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Home Range, Movements, And Habitat Use Of Blanding's Turtle (Emydoidea blandingil) in St. Lawrence County, New York.

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HOME RANGE, MOVEMENTS, AND HABITAT USE OF BLANDING'S TURTLE
(*EMYDOIDEA BLANDINGII*) IN ST. LAWRENCE COUNTY, NEW YORK

by

Timothy J. Crockett

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CONTENTS

ABSTRACT

Home Ranges and Movements of Blanding's Turtle (*Emydoidea blandingii*) in St. Lawrence County, New York.

I studied the movements, activity centers, and home ranges of Blanding's turtles (*Emydoidea blandingii*) at three sites in St. Lawrence County, New York where it is currently listed as State Threatened. I monitored 24 adult Blanding's turtles (seven males and 17 females) using radiotelemetry from May 2003 – August 2004 to provide information on spatial requirements and movements in previously undocumented populations at the easternmost limit of this species' contiguous range, Movement and home range analyses were performed on 16 telemetered adult Blanding's turtles (4 males and 12 females) with a minimum of 20 locations and assignment of a radio transmitter from at least 10 June through 15 October in either 2003 or 2004, which covered the majority of the active season. There was no significant difference between male and female home range sizes within and between the study sites, which differed in available wetland area. Additionally, there was no significant difference among the home range sizes of females at each study site. Based on the Minimum Convex Polygon (MCP) home range estimate, the mean home range area for all telemetered females was 12.26 (1.13 – 44.14) ha and 7.54 ($\pm$ 2.63) ha for telemetered males ($n = 4$). Home range size differed significantly between female and males. The number of activity centers differed among the females ($n = 12$) ranging from one to five. Males ($n = 4$) had a greater number of activity centers than females, ranging from two to four. In this study, daily movements of males ($\overline{x} = 46.03 \pm 5.12$ m) were significantly longer and more frequent

than females ($\overline{x}$ = 20.77 ±7.18 m). Four of females that were radio-tagged in 2003 and followed through 2004 showed nest site fidelity across both years. These females traveled up to 1365 m round-trip to nesting areas and back to their home wetlands in consecutive years. A management and conservation concern identified in this study that could have a negative impact on the Blanding's turtle populations in northern New York is the location of nesting areas. Telemetry data revealed that gravid females utilize areas up to 1.5 km away from resident wetlands for nesting. My study suggests that areas in the vicinity of occupied wetlands that are suitable for nesting are very important to the longevity of these populations. Further studies on the distribution, population dynamics, habitat use and requirements, and nesting ecology of Blanding's turtle populations in northern New York should be conducted to assist with the conservation of this species in the eastern periphery of its contiguous Great Lakes range.

ABSTRACT

Habitat Use by Blanding's Turtle (*Emydoidea blandingii*) in St. Lawrence County, New York

The St. Lawrence River Valley presents an opportunity to examine the habitat use of the Blanding's turtle (*Emydoidea blandingii*), in a relatively undisturbed landscape that is experiencing limited development pressure. This species is currently listed as Threatened in New York State, and its persistence is directly linked to availability of suitable habitat consisting of a mosaic of upland and wetland habitat types. Based on the need to more precisely define the habitat requirements of this species to facilitate the development of management recommendations, I conducted a radiotelemetry study from May 2003 through October 2004 on the habitat preference of Blanding's turtles. Radiotelemetry observations for 23 captured adult (>17 years old) Blanding's turtles (7 males and 16 females) from three different sites showed that use of wetland and upland habitat types differed both spatially and between sexes. Blanding's turtles were most often associated with willow- (*Salix* spp) dominated shrub swamps. However, wetland areas appear to become less preferred, as compared to upland habitats, as the spatial scale increased. This suggests that both wetlands and uplands associated with travel corridors and nesting areas must be considered in conservation management plans. In addition, average water depth and measured distances from telemetered turtles to the nearest basking structure and nearest woody vegetation were similar among the three study areas. This indicates that these microhabitat variables may help characterize Blanding's turtles habitat, and are not site-specific. Regional-specific habitat cover types which serve as indicators of

where Blanding's turtles may be found should be identified (e.g. willow- or buttonbush-(*Cephalanthus occidentalis*) dominated shrub swamp or emergent marshes), and search efforts should then focus on areas within those habitats that possess water depths ranging from 16-182 cm and average sediment depths between 6-21 cm. In northern New York, the region-specific habitat type appears to be defined by shrub swamps influenced by beaver activity that are dominated by willow interspersed with sedges, with permanent deep (30- 180 cm) open pools connected by shallow (16 – 40 cm) channels with abundant root structure at the base of the shrubs and a tree or shrub fringe. Once region-specific suitable habitats have been defined, management and conservation efforts should focus on identifying occupied wetlands and their upland counterparts, and then work toward establishing agreements with landowners and municipalities at various levels to protect these areas from habitat loss or alteration.

ACKNOWLEDGMENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

GENERAL INTRODUCTION

The Blanding's turtle (*Emydoidea blandingii*) is a freshwater turtle from the family Emydidae, which is distinguished by its highly-domed carapace, typically 18-20 cm in length, and bright yellow chin (Ernst *et al.* 1994). The primary range of this species is centered around the Great Lakes, with a relatively uninterrupted distribution extending from southwestern Quebec and southern Ontario, south and west to central Nebraska, Wisconsin, Minnesota, Illinois, Indiana, Michigan, Iowa, Missouri, South Dakota, and Iowa (Ernst *et al.* 1994), and east to northern New York (Johnson and Wills 1997, Johnson and Crockett 2006). Disjunct populations of Blanding's turtles occur at the eastern periphery of its range in New York, Maine, Massachusetts, New Hampshire, Pennsylvania (Ernst *et al.* 1994), and Nova Scotia (Herman *et al.* 1995).

In New York State, new populations of Blanding's turtles recently have been identified; however, this species is believed to have been declining for many decades (New York Natural Heritage Program 2008), due to habitat loss from residential development, habitat fragmentation, predation, disease, winter-kill, collection, increased road mortality, delayed sexual maturation, and compromised wetland (Gibbs *et al.* 2007). Blanding's turtles are late to mature, reaching sexual maturity between 13 and 20 years of age, thus limiting their reproductive potential (Congdon *et al.* 1983), which creates an additional difficulty for conserving this species.

Blanding's turtles have been identified in four regions in New York State: Dutchess County in the southern part of the state, Saratoga County in the east, St. Lawrence and Jefferson Counties in the north, and Niagara and Erie Counties in the west (New York State Natural Heritage Program 2008). Due to its limited distribution and

1

low populations, the Blanding's turtle is currently listed as a Threatened Species in New York State, and is a candidate for Federal listing.

Blanding's turtle habitat use varies throughout the year (Blanding's Turtle Recovery Team 2002) and includes use of both wetland and upland habitats (Ernst *et al.* 1994, Congdon and Gibbons 1996, Piepgras and Lang 2000), because females travel long distances overland to nest, while males use uplands throughout the active season (Congdon *et al.* 1983, Pappas and Brecke 1992, Piepgras and Lang 2000). In addition, Blanding's turtles appear to have specific wetland habitat requirements, and make use of vernal pools and wetlands of varying sizes and water depths over broad areas for feeding, reproductive activities, thermoregulation, and basking throughout the active season (Piepgras and Lang 2000). Further, the availability of wetland and nesting habitats may influence Blanding's turtle movements (Piepgras and Lang 2000). Several studies have described Blanding's turtles as making more frequent and sometimes longer-distance movements when wetlands are relatively small, or subdivided into a series of small wetlands divided by roads or upland habitats (Rowe and Moll 1991, Piepgras and Lang 2000). In areas where available wetland habitats are relatively large and unfragmented, Blanding's turtles were less likely to move between adjacent wetlands (Sajwaj *et al.* 1998, Joyal *et al.* 2000). Thus, understanding the temporal and spatial movements of Blanding's turtles is critical for conserving important habitats and the resources contained within them (Gibbons *et al.* 1990, Piepgras and Lang 2000). Based on the tendency of this species to make long-distance movements and utilize a variety of habitats throughout the year, monitoring movements provides a meaningful way to identify the spatial requirements and important habitats used by Blanding's' turtles.

