b>	0	0	<b>0</b>	0	0	<b>0</b>	1 (2.5%)	1 (5%)	<b>2</b> <b>(3.3%)</b>
June	0	0	<b>0</b>	0	0	<b>0</b>	1	1	<b>2</b>	1 (2.5%)	1 (5%)	<b>2</b> <b>(3.3%)</b>
Total	15 (37.5%)	8 (40%)	<b>23</b> <b>(38%)</b>	14 (35%)	5 (25%)	<b>19</b> <b>(31.7%)</b>	11 (27.5%)	7 (35%)	<b>18</b> <b>(30%)</b>	40	20	<b>60</b>

In both years, most turtles were caught in March and April (93 percent). No new turtles were caught from July through December, indicating that spotted turtles are much more active and easily observed during the spring. In 1998, 38 turtles (95 percent) were captured for the first time by hand, and two (5 percent) were captured for the first time in traps. In 1999, 34 turtles (83 percent) were captured for the first time by hand, and seven (17 percent) were first captured in traps.

### Seasonal Habitat Use

In 1998, 144 observations were recorded in the spring, 104 in the nesting season, 114 in the summer, and seven in the fall/winter for a total of 369 observations. In 1999, 209 observations were recorded in the spring, 188 in the nesting season, 213 in the summer, and 115 in the fall/winter, for a total of 725 observations. Almost twice the number of observations were recorded in 1999 because ten turtles were analyzed versus eight in 1998, and because observations were continued three times per week through September in 1999, as opposed to one radio tracking in September 1998. During the two years of the study, the majority of the observations (77 percent) occurred in three cover types (Open Stream, Vernal Pool, and Open Wetland).

Overall, 96 percent of the spotted turtle observations occurred in wetlands. Four spotted turtles resided almost exclusively in the emergent wetland, and three turtles resided almost exclusively in Turtle Pond. Three males traveled between wetlands. As with most activity, travel between wetlands occurred primarily in the spring. The main tributary to the Winnetuxet River provided the most-used route between the emergent wetland and Turtle Pond and the forested wetland. Most overland travel was through forested wetland. The Forested Pine/Maple Stream and Scrub-Shrub Wetland cover types were not used. Both unused wetland cover types occur east of a 300-millimeter corrugated metal pipe (CMP) that conveys the main tributary to the Winnetuxet River under an old cart path approximately 50 meters northeast of Turtle Pond. No spotted turtles were observed east of this culvert. The pipe is approximately four meters long, and as water exits the pipe it creates a small waterfall into a one-meter deep scour pool. East of the culvert, the stream flows at a slightly higher velocity, there are more riffles, and the substrate is more stony and gravelly than the stream west of the culvert where spotted turtles were observed.

Table 2  
Spotted Turtle Habitat Use \*

Cover Type <sup>1</sup>	Seasonal Use (percent)												Yearly Use (percent)		
	Spring			Nesting			Summer			Fall/Winter			1998	1999	Avg.
	1998	1999	Avg.	1998	1999	Avg.	1998	1999	Avg.	1998	1999	Avg.			
<b>FO-PM-W</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>3</b>	<b>1.5</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0.5</b>
<b>FO-PM-S</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
FO-PM-U	0	0	0	0	5	2.5	2	12	7	0	4	2	1	5	3
<b>FO-RM-W</b>	<b>26</b>	<b>7</b>	<b>16.5</b>	<b>13</b>	<b>13</b>	<b>13</b>	<b>10</b>	<b>23</b>	<b>16.5</b>	<b>0</b>	<b>10</b>	<b>5</b>	<b>14</b>	<b>14</b>	<b>14</b>
<b>FO-RM-S</b>	<b>7</b>	<b>12</b>	<b>9.5</b>	<b>4</b>	<b>5</b>	<b>4.5</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>7</b>	<b>3.5</b>	<b>3</b>	<b>6</b>	<b>4.5</b>
FO-PO-U	0	0	0	0	0	0.0	0	4	2	0	0	0	0	1	0.5
<b>OPEN-W</b>	<b>7</b>	<b>4</b>	<b>5.5</b>	<b>17</b>	<b>34</b>	<b>25.5</b>	<b>24</b>	<b>34</b>	<b>29</b>	<b>11</b>	<b>16</b>	<b>13.5</b>	<b>15</b>	<b>22</b>	<b>18.5</b>
<b>OPEN-S</b>	<b>45</b>	<b>46</b>	<b>45.5</b>	<b>33</b>	<b>16</b>	<b>24.5</b>	<b>47</b>	<b>26</b>	<b>36.5</b>	<b>22</b>	<b>44</b>	<b>33</b>	<b>39</b>	<b>32</b>	<b>35.5</b>
OPEN-U	0	0	0	0	0	0	2	0	1	0	1	0.5	1	0	0.5
<b>SCSH-W</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
<b>VP</b>	<b>15</b>	<b>32</b>	<b>23.5</b>	<b>33</b>	<b>24</b>	<b>28.5</b>	<b>14</b>	<b>1</b>	<b>7.5</b>	<b>67</b>	<b>18</b>	<b>42.5</b>	<b>27</b>	<b>19</b>	<b>23</b>
Total (Percent)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

\* Percent total observations during each season

- <sup>1</sup> State-regulated wetland areas shown in bold  
 FO-PM-W: Forested Pine-Maple Wetland  
 FO-PM-S: Forested Pine-Maple Stream  
 FO-PO-U: Forested Pine-Oak Upland  
 FO-RM-W: Forested Red Maple Wetland  
 FO-RM-S: Forested Red Maple Stream  
 FO-PM-U: Forested Pine-Maple Upland  
 OPEN-S: Open Stream  
 OPEN-U: Open Upland  
 OPEN-S: Open Wetland  
 SCSH-W: Scrub-Shrub Wetland  
 VP: Vernal Pool

*Spring:* Spotted turtles used five wetland cover types in the spring, and no upland habitat. Based on radio tracking observations, the Open Stream cover type accounted for the highest number of observations during the two-year study (45.5 percent), consistent with the Ward et al. (1976) and Graham (1995).