There are several comprehensive studies on the ecology of Blanding's turtle (Gibbons 1968, Graham and Doyle 1979, Congdon *et al.* 1983, Kofron and Schreiber 1985, Ross and Anderson 1990, Rowe and Moll 1991). However, until recently, relatively few studies have concentrated on the spatial ecology and critical habitats necessary for this species (Ross and Anderson 1990, Pappas and Brecke 1992, Piepgras and Lang 2000), and none have occurred in St. Lawrence County, New York.

In general, Blanding's turtles have been described as using productive, eutrophic inland and deep freshwater marshes (Ernst *et al.* 1994), shrub swamps with alder (*Alnus*), willow (*Salix*), cattail (*Typha*), and sedges (*Carex*), and emergent wetlands with shallow water composed of reeds, grasses, and cattail (Piepgras and Lang 2000) with a soft but firm organic bottom and abundant aquatic vegetation (Kofron and Schreiber 1985, Ernst *et al.* 1994). In southern New York, Blanding's turtles have been documented to use areas with: (1) both shallow (30 cm) and deep (120 cm) pools connected by channels, (2) open or absent tree canopy, (3) tree fringe, (4) a dense cover of shrubs, forbs, and graminoids dispersed as hummocks and tussocks throughout the wetland, and (5) coarse and fine organic debris (Kiviat 1997). However, there has been little information on the specific habitat requirements of Blanding's turtles in St. Lawrence County, which lies along the eastern edge of this species' contiguous range and the northern-most portion of its range in New York State.

In order to provide additional information on the spatial ecology of Blanding's turtles including home range and movements for undocumented populations in St. Lawrence County, New York, I examined seasonal and daily movement patterns to assess the habitat use and spatial requirements of this species. The biological requirements for

3

microhabitats within wetlands should be reflected by home range size (Carter *et al.* 1999), which is influenced by turtle movements. The analysis of movements and home ranges allowed me to examine the coarse- and fine-scale habitat selection of Blanding's turtles and determine which structural microhabitat variables are important indicators of suitable habitat in northern New York. The observations of movements and spatial requirements described in this study provide additional information that will help to identify how Blanding's turtles use available habitats, and allow comparison to other areas within New York State to identify suitable habitat regionally and define areas that require protection to ensure the persistence of this long-lived species.

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CHAPTER I: HOME RANGES AND MOVEMENTS OF BLANDING'S TURTLE (*EMYDOIDEA BLANDINGII*) IN NORTHERN NEW YORK.

INTRODUCTION

Among the principal factors responsible for the accelerating decline of the world's biodiversity are loss, degradation, and fragmentation of habitats, including wetlands (Klemmens 2000). Wetlands in the continental U.S. are being destroyed rapidly, and more than half of the original wetlands have been lost (Wilen and Frayer 1990, Gibbs 1993). Turtle populations, many of which are dependent upon wetlands, have declined at an alarming rate in North America due to habitat destruction and over collection for the pet trade and foreign food markets (Ernst *et al.* 1994). One wetland-dependent turtle that has declined throughout much of its range is the Blanding's turtle. Although life history traits and habitat requirements for the Blanding's turtle (*Emydoidea blandingii*) have only recently been studied, anthropogenic changes to wetlands or removal of individual turtles are believed to be important factors in the decline of many populations (Ross and Anderson 1990). These factors may have lead Blanding's turtles being currently listed as a Threatened Species in New York State and are a candidate for federal listing. This species occurs in four disjunct regions in New York State: Dutchess County in the southeastern portion, one population in Saratoga County in the eastern portion, Erie and Niagara Counties in the west, and St. Lawrence County in northern New York (Kiviat *et al.* 2000, New York Natural Heritage Program 2008). Northern populations of this large, semi-aquatic turtle appear to be near the eastern limits of its primary contiguous range (Petokas and Alexander 1981, Johnson and Wills 1997). Within the past two decades, a number of comprehensive studies have been made on the

ecology of this turtle (Gibbons 1968, Graham and Doyle 1979, Congdon *et al.* 1983, Kofron and Schreiber 1985, Ross and Anderson 1990, Rowe and Moll 1991), although until recently, relatively few have concentrated on the spatial ecology and critical habitats necessary for this species (Ross and Anderson 1990, Pappas and Brecke 1992, Piepgras and Lang 2000). Understanding the temporal and spatial movements of turtles is critical for conserving important habitats and the resources contained within them (Gibbons *et al.* 1990, Piepgras and Lang 2000).

Blanding's turtles make use of both wetland and upland habitats (Ernst *et al.* 1994, Congdon and Gibbons 1996, Piepgras and Lang 2000) where females travel long distances overland to nest and males make use of uplands throughout the active season (Congdon *et al.* 1983, Pappas and Brecke 1992, Piepgras and Lang 2000). Studies in Illinois (Rowe and Moll 1991), Maine (Joyal 1996) and Nova Scotia (Herman *et al.* 1994), provide examples where Blanding's turtles use vernal pools and wetlands of varying sizes and water volumes over broad areas for feeding, reproductive activities, thermoregulation, and basking (Piepgras and Lang 2000). This study was conducted to examine seasonal and daily movement patterns and spatial requirements of Blanding's turtles in northern New York to provide baseline information to facilitate development of conservation strategies.

Study Area

I selected three study sites in St. Lawrence County, New York known or suspected to contain Blanding's turtles. Precise location descriptions are not provided due to the threatened status of this species in New York State. For the purpose of distinguishing sites, they are named Site 1, Site 2, and Site 3.

All three study sites are situated in the St. Lawrence Plain ecozone (Will *et al.* 1982). The St. Lawrence Plain ecozone is comprised of flat and rolling plains ranging in elevation from 76 to 122 m and averaging 91 m. The bedrock consists of Trenton limestone and Potsdam sandstone. The soils are of medium productivity and belong to the Granville-Swanton-Livingston-Grenville series. Annual snowfall is 152 to 254 cm, and the growing season is 150 to 165 d. Within the St. Lawrence Plain ecozone, northern hardwoods are the dominant forest type and are found in small woodlots usually located in low-lying swampy areas; additionally a large proportion of brushland exists as a result of land abandonment. Agriculture is the predominant land use of the St. Lawrence Plain ecozone (Will *et al.* 1982). All of the sites were influenced by beaver (*Castor canadensis*) activity, which resulted in flooding of preexisting streams and pooling of water, leading to the creation of shrub-dominated wetlands.

Site 1 is an impounded wetland with a mosaic of areas dominated by speckled alder (*Alnus incana*), shrub willow (*Salix* spp.), sedges (*Carex* spp.), cattails (*Typha* spp.), and open water pools. This site is bordered by a town road underlain by culverts that influence the drainage and water levels. Red maple (*Acer rubrum*) forested swamps surround this wetland. Uplands in this area are mixed deciduous forests containing red maple, sugar maple (*Acer saccharum*), and beech (*Fagus grandifolia*). Pastures and agricultural fields surround the area are used as nesting areas and are composed of glacial sand deposits. Beaver have impounded a stream in a pasture that drains from a larger wetland, creating Site 2. The wetland portion of this site is completely dominated by shrub willow, with cattail and sedge stands on the borders. The forested swamps surrounding the wetland are comprised of northern white-cedar (*Thuja occidentalis*) and

red maple. Pastures, cornfields, and residential housing are found to the south and east of this site, and mixed deciduous northern hardwood forest comprise the north and west borders. Nesting areas of glacial deposits exist within the hardwood forest to the north. Site 1 and Site 2 are 1.5 km apart, which would allow movement by Blanding's turtles between them. Therefore, these two sites were combined in the following analyses. Site 3 is approximately 18 km to the northeast of Site 1 and Site 2 and was considered independent in the analyses.

The wetland complex at Site 3 was also created by beavers, which impounded linear drainages that flow into a tributary of Lake St. Lawrence. This site is also a patchwork of willow-dominated swamps, alder thickets, and emergent cattail and sedge marshes surrounded by red maple forested swamps and northern hardwood forests dominated by red maple, sugar maple, and beech with white pine (*Pinus strobus*) and hemlock (*Tsuga candensis*) interspersed throughout. Land use in the vicinity of Site 3 consists of a complex of agricultural fields, wetlands, upland forests, forested swamps, a few residential homes, and a marina and a state campground.