*Nesting:* Again, during both years, all spotted turtles were recorded in wetlands. Almost 80 percent of the observations occurred in three cover types: Vernal Pool, Open Wetland, and Open Stream. No nests were found during the study, but observations every 48 hours during the nesting season indicate only one female left wetland areas. This individual was found dead on the shoulder of Route 58 (east side) eight days after capture. Five data points noted between her capture point near Kettle Pond and where she was found dead indicate a south-southwest movement through the emergent wetland towards the wetland on the west side of Route 58 (total distance approximately 265 meters).

*Summer:* Spotted turtles used uplands the most during the summer (10 percent of the time). Open Stream was the most intensively used habitat in 1998 (47 percent), followed by Open Wetland (24 percent). In 1999, Open Wetland was used most heavily (34 percent), and the Open Stream and Forested Red Maple Wetland cover types were used almost equally (26 and 25 percent, respectively). Most studies have shown that turtles migrate to upland areas to estivate in forms during the summer to escape the heat and conserve energy. Perillo (1995) found that spotted turtles left wetlands in the summer to estivate in upland habitat. In Massachusetts, Graham (1997) observed spotted turtles estivating primarily in upland fields, except for one male and one female estivating under a tussock sedge clump in a bog. However, Ward et al. (1976) observed estivation occurring in early successional paludal woods in Maryland. Turtles that resided in Turtle Pond migrated to nearby forested wetland areas during both summers, with rare observances in adjacent uplands. Turtles that resided in the emergent wetland remained in the wetland during both years, buried in the banks of the channel or in forms under clumps of tussock sedge or soft rush, and did not leave the wetland.

Gibbons (1986) stated that food availability is one factor influencing turtles' shift from aquatic habitats to uplands as water levels in wetlands fall. Macroinvertebrates collected from this sampling location included crayfish (Cambaridae), backswimmers (Notonectidae), fairy shrimp (*Eubranchipus* sp.), and scavenger beetles (Hydrophilidae). Caddis fly larva (Hydropsychidae) and one cluster of spotted salamander (*Ambystoma maculatum*) eggs were also found in the emergent wetland in the spring. Though the streams in the emergent wetland and the main tributary to the Winnetuxet River dried in most areas as the summer progressed, the western portion of the emergent wetland contained standing pools of water throughout the season. Possibly spotted turtles did not need to leave the emergent wetland in search of other food supplies.

*Fall/Winter:* Spotted turtles were recorded 97.5 percent of the time in wetlands. Six individual spotted turtle hibernacula were located. Three were in the emergent wetland and three were in Turtle Pond. Hibernacula for turtles located both years were found within 6 meters of the previous year's location. The two hibernacula that were located only in 1999 were also found in the same location as where turtles were captured in the spring, similar to results found by Graham (1995).

### *Population Dynamics*

The population of spotted turtles appears to be healthy, with a relatively equal proportion of males to females (19 males and 18 females), and a substantial number of juveniles (23). Turtles of all ages were captured, ranging from hatchlings to adults greater than 17 years old. Juveniles are often underrepresented in turtle population studies (Ernst 1976), possibly because they are more secretive than their adult counterparts, and also because of higher mortality rates in younger age classes. The high number of juveniles captured indicates substantial recruitment into the population. Males and females were almost equally represented, again indicating a healthy population.

*Home Range:* Home ranges were determined for the nine turtles that were observed on at least 20 occasions (5 females and 4 males). Home ranges for 1998 are shown on Figure 2 (end of paper), and home ranges for 1999 are shown on Figure 3 (end of paper). Ranges vary from 0.4 to 2.2 hectares for males and 0.03 to 1.3 hectares for females (Table 3).

Table 3  
Spotted Turtle Home Range Sizes

Turtle	Male Size (hectares)				Turtle	Female Size (hectares)			
	1998	1999	Avg.	2-year		1998	1999	Avg.	2-Year
S2	2.2	1.4	<b>1.8</b>	<b>2.3</b>	S1	1.3	0.2	<b>0.75</b>	<b>1.3</b>
S3	2.1	1.9	<b>2.0</b>	<b>2.5</b>	S4	0.2	0.4	<b>0.30</b>	<b>0.6</b>
S5	0.6	1.7	<b>1.15</b>	<b>1.7</b>	S6	1.3	1.0	<b>1.15</b>	<b>1.5</b>
S7	0.4	1.1	<b>0.75</b>	<b>1.3</b>	S8	0.03	0.4	<b>0.22</b>	<b>0.4</b>
					S10	N/A	0.9	<b>N/A</b>	<b>N/A</b>
					S101	N/A	0.8	<b>N/A</b>	<b>N/A</b>
<b>Avg.</b>	1.33	1.5	<b>1.43</b>	<b>1.95</b>	<b>Avg.</b>	0.71	0.74	<b>0.61</b>	<b>0.95</b>

Spotted turtles were fairly active, particularly in the spring and the early part of the nesting season, and the discrepancies between years may indicate individual points picked up one occasion during one year but not the next. For example, the home range of S2 was more than 25 percent smaller in 1999, but the majority of the use occurred within the same area in both years. During the 1998 nesting season, S2 was found once in the Forested Red Maple Wetland east of the MassHighway depot, and this observation was included within the home range analysis (no data points were deleted for any turtles). S1 was also found in this cover type, and though both turtles were more frequently found there during spring 1998 (and neither one was found there during the 1999 season), the one recorded foray made by S2 into this area greatly enlarged his home range.

The home ranges of turtles are similar to those found by Graham in 1995. Graham also found that females occupied a substantially smaller home range than males. Our study also showed that females' home ranges were, on average, smaller than males (0.66 hectares and 1.61 hectares, respectively).