METHODS

Trapping

In 2003 and 2004 Blanding's turtles were trapped using either 0.6- or 0.8 m-diameter aquatic nylon hoop traps where water depth exceeded 30 cm. Traps were baited with whole sardines in soybean oil, and bait was changed in a given trap approximately every 5 d. Traps were checked once daily. Air and water temperature and cloud cover were recorded daily. Turtles also were collected during chance encounters while conducting field surveys and while they were crossing roads.

Data collected from captured Blanding's turtles included measurements of the carapace and plastron length, width, and height (mm), weight (g), sex (if discernable), approximate age, and reproductive status. Length and width measurements were taken along the longest distance, rather than along the midline. Females were examined for eggs by palpating in front of the hind limbs and working posterior to anterior toward the interior of the body cavity. Males were identified by a moderately-concave plastron and greater pre-anal tail length and females were identified by a flatter plastron and a shorter pre-anal tail length (Ernst *et al.* 1994). Approximate age was determined by counting annuli on a costal scute and verified by counting annuli on a plastral scute (Graham 1979). Costal scutes are often worn on individuals over 20 years of age, which made age estimation difficult for older individuals. Each turtle was identified by notching the marginal scutes with a triangular file (Cagle 1939). Additionally, Passive Integrated Transponders (PIT) were injected on the left side of each turtle, and read using an AVID® scanner to identify road-killed turtles whose notch code was destroyed or missing. All turtles were released within 10 – 24 h of capture and returned to within 10 m of their capture location.

Radio Telemetry and Home Range

Radio transmitters were attached to 24 adult Blanding's turtles (seven males and 17 females). Blanding's turtles with carapace lengths over 164 mm are considered adults, and while they may be reproductive around this size (Pappas and Brecke 2000) females possessing carapace lengths over 190 mm are more likely to be sexually mature (Kiviat 1993; Ernst *et al.* 1994).

12

We used single stage radio transmitters (High Tech Express, model WL300-7PN) with 350 - 540 d of life. Transmitters were attached on the right posterior of the carapace parallel to the marginal scutes, and the antenna was wrapped around the perimeter of the shell toward the anterior of the carapace. Duct tape was used to temporarily hold the transmitter in place on the turtle, and then the transmitter was fixed to the carapace using 5 - min epoxy. The epoxy filled the space between the carapace and transmitter and completely covered the transmitter and antenna. Locations of radio-tagged turtles were obtained a minimum of two times per week using a hand-held receiver (AVM, model LA12-Q) and 5 – element antenna. The procedure for monitoring radio-tagged turtles involved following the graded strength of the transmitter's signal to the actual location of the turtle, and obtaining either visual confirmation or determining the turtle's approximate location within a 0.5-m radius if no visual confirmation could be obtained. A WAAS-enabled Global Positioning System (GPS) location was recorded with a Garmin V GPS (Garmin V Specifications.2003) unit in Universal Transverse Mercator (UTM) coordinates in the field and later entered as an X, Y coordinate into ArcGIS 8.3 (E.S.R.I. 2003).

Movements and home range analyses were performed on 16 adult Blanding's turtles (four males and 12 females) with the program Ranges VI (Kenward *et al.* 2003). Each of these individuals had to meet the following requirements for analysis: 1) have a minimum of 20 locations and 2) assignment of a radio transmitter from at least 10 June through 15 October in either 2003 or 2004, which covered the majority of the active season. Incremental area analysis (IAA) was used to determine the minimum number of locations required for home range to stabilize (Kenward *et al.* 2003). In this technique,

an outline is drawn around the first three locations, and the area is estimated. Successive radio locations are added to the estimate until all of the locations are used. This permits the consecutive areas, which tend to increase initially as the animal is observed using different parts of its range, to be plotted against number of locations until there is evidence of stability, which indicates that adding further locations will not improve the home range estimate (Kenward 2003). Stabilization occurs when adding additional locations does not result in further increase in home range size, and the plotted area curve reaches an asymptote.

Home ranges were analyzed using three different methods: the multinuclear cluster, minimum convex polygon (MCP) and adaptive kernel (AK) methods, all with a harmonic mean center using 95% of the locations. Using 95% of the total home range eliminates extreme outliers, which may exclude areas where the animal may never visit again. The 95% home range area calculation also represents the area where the animal spends 95% its time and excludes exploratory behavior (Boitani and Fuller 2000). These three methods were used to provide a range of home range sizes because each method estimates home range differently, and because each has been used in previous studies of Blanding's turtles.

The multinuclear cluster analysis of home range size uses nearest-neighbour locations to define high-use areas in multinuclear ranges (Kenward *et al.*, 2003) and may underestimate areas of utilized habitat if the number of locations is relatively small (Carter *et al.* 1999). This method systematically separates clusters of locations and creates polygons around 95% of the observations, while excluding the remaining 5% of locations that were outliers and large areas where individuals traveled over but did not

remain stationary (Barlow 1999). Therefore, the number of activity centers and home range size was estimated using this method. The sum of the area of activity centers for each individual turtle is reported because many of the individuals had more than one activity center.

The MCP method of estimating home range involves drawing the smallest convex polygon possible that encompasses all known or estimated locations for an individual (Boitani and Fuller 2000). This method has certain limitations, in that it provides only a crude outline of an animal's home range, is sensitive to extreme data points, ignores information provided by interior data points, and may incorporate areas that an individual does not use with equal intensity (Boitani and Fuller 2000). However, the primary benefit of the MCP method is that it is conceptually simple and is not limited by assumptions that animal movements or home ranges must fit into a specific distribution. Additionally, the MCP method allows comparison to other studies, and calculating the MCP for all radio-locations of all turtles at a study site combined allows the representation of the minimum area used by Blanding's turtles radio-tracked during this study. Thus, inclusion of all areas potentially utilized by a mobile species whose home range includes multiple wetland and upland habitats is especially useful for conservation efforts (Piepgras and Lang 2000; Joyal *et al.* 2000).

The AK method for estimating home range produces an unbiased estimate of locations from data that are not influenced by grid size or placement. However, as with the MCP, the AK method may produce home range outlines that include areas that are not part of the animal's normal home range (Powell 1965). Home ranges were estimated using this method to facilitate comparisons with other studies of this species.

Daily Movements

Due to shifts in activity centers and other movements, telemetered turtles were not monitored on a daily basis in all cases. Daily movements were determined by calculating the straight-line distance between consecutive locations and dividing the total straight-line distance traveled by the number of days between locations. Additionally, mean daily movements of males and females were analyzed in a monthly context for 2003 and 2004. I anticipated that females would move the greatest distances during the nesting period, and male movements would be relatively consistent throughout the active season. Hamernick (2000) reported that females moved less often than males but over longer distances. Additionally, Ross and Anderson (1990) found that minimum daily movements of females in Illinois were greater than male movements, while Rowe (1987) reported no obvious difference between male and female movements.

Nesting Movements

Blanding's turtles may utilize human-disturbed areas such as plowed fields, road side berms, active agricultural lands and gravel pits for nesting (Linck *et al.* 1989). Natural nesting sites have been observed in grasslands characterized by sandy loam or sandy soils (Ross and Anderson 1990) and areas with sparse herbaceous vegetation interspersed with bare mineral soil (Kiviat *et al.* 2000). The distance of potential nest sites from water may vary from 2.0 m to greater than 1.0 km (Congdon *et al.* 1983), and nest observations in areas adjacent to marshes where they are not considered residents have been recorded (Congdon *et al.* 1983, Ross and Anderson 1990). In this study, movements associated with nesting included the total distance traveled from a gravid female's primary wetland to a nesting area, and the distance traveled either back to that

16

wetland or a new activity center. These movements were examined on a daily basis by dividing the total straight-line distance included in the overall nesting movement by the number of days between leaving and returning to a resident wetland.

Statistical Analyses

All data were tested for normality using the Shapiro–Wilks' Test for normality with SPSS for Windows (SPSS 2001). This test assesses normality using symmetry and kurtosis measures (Zar 1999), and produces a W statistic. The null hypothesis that the respective distribution is normal is rejected if the test statistic (W) is > 0.05. The Shapiro-Wilks' W test is the preferred test of normality because of its good power properties as compared to a wide range of alternative tests (Shapiro *et al.* 1968), and is appropriate for samples where n < 50 (Zar 1999). This test revealed that the home range sizes varied within each method of home range calculation. The W statistics were significant for the cluster ($W = 0.659$, df = 22, $p = 0.00$), MCP ($W = 0.798$, df = 22, $p = 0.00$), and AK ($W = 0.831$, df = 22, $p = 0.002$) methods. These data did not meet the requirements of normality and homoscedasticity (Zar 1999), due to unequal variances. I transformed the data to logarithms in base 10 with SPSS to allow use of parametric testing to be utilized.

Home range sizes generated in Ranges VI (Kenward *et al.* 2003) were compared using SPSS for Windows (SPSS 2001). A one-way analysis of variance with a Tukey Post Hoc test was used to test for differences between the methods of home range estimation. Student *t* tests were used to test for differences between male and female home range size, differences in the number of activity centers within and among sites, and the size of the home range estimates between individuals at each study site. The

significance level for all statistical analyses was alpha = 0.05, and, unless otherwise noted, $\overline{x} \pm 1$ SD are given throughout.

RESULTS

Between May 2003 and November 2004, a total of 24 adult Blanding's turtles (17 females and seven males) at three different wetlands were radiotracked and located from six to 35 times ($\overline{x} = 24 \pm 9.2$) for periods of eight to 16 mo. From May to August 2003, eight of 24 adult turtles (four males and four females) were radiotracked; however, only three of the females and one of the males possessed sufficient records for an analysis of home range. In 2004, 12 females and four males with ≥ 20 locations were included in the home range analysis.

Home Range and Activity Centers.

Using the IAA, home range did not increase, and the area estimate stabilized, after an average of 20 locations were added to the cluster, MCP, and AK estimates, respectively. Therefore, a minimum of 20 locations were required to estimate home range area for each telemetered turtle. Home range sizes of Blanding's turtles with ≥ 20 locations are given in Table 1.

There was no significant difference ($t = 1.065$, df = 14, $p = 0.305$) between the cluster estimates of home range sizes of adults at Site 1/Site 2 ($\overline{x} = 3.3 \pm 3.9$ ha) and Site 3 ($\overline{x} = 2.1 \pm 2.1$ ha). Additionally, there was no significant difference between Blanding's turtles at these two sites when using the using the MCP 95% ($t = 1.40$, df = 14, p = 0.18) and the AK 95% ($t = 1.66$, df = 14, $p = 0.12$) methods. No significant differences were observed between the 2003 and 2004 home range estimates for 95% cluster ($t = -1.18$, df = 20, $p = 0.25$), MCP ($t = -0.083$, df = 20, $p = 0.93$), and AK ($t =$

0.387, df = 20, p = 0.70). Cluster home range sizes of females at Lisbon and Site 3 in 2004 were similar (t = -0.763, df = 10, p = 0.463), therefore, data from females at both sites were combined. There were significant differences between the three methods used for the home range estimations (ANOVA: F = 13.402, df = 2, p = 0.00). A Tukey post hoc test with multiple comparisons revealed that there was no significant difference between the MCP and AK estimates (p = 0.175). However, a significant difference was discovered between the cluster and MCP home range estimates (p = 0.005) and between the cluster and AK estimates (p = 0.000), where cluster home ranges were smaller than both MCP and AK home ranges.

Among all adult females that were radiotracked in 2004 with $\geq$ 20 locations (n = 12), the number of activity centers for each female differed significantly (t = 6.384, df = 11, p = 0.00), and ranged from one to five with a mean of 2.4 $\pm$ 1.31. The multinuclear cluster analysis produced home range size estimates for all telemetered females that were not significantly different (t = -0.041, df = 15, p = 0.968) and ranged from 0.13 to 4.47 ha with a mean of 1.24 ha. Based on the MCP home range estimate, the mean home range area for all telemetered females was 12.26 (1.13 – 44.14) ha, and 31.38 (1.87 – 97.19) ha using the AK estimate (Table 1).

An example of a home range and activity center estimate for female L2R2 is depicted in Figure 1. The first activity center was 1.03 ha and was occupied for 15 d from the first radio location of the study. Her first major movement was 962.1 m to her second activity center (0.03 ha) where she remained for 4 d during nesting. This was followed by a 767.2 m movement to a 1.07 ha activity center that was occupied for 88 d. Finally, this female moved 429.5 m to the activity center that she occupied at the

beginning of the active season, where she remained for the last 31 days of the study. This female's total home range (summed activity centers) was 2.13 ha.

Males tended to have a greater number of activity centers than females. The number of activity centers for the five males ranged from two to four, with a mean of 2.67 ($\pm$ 0.82). Using the cluster estimate, male home range size ranged from 0.13 to 2.76 ha with a mean area of 1.13 ($\pm$ 1.19) ha. The mean home range area for males ($n = 4$) was 7.53 ($\pm$ 2.63) ha with the MCP method, and 14.37 ($\pm$ 12.99) ha using the AK estimate. Home range size did not differ between sexes based on cluster ($t = -0.651$, df = 14, $p = 0.526$), and AK ($t = 0.498$, df = 14, $p = 0.626$). However, there was a significant difference between female ($\overline{x} = 12.26 \pm 13.90$ ha) and male ($\overline{x} = 7.54 \pm 2.63$ ha) MCP home range estimates ($t = -8.917$, df = 14, $p = 0.00$) in 2004. This difference is likely due to the inclusion of female nesting movements in the home range estimate.

Daily Movements

From May to August 2003 and May to September 2004, daily movements were estimated for 24 adult Blanding's turtles, based on grand means of straight-line distances between radio locations of individual turtles. Average daily movements of all telemetered turtles in 2004 varied between 1.0 and 51.51 m ($\overline{x} = 27.65 \pm 13.8$ m, $n = 23$). Additionally, males tracked in 2004 ($\overline{x} = 46.03 \pm 5.12$ m) made significantly longer average daily movements than females ($\overline{x} = 20.77 \pm 7.02$ m) ($t = -7.331$, df = 21, $p = 0.000$). During 2003, data on movements were collected from May through August. Based on these data, the mean distances of female movement were longest in June, while males moved more consistently throughout the study period. In 2004, female mean daily movements peaked in June (Figure 2) and males moved the greatest distances in August.

Males tended to move greater distances on a monthly basis compared to females, although longer daily movements by females were generally observed during the nesting season in June (Figure 2).

Nesting Movements

Gravid females were observed moving to nesting areas from 2 June through 17 June and returning to their resident wetlands from 9 June through 25 June 2004. Typical nesting habitats consisted of glacial sand deposits and plowed agricultural fields with a sand or sandy loam substrate with little to no vegetation or canopy cover. Travel to and from nesting areas lasted from two to 10 d (Table 2). The total estimated distance moved by gravid females prior to and following nesting ranged from 15 to 1345 m, with a mean distance of 951.86 ± 435.35 m. Additionally, the straight-line distance from each female turtle's wetland to its nesting area ranged from 70 to 1343 m with a mean distance of 551 ± 448.87. There was a significant difference ($t = 2.784$, df = 7, $p = 0.027$) in the straight-line distance between wetlands and nesting areas and the estimated distance moved by telemetered turtles. Mean daily movements associated with nesting ranged from 7.4 to 224.2 m ($\bar{x} = 125.7 \pm 74.22$ m). There was no significant difference in the mean daily movements of radio-tagged gravid females at Site 3 ($\bar{x} = 161.82 \pm 211.38$ m) and Site 1/Site 2 ($\bar{x} = 121.71 \pm 108.80$ m, $t = -1.092$, df = 7, $p = 0.311$).

Telemetered turtles observed in the nesting areas, but who did not deposit eggs on a given evening, typically moved back to vernal pools near the nesting area. With the exception of one individual, all of the telemetered females ($n = 9$) did not nest on the first night that they arrived at the nesting area. Nine of the radio-tagged females exhibited nest searching that did not result in egg deposition. Nest searching activity was observed

for up to three consecutive nights. All of the telemetered gravid females eventually nested during the nesting period.