Aquatic turtles, such as spotted turtles, are often found in well-defined populations (Gibbons 1968). This was confirmed for spotted turtles in the study area. Spotted turtles showed a great deal of overlap in their home ranges, both with other tagged spotted turtles as well as between-year for the same individuals. All turtles spent a portion of their time in the emergent wetland, and one female was never recorded outside the emergent wetland. Another female was observed most frequently in the emergent wetland, but was occasionally seen in the stream in forested wetland. Most turtles (six of eight) traveled back and forth between Turtle Pond and the emergent wetland, usually swimming or crawling in the main tributary to the Winnetuxet River or, less frequently, through the forested wetland.

Home range lengths and distances turtles moved from their hibernacula were determined for tracked turtles and are presented in Table 4. The data indicate much year-to-year and individual variability in the distance moved.

Table 4  
Spotted Turtle Home Range Lengths and Distance Moved from Hibernacula

Turtle	Sex	Home Range Length <sup>1</sup> (meters)			Distance Moved From Hibernacula <sup>2</sup> (m)			
		1998	1999	Mean	Maximum		Mean	
					1998	1999	1998	1999
S1	F	280	96	<b>188</b>	790	187	142	66
S2	M	272	272	<b>272</b>	741	772	185	141
S3	M	300	293	<b>297</b>	--	869	--	299
S4	F	102	142	<b>122</b>	--	--	--	---
S5	M	267	304	<b>285</b>	--	--	--	--
S6	F	284	278	<b>281</b>	--	--	--	--
S7	M	193	322	<b>258</b>	--	825	--	99
S8	F	32	105	<b>69</b>	70	--	23	--
S10	F	N/A	364	<b>182</b>	--	816	--	104
S101	F	N/A	288	<b>288</b>	--	--	--	--
Mean		216	246	<b>224</b>	533	694	117	142

<sup>1</sup> N/A indicates the turtle was not tracked, or less than 20 observations were recorded.

<sup>2</sup> Maximum distance from hibernaculum that a turtle was observed. Distance moved from hibernacula are provided for those turtles that were tracked to hibernacula in 1998 and/or 1999. The -- notation indicates that no hibernaculum was located.

The spotted turtle population was estimated to be 78 turtles within the two-year period. The population density is estimated to be 18.8 turtles per hectare in the study area, based on 3.2 hectares of suitable habitat. The estimate is based on an annual sampling period, and therefore may not account for immigration or emigration from the study area. The numbers may be artificially high because suitable habitat was defined as the polygon that encompassed all turtle observation instead of total suitable habitat types available to spotted turtles. The population estimate is higher compared to Graham's assessment of 6.7 spotted turtles per hectare in central Massachusetts. A study reported in Ernst et al. (1994) estimated spotted turtle density for a population in Pennsylvania to be between 39.5 and 79.1 turtles per hectare.

### *Box Turtles*

Thirty-seven individual box turtles were captured during the study. Including 1998 recaptures, a total of 49 box turtles were captured. During the two-year study period, 24 individual males (65 percent), 11 individual females (30 percent), and two individual juveniles (5 percent) were captured. In 1998, 18 males were captured (75 percent), five females were captures, and one juvenile was captured (4 percent). In 1999, 16 males were captured (64 percent), eight females were captured (32 percent), and one juvenile (4 percent) was captured. During the 1999 field season, 26 box turtles were captured and marked; 12 of these were recaptures from 1998.

April represented the highest capture rate for both years (71 percent in 1998 and 54 percent in 1999). Four box turtles were captured in March 1998, while none were captured in March 1999. It is likely that turtles emerged earlier than usual from hibernation in 1998 because of unusually warm temperatures. Evidence of recent emergence from hibernation at the end of March and first week in April was noted as soil caked in the interstices of the scutes and small, fresh cuts on some of the turtles' feet.



Table 5  
Box Turtle Capture Frequencies

Month	Juveniles			Adults						Total (percent)		
	1998	1999	Total	1998 Males	1999	Total	1998 Females	1999	Total	1998	1999	Total
March	0	0	0	3	0	3	1	0	1	4	0	4 (11%)
April	1	0	1	14	5	19	2	2	4	17	7	24 (65%)
May	0	1	1	0	1	1	1	1	2	1	3	4 (11%)
June	0	0	0	0	0	0	0	2	2	0	2	2 (5%)
August	0	0	0	1	0	1	0	0	0	1	0	1 (3%)
October	0	0	0	0	0	0	1	1	2	1	1	2 (5%)
Total	1	1	2 (5%)	18	6	24 (65%)	5	6	11 (30%)	24	13	37

Seven individual turtles were fitted with radio transmitters during the study (five females; two males). Three box turtles (one female and two males) were tracked both years.

### Seasonal Habitat Use

In 1998, 108 observations were recorded in the spring, 77 in the nesting season, 86 in the summer, and 9 in the fall/winter for a total of 280 observations. In 1999, 58 observations were recorded in the spring, 88 in the nesting season, 85 in the summer, and 50 in the fall/winter, for a total of 281 observations. Box turtles used seven of the eleven cover types (Table 6).