DISCUSSION

Home Ranges and Activity Centers

Calculated home range sizes for adult Blanding's turtles in northern New York are smaller than estimates in Minnesota (Hamernick 2000; Piepgras and Lang 2000) and larger than estimates in Maine (Joyal *et al.* 2000) and central Wisconsin (Ross and Anderson 1990) (Table 3). In my study, there was no significant difference between male and female home range sizes within and between the study sites, even though the three study sites differed in wetland area. Additionally, there was no significant difference among the home range sizes of females at each study site. Ross and Anderson (1990) and Rowe (1987) also reported similar home range size within and between sexes. The number of activity centers of both male and female turtles in this study are similar to those in Minnesota (Piepgras and Lang 2000), Wisconsin (Ross and Anderson 1990), Illinois (Rowe and Moll 1991), and Maine (Joyal 1996). The number of activity centers differed among the females tracked in 2004, ranging from one to five. This range could be attributed to differences in reproductive activity; nine of the 12 radiotagged females with at least 20 locations nested, while the remaining four females with the sufficient number of locations did not have eggs or enlarged follicles during the active season. Females making nesting movements would establish activity centers away from their primary wetlands, while females that were not gravid and remained in their resident wetlands had a fewer number of activity centers. Males had a greater number of activity centers than females. This difference could be attributed to telemetered females moving

22

once or twice over long distances during the active season, with these movements associated with nesting. Conversely, male movements were more frequent and over longer distances than females. This observation is presumably linked to mate searching behavior in males (Rowe and Moll 1991, Bodie and Semlitsch 2000, Piepgras and Lang 2000, Hamernick 2000). During this study males were discovered copulating with females from May through the beginning of September, an observation that supports movements related to mate searching throughout the active season.

Daily Movements

Daily movements of males ($\bar{x}$ = 46.03 ±5.12 m) were significantly longer than females ($\bar{x}$ = 20.77 ±7.18 m) in this study. This observation differs from Rowe (1987), where daily movements did not differ between sexes, while both Ross and Anderson (1990) and Piepgras and Lang (2000) reported that males made significantly shorter daily movements than females. The latter study indicated that shorter male movements were related to post-nesting movements of females and distances between wetlands with open water (Piepgras and Lang 2000). Additionally, female Blanding's turtles tracked in 2003 made longer daily movements than female turtles tracked in 2004. The larger values for daily movements of turtles tracked in 2003 may have been due to the small sample size of females which were not followed throughout the entire active season. Thus, female movements recorded in 2003 may have been concentrated around the nesting season and did not include the shorter movements in the spring and early fall, as in 2004.

The mean daily movements of male and female Blanding's turtles estimated in this study are much shorter than distances moved in other studies (Ross and Anderson

23

1990, Rowe and Moll 1991). Females from Minnesota, Illinois and Wisconsin averaged 45 (range = 6–142) m, 32.4 ± 28.71 m and 95.1 ±79.0 m respectively, compared to 20.77 ± 7.08 m in this study. Mean distances moved by males in this study ($\bar{x}$ = 46.03 ± 5.1 m) was similar to both the Wisconsin ($\bar{x}$ = 48.4 ± 41.2 m) and Illinois ($\bar{x}$ = 48.9 ± 41.7 m) studies. However, Piepgras and Lang (2000) estimated that average daily strait-line movement distance of males was 26 (range = 1–133) m. Differences between mean daily movements of females in the Illinois, Minnesota, and Wisconsin studies, as compared to female Blanding's turtles in the northern New York study, could be attributed to the abundance of resources within primary wetlands inhabited by telemetered turtles, as Rowe and Moll (1991) indicated that movements within activity centers were likely associated with resource acquisition. Although I included reproductive movements of females in the mean daily movement estimates, a similar pattern may be apparent because adequate resources may be present in the large wetland complexes that are characteristic of the northern New York sites. As with home range size, daily movements may be explained in the context of maximizing individual reproductive success (Morreale *et al.* 1984). The larger mean daily movement of males compared to females in this study could be related to a male's continued mate searching throughout the active season, which could increase the number of eggs potentially fertilized. Conversely, once a female is fertilized, her reproductive success is limited by the amount of energy she can acquire to convert to offspring (Morreale *et al.* 1984). Thus, inseminated females would not benefit from mate searching and long-distance travel not associated with nesting activities. Additionally, Rowe and Moll (1991) documented that males are more active than females on a monthly basis, whereas female movements peaked in May.

24

Nesting Movements

In northern New York, gravid females traveled longer distances to nesting areas than in Wisconsin (Ross and Anderson 1990) and Minnesota (Piepgras and Lang 2000), although similar nesting distances were documented in studies from Michigan (Congdon *et al.* 1983), Illinois (Rowe and Moll 1991), and Maine (Joyal 1996). Congdon *et al.* (1983) suggested that female Blanding's turtles travel long distances to find nesting areas with suitable physical conditions even though the energy costs and risks are higher than if nests were located nearer to home wetlands. In northern New York, the four females that were radio-tagged in 2003 and followed through 2004 showed nest site fidelity across both years. These females traveled up to 1365 m round-trip to nesting areas and back to their home wetlands in consecutive years. This observation is similar to nesting activity of females in Michigan (Congdon *et al.* 1983).

The dates of the nesting period for Blanding's turtles are variable across its range (Congdon 1983, Ross 1985, Rowe and Moll 1991). The range of dates for the nesting period in this study (2 June – 25 June) are similar to Illinois (26 May – 22 June; Rowe and Moll 1991), southeastern Michigan (23 May – 9 June; Congdon *et al.* 1983), and central Wisconsin (12 June – 2 July; Ross 1985). The onset of nesting in northern New York is later than studies in Illinois and southeastern Michigan, and similar to central Wisconsin. This may lend support to the hypothesis of Congdon *et al.* (1983) that a certain number of warm days in April (and May in northern New York) are necessary for gravid females to complete vitellogenesis. Therefore, the higher latitude of northern New York and Wisconsin would cause a time lag in the onset of nesting when compared with populations at lower latitudes.

MANAGEMENT IMPLICATIONS

One primary management issue identified in this study that could have a negative impact on the Blanding's turtle populations in northern New York is the location of nesting areas. Telemetry data revealed that gravid females utilize nesting areas up to 1.5 km away from resident wetlands. This species exhibits high nest site fidelity (Congdon *et al.* 1983, Standing *et al.* 2000), and all of the telemetered females followed in 2003 and 2004 used the same nesting areas in both years. There are limited natural areas in the vicinity of the sites in this study that are suitable for nesting, which makes them very important to the longevity of these populations.

Another important management issue is the location of nesting areas on privately-owned property. All three sites in this study have excellent nesting, wetland, and upland habitats that are located on private property, which can affect both the type of impact and the level of control over human actions on the landscape (Blanding's Turtle Recovery Team 2002). For example, during the 2003 and 2004 field seasons, the use of off-road vehicles posed a significant threat to both turtle nesting activity and the survivorship of nests, by causing both gravid female Blanding's and painted turtles (*Crysemys picta*) at the study sites to abandon nest searching, avoid nesting areas when disturbed, and desert nests before the process was completed. Operation of these vehicles in the nesting areas resulted in turtle nests being unearthed and crushed by the tires of the vehicles, and newly hatched turtles being run over during emergence. Although off-road vehicles may be concentrated to a limited portion of the nesting areas, any loss of nests or incomplete construction of nests could have a significant impact on Blanding's turtle populations in the area.

Changes in land use on private lands can also have detrimental impacts on Blanding's turtle populations. As indicated in my study, Blanding's turtles require large areas including both wetland and upland habitats to carry out annual activities including travel between wetlands and nesting areas. If landscapes are altered by anthropogenic effects, isolation of necessary habitat features may have negative impacts (Marchand and Litvaitis 2004). For example, development of uplands adjacent to wetlands can destroy important habitats that serve as linkages for migrating between upland and wetland habitats.

Blanding's turtles in northern New York use multiple areas within wetland complexes and require seasonally predictable water levels at nesting, over-wintering, and drought refuge sites (Blanding's Turtle Recovery Team 2002). Significant alteration in the water levels in wetlands occupied by Blanding's turtles may force this species to cross terrestrial habitats in search of areas with suitable water depths (Hall and Cuthbert 2000). These overland movements have the potential to place Blanding's turtles in vulnerable situations, including crossing roads and venturing into areas that may also be lacking suitable water depths. Additionally, this species may exhibit fidelity to over-wintering sites (Blanding's Turtle Recovery Team 2002). Thus, if turtles that immigrate to areas with suitable water depths during the active season return to their original location that does not possess suitable water levels, the potential for winterkill may increase (Hall and Cuthbert 2000). This suggests that both uplands and wetland complexes require protection from changes in land use, unnatural flooding, and deliberate draining.

During overland movements, road mortality poses the most direct threat to Blanding's turtles in northern New York. The loss of even one adult female per year can affect a population over time. Roads can represent a significant, additive source of mortality that turtle populations may to be unable to adjust to (Gibbs and Amato 2000). This species exhibits delayed sexual maturity (Congdon *et al.* 1993, Ernst *et al.* 1994) and lengthened generation times (Congdon *et al.* 1983). Roads increase the risk of mortality prior to first reproduction and can reduce the recruitment of breeding individuals more than natural factors. In 2003 and 2004, 12 individual gravid females ranging from 19 to greater than 25 years old were found dead on roads that bisect or are adjacent to the wetlands in of this study. These females may have represented a major proportion of the mature turtles in these populations. Some form of management including constructing fencing, changing speed limits in known migration areas, or establishing signs may help to reduce the amount of road mortality experienced by Blanding's turtles in northern New York.

Finally, some form of public education and communication with landowners in the vicinity of Blanding's turtle populations is necessary to ensure protection of this species' habitat (Blanding's Turtle Recovery Team 2002). Additionally, further studies on the distribution, population dynamics, habitat use and requirements, and nesting ecology of Blanding's turtle populations in northern New York should be conducted to contribute to the conservation of this species in the eastern periphery of its contiguous Great Lakes range.

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Table 1. Home range size (ha) of telemetered Blanding's turtles in northern New York in 2003 (A) and 2004 (B), estimated via cluster, minimum convex polygon (MCP), and bivariate normal kernel (AK) analyses.

A

Turtle ID	Site	Sex	# Locations	# Activity Centers	Cluster-95%	MCP-95%	AK-95%
L2R11	Site 1	F	22	2	1.44	11.01	41.13
L11R12	Site 3	F	22	1	1.60	1.63	3.52
L9R9	Site 3	F	20	2	6.68	19.41	47.84
			Mean	1.67	3.24	10.68	30.83
L8R11	Site 1	M	22	2	4.44	5.75	8.75

B

Turtle ID	Site	Sex	# Locations	# Activity Centers	Cluster-95%	MCP-95%	AK-95%
L2R9	Site 3	F	31	4	2.76	44.14	97.19
L3R2	Site 3	F	20	4	0.16	10.92	32.00
L3R4	Site 3	F	21	2	0.57	2.53	11.62
L12R3	Site 3	F	28	2	4.74	19.95	35.63
L2R2	Site 1	F	32	3	2.49	33.86	88.71
L2R11	Site 1	F	33	2	1.13	1.13	17.90
L1R1,4	Site 2	F	34	2	0.49	1.78	1.87
L1R1,7	Site 2	F	29	1	14.18	14.18	54.10
L9R9	Site 2	F	24	1	8.03	8.03	26.98
L9R11	Site 2	F	30	2	1.86	4.68	5.21
L10R10	Site 2	F	31	1	1.37	1.80	2.22
L11R12	Site 2	F	31	5	0.49	4.15	3.11
			Mean	2.42	3.19	12.26	31.38
L2R10	Site 1	M	35	2	3.45	7.77	3.73
L12R11	Site 1	M	33	3	1.88	6.64	10.41
L1R12	Site 2	M	32	4	2.45	11.01	33.31
L4R8	Site 2	M	24	2	2.19	4.73	10.02
			Mean	2.75	2.49	7.54	14.37

Table 2. Total distance traveled during nesting activities; the number of days included during nesting movements; and mean daily movements of eight females of radio-tagged Blanding's turtles in northern New York in 2004.

Turtle ID	Site	Dates of Nesting Activity			# Days	Estimated Total Nesting Distance (m)	Mean Daily Movement (m)
L2R9	Site 3	17-Jun-04	-	23-Jun-04	6	1345.57	224.26
L3R4	Site 3	10-Jun-04	-	17-Jun-04	7	365.19	52.17
L3R7	Site 3	10-Jun-04	-	16-Jun-04	6	494.9	82.48
L12R3	Site 3	17-Jun-04	-	25-Jun-04	8	1351.97	169
L2R2	Site 1	10-Jun-04	-	16-Jun-04	6	1319.66	219.94
L2R11	Site 1	6-Jun-04	-	16-Jun-04	10	1364.78	136.48
L1R1,7	Site 2	2-Jun-04	-	9-Jun-04	7	609.28	87.04
L9R9	Site 2	10-Jun-04	-	15-Jun-04	5	763.5	152.7
			Total Mean Distance			951.86	140.51

Table 3. Comparison of Blanding's turtle home range sizes from this study with estimates from other studies. The multinuclear cluster, minimum convex polygon (MCP), and bivariate normal kernel (AK) methods were used to estimate home range in this study.

Investigators	Location	Mean HR Size (ha)	Method	Signif. M v F?
This Study, 2004	Northern NY	Male=2.5, Female=3.2	Cluster	N
"	"	Male=7.5, Female=12.3	MCP	N
"	"	Male=14.4, Female=31.4	AK	N
Hamernick, 2001	SE MN	Male=94.9, Female=60.8	MCP	N
"	"	Male=122.9, Female=58.4	AK(95%)	N
"	"	Male=56.9, Female=18.9	PB	N
Piepgras and Lang, 2000	Central MN	Male=7.8, Female=7.8	GS	N
"	"	Male=38.4, Female=35.4	MCP	N
"	"	Male=53.4, Female=63.0	AK(95%)	N
Joyal, 1996	Maine	0.91*	MPM*	?
Rowe and Moll, 1991	NE Illinois	Male=1.4, Female=1.2*	MPM**	N
Ross and Anderson, 1990	Central WI	Male=0.76, Female=0.64	MPM**	N
Rowe, 1987	NE Illinois	9.5	MCP	?

* = derived from summed centers of activity (Piepgras and Lang, 2000)
** = MPM is equivalent to the MCP method

Legend:
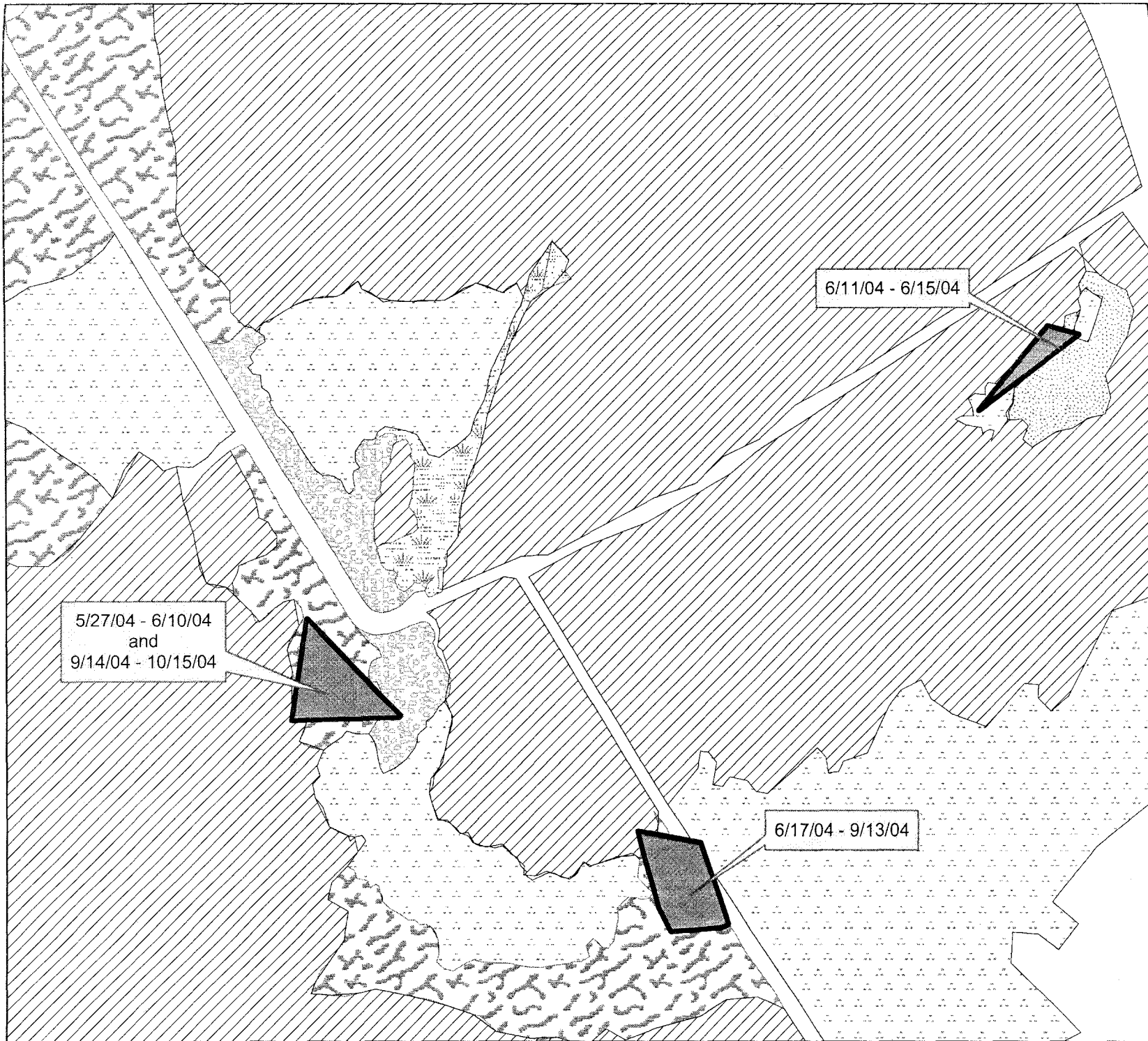
- Forested Swamp
- Herbaceous Emergent
- Activity Center
- Nest Site
- Pond
- Shrub Swamp
- Upland Forest
- Woody Emergent
- Vernal Pool