Table 6  
Box Turtle Habitat Use \*

Cover Type <sup>1</sup>	Seasonal Use (percent)												Yearly Use (percent)		
	Spring			Nesting			Summer			Fall/Winter			1998	1999	Avg.
	1998	1999	Avg.	1998	1999	Avg.	1998	1999	Avg.	1998	1999	Avg.			
<b>FO-PM-W</b>	<b>12</b>	<b>2</b>	<b>7</b>	<b>3</b>	<b>0</b>	<b>1.5</b>	<b>2</b>	<b>1</b>	<b>1.5</b>	<b>11</b>	<b>0</b>	<b>5.5</b>	<b>7</b>	<b>1</b>	<b>4</b>
<b>FO-PM-S</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
FO-PO-U	20	22	21	21	17	19	25	17	21	0	30	15	18	20	19
<b>FO-RM-W</b>	<b>11</b>	<b>4</b>	<b>7.5</b>	<b>9</b>	<b>1</b>	<b>5</b>	<b>15</b>	<b>13</b>	<b>14</b>	<b>0</b>	<b>4</b>	<b>2</b>	<b>10</b>	<b>6</b>	<b>8</b>
<b>FO-RM-S</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0.5</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
FO-PM-U	22	57	39.5	11	2	6.5	8	7	7.5	78	18	48	25	18	21.5
<b>OPEN-W</b>	<b>0</b>	<b>2</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0.5</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0.5</b>
<b>OPEN-S</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
OPEN-U	35	13	24	55	69	62	45	60	52.5	11	48	29.5	39	51	45
<b>SCSH-W</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>10</b>	<b>5</b>	<b>3</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>4</b>	<b>2.5</b>
<b>VP</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>0.5</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

\* Percent total observations during each season

- <sup>1</sup> Wetland areas shown in bold  
FO-PM-W: Forested Pine-Maple Wetland  
FO-PM-S: Forested Pine-Maple Stream  
FO-PO-U: Forested Pine-Oak Upland  
FO-RM-W: Forested Red Maple Wetland  
FO-RM-S: Forested Red Maple Stream  
FO-PM-U: Forested Pine-Maple Upland  
OPEN-S: Open Stream  
OPEN-U: Open Upland  
OPEN-S: Open Wetland  
SCSH-W: Scrub-Shrub Wetland  
VP: Vernal Pool

Fifteen percent of the observations occurred in wetlands. In general, box turtles were found in forested upland in the spring, in open upland during the nesting season and first part of the summer, and moved back into forested areas during the latter half of the summer season; this is consistent with trends noted in the literature. B5 and B2 (both females) were exceptions. One female was never recorded in the Open Upland cover type, and may be representative of a more typical habitat choice of floodplain forests as described by Stickel (1959), though Ernst et al. (1994) include pastures and meadows as secondary habitat. In both 1998 and 1999, another female was found almost exclusively in Open Upland, except for a few observations in the summer, where she was found in Forested Pine-Maple Upland in 1998, and in Forested Pine-Oak Upland in 1999.

As the spring progressed, box turtles were more frequently found in Open Upland in both years. During the nesting season, habitat use shifted to mostly Open Upland, except for one female that was found mostly in forested wetland. Three out of five turtles were recorded north of the main tributary to the Winnetuxet River, but all turtles were most often found south of the Winnetuxet River (and south of the new alignment).

*Spring:* Box turtles were recorded in forested wetlands 14.5 percent of the time during the two-year study. Most studies indicate box turtles spend at least a portion of the spring in woodlands (Stickel 1950, Ernst et al. 1994).

*Nesting:* During the nesting season, seven cover types were used. The majority of observations (62 percent) occurred in Open Upland. This is consistent with the literature, which indicates that females search for sunny, well-drained sites to lay eggs. Twelve and one-half percent of the box turtle observations during the nesting season occurred in wetlands. Use of wetlands was predominantly in the Scrub-Shrub and Forested Red Maple Wetland cover type. Open Upland was the most intensively used cover type during the nesting season. Three (depredated) nests were found in the MassHighway maintenance depot (Open Upland) in areas of sandy soils and sparse vegetation.

*Summer:* During the summer, Open Upland was again the most favored cover type. Other studies (Ernst et al. 1994, Stickel 1950) have found that box turtles estivate in woodlands during the summer to avoid the high heat. Woodlands also offer higher humidity than open areas, which may benefit box turtles by allowing them to conserve water more efficiently. The most time spent in wetlands occurred during the summer, with 19 percent of the observations recorded in wetlands (22 percent in 1998 and 16 percent in 1999).

In 1998, the high frequency of Open Upland use is attributed primarily to two animals (one male and one female). The male spent a substantial portion of the season at the field/forest edge, with occasional forays into the meadow itself. The female spent almost the entire season in the clearcut, but there are many slash piles and downed trees in the clearcut that she was found under, and which may have afforded higher cover and humidity retention than is typically associated with open habitats.

*Fall/Winter:* Consistent with the literature, hibernacula were found for five individuals in forested portions of the study area. All were in forested upland habitat (one on an ecotone between Forested Pine-Maple Upland and Forested Red Maple Wetland). One male was tracked to his hibernacula both years, and the hibernacula were located approximately three meters apart from each other. The hibernacula for two turtles were located at the edge of their home ranges, while hibernacula for the remaining three were more centrally located.

### *Population Dynamics*

The study area supports a substantial number of box turtles. Thirty-seven individual box turtles were captured, but it is not known whether they are all residents, or if all or a portion of their home range is within the study area, or how many individuals may be transients. Based on the age distribution and sex ratios, it is likely that the box turtle population is declining.

In contrast to the relatively large number of juveniles in the spotted turtle population, the box turtle population was found to contain only two juveniles. Although it is possible that juveniles were more difficult to find than their adult counterparts, the low percentage of captures (four percent) indicates low recruitment into the population. The heavily skewed adult to juvenile ratio may be influenced by difficulty in finding juveniles because they are smaller, are less active, and are subject to higher predation. The sex ratio and age classes captured are typical of declining populations, where numbers of males heavily outweigh the numbers of

females, and few juveniles are seen. Based on individual captures, the male to female ratio in the population is approximately 2.2:1, and the ratio of adults to juveniles is 18.5:1.

*Home Range:* Home ranges for 1998 are shown on Figure 4 (end of paper), and home ranges for 1999 are shown on Figure 5 (end of paper). Home ranges vary from 1.2 to 4.3 hectares for females and 2.4 to 7.5 hectares for males (Table 7). Between-year comparisons are available for two males and one female. The home ranges for males varied only 0.1 hectare between years for both males and varied substantially more for the one female (1.8 to 3.4 hectares). The home range of one male overlapped almost exactly between the two years. Average home range sizes were within the range of sizes reported by Schwartz and Schwartz (1991) for three-toed box turtles (*Terrapene c. triunguis*) in Missouri (between 2.2 and 10.6 hectares). One male was tracked to his hibernacula both years, and the distances traveled from hibernacula differed by only eight meters between 1998 and 1999 (Table 8).

Table 7  
Box Turtle Home Range Sizes

Turtle	Male Size (hectares)			Turtle	Female Size (hectares)		
	1998	1999	Avg.		1998	1999	Avg.
B1	7.3	7.5	7.4	B2	3.2	--	3.2
B3	2.5	2.4	2.45	B4	4.3	--	4.3
				B5	1.8	3.4	2.6
				B6	--	1.2	1.2
				B7	--	4.7	1.7
Avg.	4.90	4.95	4.93	Avg.	3.10	3.10	2.6

Table 8  
Box Turtle Home Range Lengths and Distance Moved from Hibernacula

Turtle	Sex	Home Range Length <sup>1</sup> (m)			Distance Moved From Hibernacula <sup>2</sup> (m)			
		1998	1999	Mean	Maximum		Mean	
					1998	1999	1998	1999
B1	M	402	442	422	937	--	475	--
B2	F	267	N/A	134	700	--	451	--
B3	M	295	268	282	850	858	503	504
B4	F	419	N/A	419	--	--	--	--
B5	F	250	291	271	--	638	--	291
B6	F	N/A	204	204	--	--	--	--
B7	F	N/A	394	394	--	773	--	404
Mean		327	320	304	829	756	476	399

<sup>1</sup> N/A indicates the turtle was not tracked, or less than 20 observations were recorded.

<sup>2</sup> Maximum distance from hibernaculum that a turtle was observed. Distance moved from hibernacula are provided for those turtles that were tracked to hibernacula in 1998 and/or 1999. The -- notation indicates that the turtle was not tracked to a hibernaculum.

Most studies indicate that box turtles are not territorial and are not aggressive to other members of their species [Stickel 1950, Ernst et al. 1994 (but see Boice 1970)]. One male was observed on two occasions fighting with another male box turtle (on May 5, 1998, and July 23, 1998). Since this animal's home range overlapped with three other turtles, it is unlikely that he was defending a territory. Ernst (1994) speculated that the aggressive behavior occasionally observed between two males may be mistaken courtship behavior.

*Population Estimate:* The box turtle population size was estimated to be 50 turtles. Assuming a 16.6-hectare area of suitable habitat, the box turtle population density approximates 3.0 turtles per hectare. Suitable

habitat was defined as the polygon encompassing all turtles' home ranges. Studies conducted in the 1940s in Maryland indicate densities between 8.9 to 12.4 turtles per hectare (Ernst et al. 1994). Subsequent samplings of these same populations indicate a decline in all of them, both in density and proportion of females (*ibid.*).

### Conclusions

Federal and state regulations require development projects to avoid impacts to rare species and their habitats. Massachusetts is the third most densely developed state in the United States (Kittredge 1996), and impacts to rare species habitat cannot always be avoided. In these cases, public and private developers must work with state and federal agencies to mitigate unavoidable impacts.

Placement of the western portion of the new alignment was constrained by the existing Route 44 alignment. The emergent wetland adjacent to Route 58 was of particular interest to NHESP for this study because two juvenile wood turtles were observed here on three separate occasions in April 1990. No wood turtles were found in the entire study area during the two-year study, and it is likely that the two juveniles were transients without established home ranges. This wetland proved to be the most productive area for spotted turtles. Although the new highway itself is outside the home ranges of spotted turtles tracked in this study, the southern entrance ramp will bisect the spotted turtle population, isolating the emergent wetland from Turtle Pond. Design features on the entrance ramps will prevent turtles from climbing onto the roadway. Because the study showed the stream channel was the primary means of travel between the two habitat types, MassHighway proposed a 1.8-meter by 1.8-meter box culvert to convey the stream channel under the southern entrance ramp instead of the 600-millimeter reinforced concrete pipe included in the final highway design. Spotted turtle use of the box culvert will be assessed during a future study. A long-term study would also provide data on population trends.

The new alignment is not likely to have as great an effect on the box turtle population, based on the tracked turtles home ranges. One turtles' home range will be bisected by the southern entrance ramp, as well as altered by the new alignment. Most use of all turtles occurred south of the new alignment in forested upland, open upland, forested wetland, and scrub-shrub wetland. There may be some shifts in box turtles home ranges, since some use was observed north of the proposed alignment. Approximately 100 meters of the Winnetuxet River and adjacent floodplain will be bridged by the new alignment, and it is possible that turtles will continue to pass under the alignment in the area of the new bridge. Changes in box turtle home ranges will be determined during a future study. The forest north of the new alignment contained less woody debris and deadfall than what the box turtles were frequently found under south of the alignment. Open uplands used by box turtles consisted of disturbed, sparsely vegetated areas, particularly the MassHighway maintenance depot. Only one turtle used an open meadow north of the new alignment (during the summer); the meadow was probably not used for nesting because the soil contained dense root materials difficult for nesting.

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Christopher Ross, Environmental Engineer, Massachusetts Department of Environmental Protection Wetlands and Waterways Division. Mr. Ross has over 14 years of experience in regulating, by permit, projects within the jurisdiction of the Wetlands Protection Act with an emphasis on Highway projects. As the lead review engineer he coordinated all aspects of the wetland permitting with the State, Federal and local environmental agencies. Mr. Ross holds a Bachelors Degree in Civil Engineering Technology from Northeastern University.