6/11/04 - 6/15/04

5/27/04 - 6/10/04
and
9/14/04 - 10/15/04

6/17/04 - 9/13/04

N
W E
S

0   65   130   260
Meters
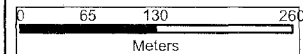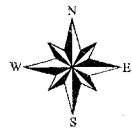
Figure 1. Activity centers and dates of residency for an adult female Blanding's turtle at Site 1 in northern New York, monitored from May 2004 through October 2004. This female was hand-captured and released in her first activity center (left, center), then moved to a vernal pool (top, right) where she remained until egg deposition occurred, before making a long overland movement back to another part of the wetland (bottom, center) were she remained until she moved to her original activity center (left, center) where she presumably overwintered.
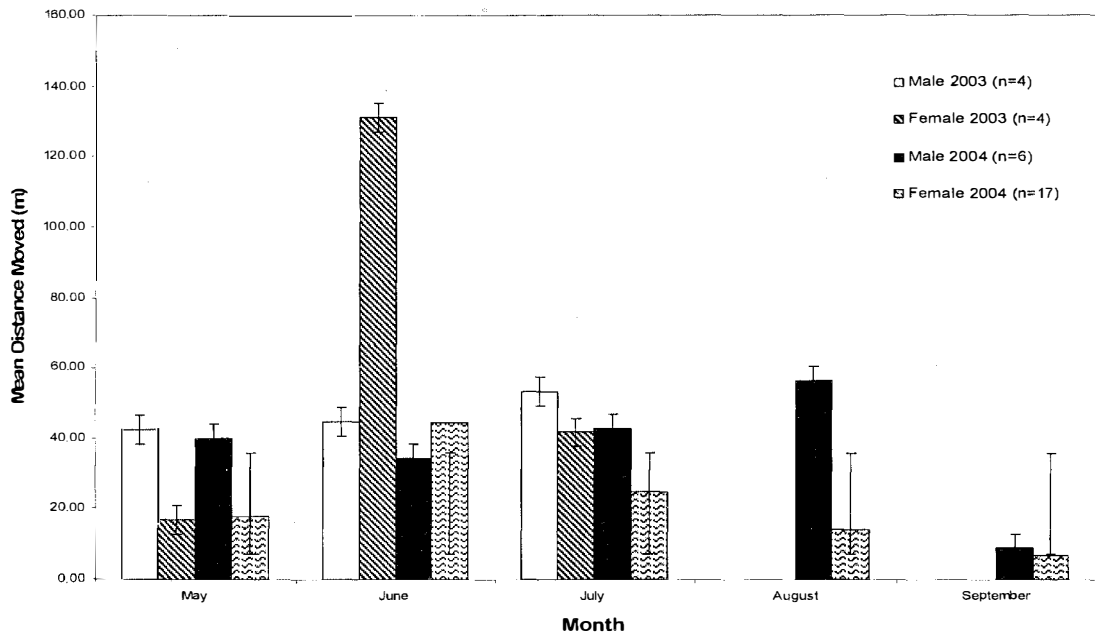
Figure 2. Monthly pattern of mean daily movements of Blanding's turtles in northern New York during the active periods from May through August in 2003, and from May through September in 2004.

CHAPTER II: HABITAT USE BY BLANDING'S TURTLES (*EMYDOIDEA BLANDINGII*) IN NORTHERN NEW YORK

INTRODUCTION

Among the principle factors responsible for the accelerating decline of the world's biodiversity are loss, degradation, and fragmentation of habitats, including wetlands (Klemens, 2000). Wetlands in the continental United States are being destroyed rapidly, where more than half of the estimated 221 million acres of wetlands present at the time of Colonial America have been lost (Wilen and Frayer 1990, Gibbs 1993). In North America, road mortality (Gibbs *et al.* 2007) habitat destruction, and over collection have contributed to the decline of many turtle populations (Ernst *et al.* 1994). One turtle species that probably is declining due to anthropogenic changes to wetlands or removal of individuals is Blanding's turtle, *Emydoidea blandingii* (Christiansen 1981, Ross and Anderson 1990). The decline in Blanding's turtle populations has led to its listing as a Threatened Species in several states, including New York, and as candidate for federal listing. This species occurs in four disjunct regions in New York State: Dutchess County in the southeast, Saratoga County in the east, the eastern end of Lake Erie in the west, and the St. Lawrence Valley in the north (Kiviat *et al.* 2000, Gibbs et al. 2007, New York State Natural Heritage Program 2008). The northern populations of this species are at the eastern limits of its contiguous Great Lakes range (Petokas and Alexander 1981, Johnson and Wills 1997, Johnson and Crockett 2006). A number of comprehensive studies have been conducted on the ecology of this turtle (Gibbons 1968, Graham and Doyle 1979, Congdon *et al.* 1983, Kofron and Schreiber 1985, Ross and Anderson 1990, Rowe and Moll 1991), with relatively few concentrating on the critical habitats necessary

at different spatial scales for this species (Ross and Anderson 1990, Pappas and Brecke 1992, Piepgras and Lang 2000). If this species is to be preserved, it is important to understand how it uses the different habitat types that comprise the landscape where it occurs, including aquatic, upland, and lowland areas. Additionally, protection of this species requires that the structural microhabitat characteristics and vegetative composition of aquatic habitats used by Blanding's turtles are well understood, so that preferred habitats can be protected and effective conservation efforts implemented.

Blanding's turtles use wetland and upland habitats (Ernst *et al.* 1994, Piepgras and Lang 2000), with females traveling long distances overland to nest in areas with sandy loam or sandy soils (Ross and Anderson 1990), and sparse herbaceous vegetation interspersed with bare mineral soil (Kiviat *et al.* 2000), males using uplands throughout the active season (Congdon *et al.* 1983, Ross and Anderson 1990, Pappas and Brecke 1992, Butler and Graham 1995, Linck and Moriaty 1997, Piepgras and Lang 2000). Studies in Illinois (Rowe and Moll 1991), Maine (Joyal 1996), and Nova Scotia (Herman *et al.* 1995), indicated that Blanding's turtles use vernal pools and wetlands of varying sizes and water volumes over broad areas for feeding, reproductive activities, thermoregulation, and basking (Piepgras and Lang 2000).

The primary wetland habitats occupied by Blanding's turtles usually include productive, eutrophic inland and deep freshwater marshes (Ernst *et al.* 1994), shrub swamps with alder (*Alnus*), willow (*Salix*), cattail (*Typha*), and sedges (*Carex*), and emergent wetlands with shallow water composed of reeds, grasses, and cattail (Piepgras and Lang 2000) with a soft but firm organic bottom and abundant aquatic vegetation (Kofron and Schreiber 1985, Ernst *et al.* 1994). In New York, Blanding's turtles use

areas with: (1) both shallow (30 cm) and deep (120 cm) pools connected by channels, (2) open or absent tree canopy, (3) tree fringe, (4) a dense cover of shrubs, forbs, and graminoids dispersed as hummocks and tussocks throughout the wetland, and (5) coarse and fine organic debris (Kiviat 1997).