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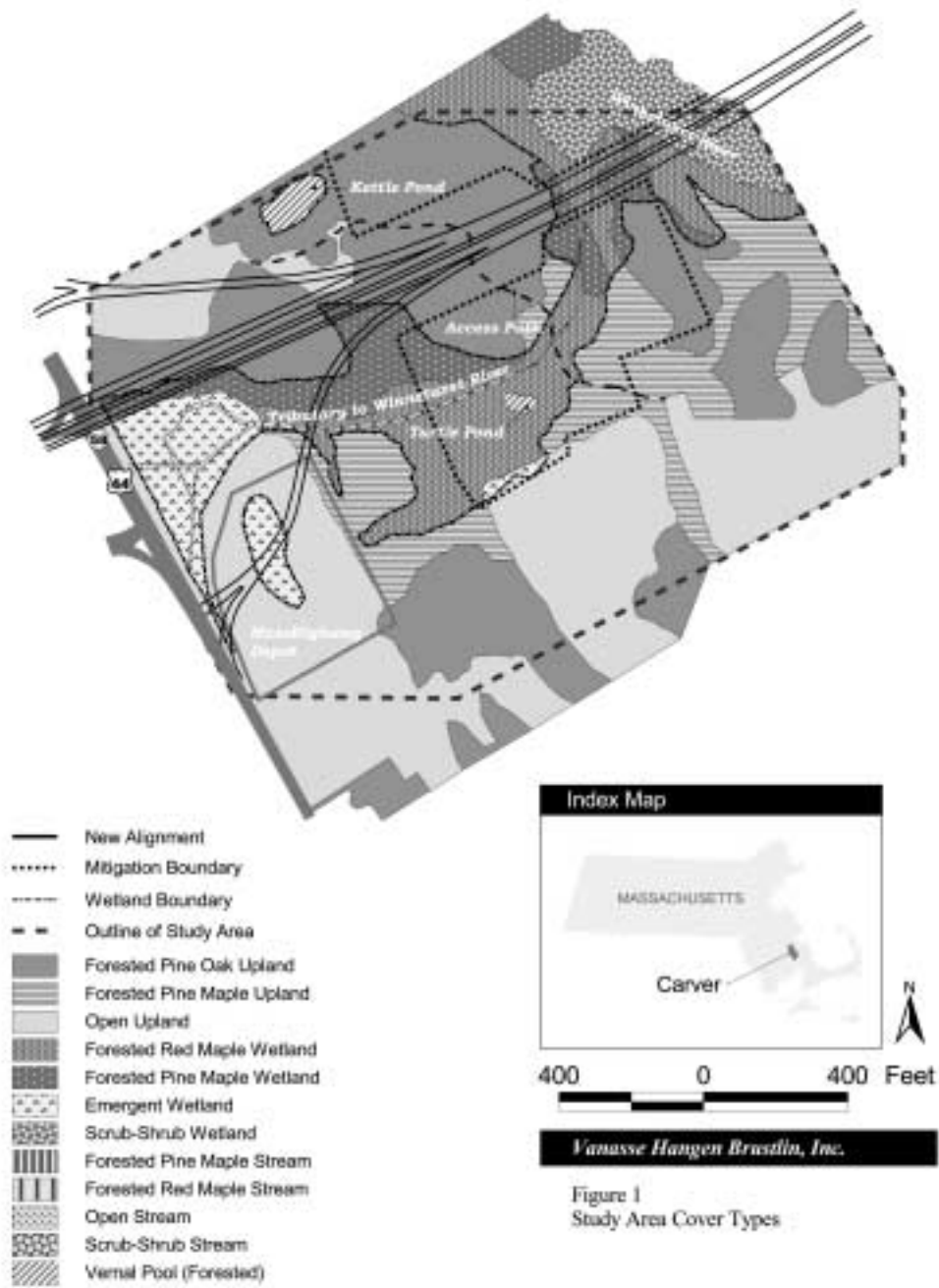


Fig. 1. Study Area Cover Types

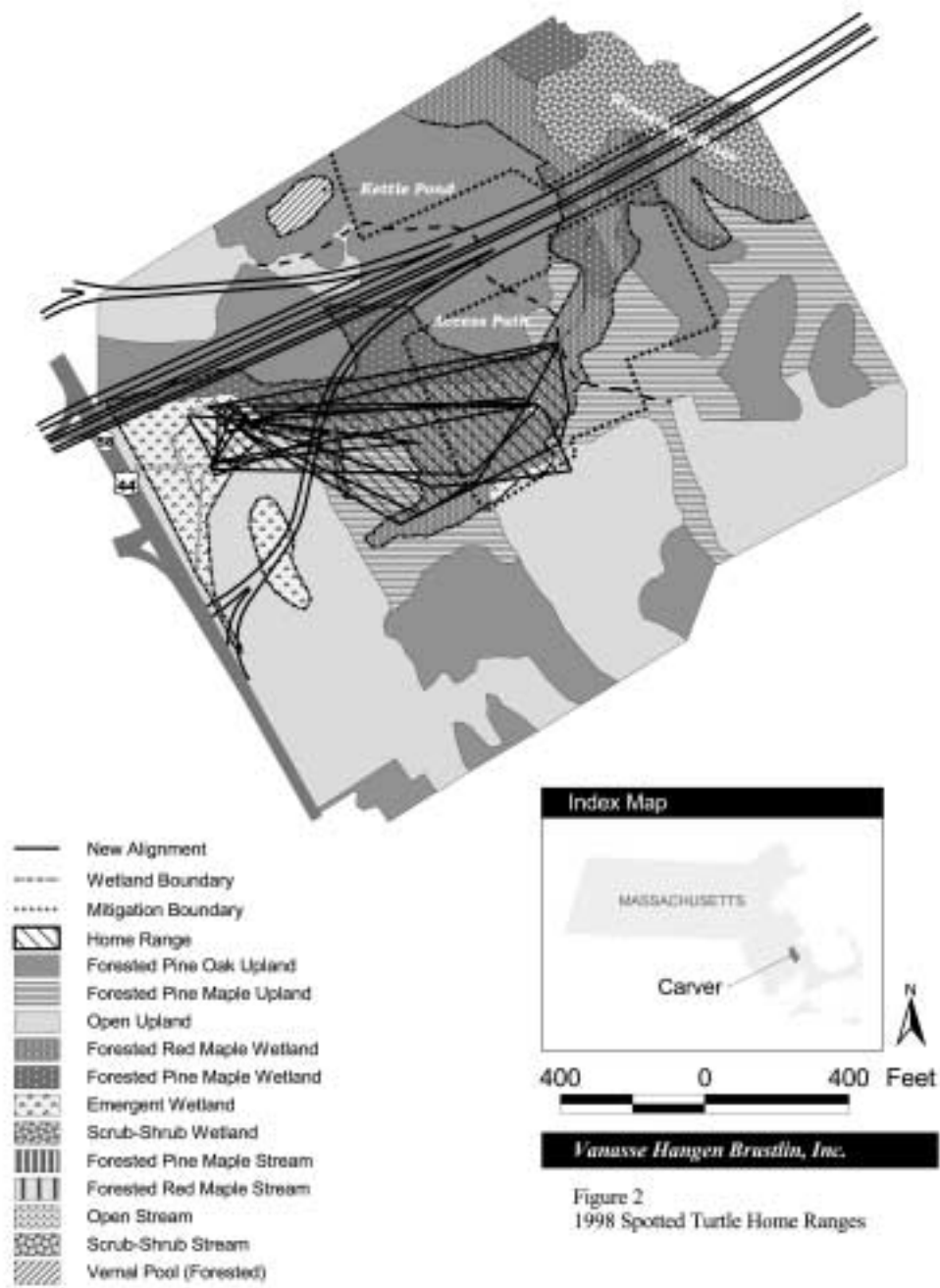


Fig. 2. 1998 Spotted Turtle Home Ranges

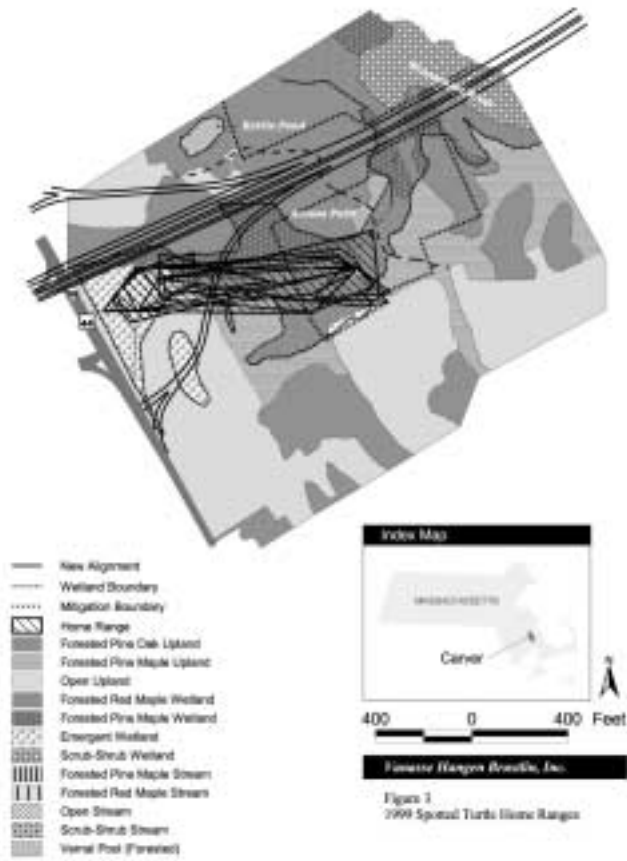


Fig. 3. 1999 Spotted Turtle Home Ranges



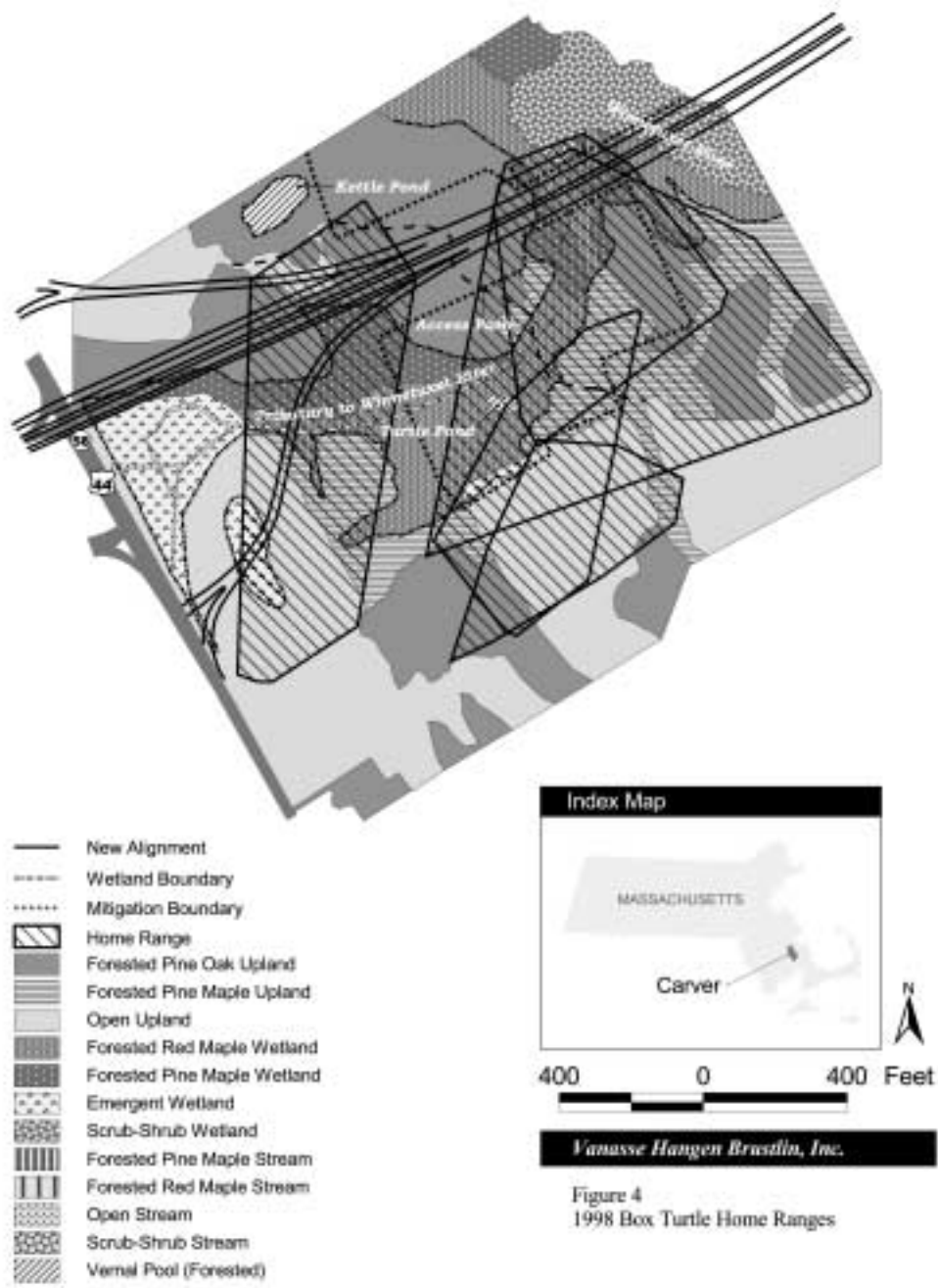


Fig. 4. 1998 Box Turtle Home Ranges

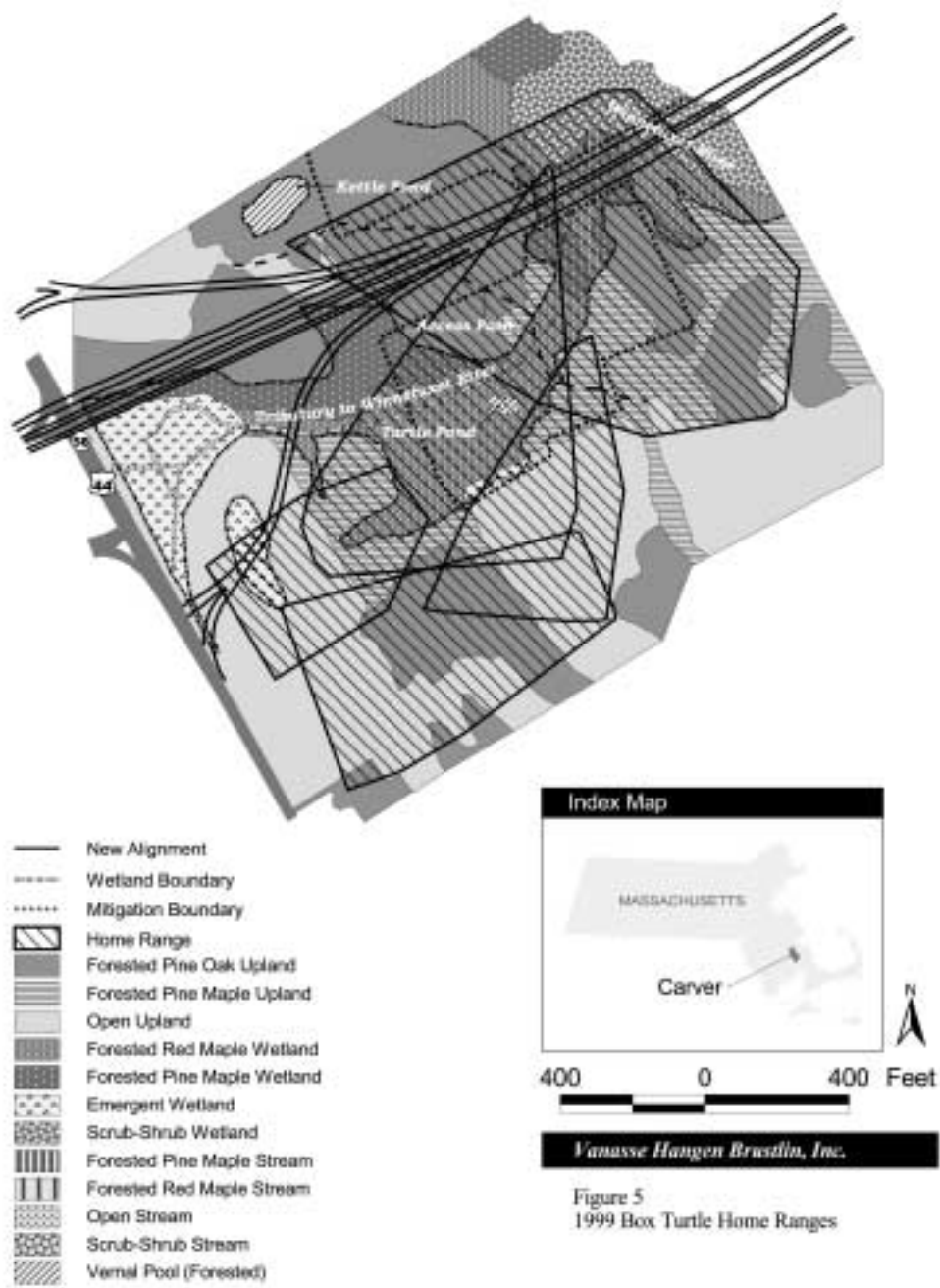


Fig. 5. 1999 Box Turtle Home Ranges