This study examined how Blanding's turtles in northern New York use habitat at coarse- and fine-spatial scales, and assessed whether structural microhabitat variables influence habitat selection, with the goal of providing information useful for the management and conservation of this species.

STUDY AREA

Three study sites were selected in St. Lawrence County, New York that were known or suspected to contain Blanding's turtles. Precise location descriptions are not provided due to the threatened status of this species in New York State. For the purpose of distinguishing sites, they are named Site 1, Site 2, and Site 3. All of the sites were influenced by beaver (*Castor canadensis*) activity, which resulted in flooding of preexisting streams and pooling of water leading to the creation of shrub-dominated wetlands.

Site 1 is an impounded wetland with a mosaic of areas dominated by speckled alder (*Alnus incana*), shrub willow, sedges, cattails, and open water pools. This site is bisected in part by a town road underlain by culverts that influence the drainage and water levels. Red maple (*Acer rubrum*) forested swamps surround this wetland. Uplands in this area are mixed deciduous forests containing red maple, sugar maple (*Acer saccharum*), and beech (*Fagus grandifolia*). Pastures and agricultural fields surrounding the area are used as nesting areas and are composed of glacial sand deposits.

Beaver have impounded a stream in a pasture that drains from a larger wetland, creating Site 2. The wetland portion of this site is completely dominated by dense shrub willow, with cattail and sedge stands on the borders. The forested swamps surrounding the wetland consist primarily of northern white cedar (*Thuja occidentalis*) and red maple. Pastures, cornfields, and residential housing occur to the south and east of this site, and mixed deciduous northern hardwood forest comprises the north and west borders. Nesting areas exist within the hardwood forest to the north, in clearings with glacial sand deposits.

The wetland complexes at Site 3 also were created by beavers, which impounded linear drainages that flow into a tributary of Lake St. Lawrence. This site is a mosaic of willow-dominated swamps, alder thickets, and emergent cattail and sedge marshes surrounded by red maple forested swamps and northern hardwood forests dominated by red maple, sugar maple, and beech with white pine (*Pinus strobus*) and hemlock (*Tsuga candensis*) interspersed throughout. Land use in the vicinity of Site 3 consists of a complex of agricultural fields, wetlands, upland forests, forested swamps, a few residential homes, and a marina and a state campground.

METHODS

Trapping

Trapping was conducted in 2003 and 2004 at a total of 22 sites using either 0.6- or 0.8 m-diameter aquatic nylon hoop traps where water depth exceeded 30 cm. Traps were baited with whole sardines in soybean oil, and bait was changed every 5 d. Traps were checked once daily and environmental data were recorded for each survey period. Turtles were also collected during chance encounters while they were crossing roads, or

43

if they were found during field surveys. The trap sites that produced the greatest number of turtles during the 2003 surveys were selected for the radio telemetry study areas for the 2004 season.

Data collected from captured Blanding's turtles included measurements of the carapace and plastron length and width, and shell height to the nearest millimeter (mm), weight (g), sex, approximate age, and reproductive status. The approximate age of turtles was determined by counting the annuli on the left abdominal scute of the plaston, where each annuli is considered to represent one year of growth (Sexton 1959, Wilbur 1975). Each turtle was identified by notching the marginal scutes with a triangular file (Cagle 1939). Additionally, Passive Integrated Transponders (PIT) were injected to identify road-killed turtles whose notch code had been destroyed or was missing. PIT tags were read using an AVID ® scanner. All turtles were released within 10 – 24 h of capture and returned to within 10 m of their capture location.

Radio Telemetry

Radio transmitters (Hi-Tech Services model WL300) were attached to 23 adult Blanding's turtles (seven males and 17 females) on the right posterior of the carapace parallel to the marginal scutes, using 5-min epoxy. Telemetered turtles were relocated a minimum of two times per week using a hand-held receiver (AVM, model LA12-Q) and a 5–element antenna (A.F. Antronics, model F151-3FB and F150-3FB). A WAAS-enabled Global Positioning System (GPS) Location were recorded with a WAAS-enabled Global Positioning System (Garmin V GPS) unit in universal transverse mercator (UTM) coordinates in the field and later entered as an X, Y coordinate into ArcMap 8.3 GIS (E.S.R.I. 2003).

Habitat Use

At each radiolocation, a 10-m diameter circular plot was established by measuring 5 m away from the turtle in the four cardinal directions. Within this plot, the habitat was classified into five habitat categories modified from Will *et al.* (1982), based on the dominant vegetation types within each plot: woody emergent swamp, shrub swamp, herbaceous emergent marsh, forested swamp, or upland.

Each of the habitat types were examined at several spatial scales. I created land cover data by digitizing aerial photographs from the New York State Geographic Information Systems Clearinghouse website (2003) into five coarse-scale habitat types using ArcMap 8.3 (E.S.R.I. 2003) for the three sites. The relative boundaries and vegetative cover types of the digitized land cover data were compared to wetland inventory maps from the New York State Department of Environmental Conservation (NYSDEC) and the National Wetland Inventory (NWI) to assist in the classification of the cover types of the digitized polygons. The digitized land cover data were also verified in the field to ensure that the interpretation of the area of each cover type depicted on the aerial photographs and digitized habitat boundaries matched the conditions of each site. The habitat composition of each study site was defined by the outermost radio locations of all Blanding's turtle observations, plus a 20 m buffer zone to include occasional sallies outside of established home ranges that may not have been detected when the time between radio locations was greater than 4 d. Rowe and Moll (1991) observed Blanding's turtles moving to areas adjacent to their activities center and back within a 24-h period, which led to the addition of the 20 m buffer zone in this study. The area of each coarse-scale habitat type was calculated for each site using ArcGIS 8.3

(E.S.R.I. 2003) and the created land cover layer was used to obtain the proportions of each coarse habitat type within the sites.

Home ranges were estimated for each telemetered Blanding's turtle using Ranges VI (Kenward *et al.* 2003) and the Minimum Convex Polygon (MCP) method. Because the MCP method has been widely used, I could compare my data to those from similar studies. Also, I calculated the MCP for the combined radio-locations for all turtles at a study site, which allowed representation of the minimum area used by Blanding's turtles radio-tracked during this study (Figures 1- 3). Inclusion of all areas potentially utilized by a mobile species whose home range includes multiple wetland and upland habitats is especially useful for conservation efforts (Piepgras and Lang 2000, Joyal *et al.* 2000). Outlines of individual home ranges were generated and overlaid on the land cover data to examine the proportion of each habitat category within each home range.

In order to compare the habitat characteristics between radio location points and points without turtles, I generated random points within the polygon created for each site from the MCP home ranges for all turtles. To ensure that each random point was paired with a Blanding's turtle radio location, I created a total of 375 random points. However, due to time constraints, only 356 random points were located in the field. Random points were generated using the Random Point-in-Polygon Generation Program 2nd revision (Sawada 2002), which is a Visual Basic Macro Installation for ArcGIS. This program creates a set of *n* random points within a selected polygon (multipart or single part) within a polygon layer. Once the points are generated, the program produces x, y coordinates and a Z value for each point in the coordinate system that the user selects. The random point data generated using this program were created in Universal

Transverse Mercator (UTM) coordinates in NAD 1983 Zone 18.   Once the random

points were created, the data were uploaded into a Garmin V GPS unit. I used a GPS unit

to locate points in the field in the order that they were generated.

When assessing habitat selection, the habitat categories used by Blanding's

turtles were compared to the proportions available within each site. Specifically, my

analysis of habitat use was based on a conceptual, hierarchical model of habitat selection

proposed by Johnson (1980), which provides a framework for analyzing habitat use at

different spatial levels. This approach compares habitat use and availability in stages or

orders, due to the difficulty of defining availability and the different levels of choice

encountered by an individual (Johnson 1980, Aebischer *et al.* 1993).   First order habitat

selection is represented by the complete geographic distribution of Blanding's turtles,

which was not examined in this study. Johnson's second order selection, which was

addressed in this study, and describes the composition of habitat types within an

individual's home range with respect to the proportions of habitats available at local sites

where the animal is found. In this study, the second order selection is considered

"coarse-scale" habitat selection. Additionally, this study examined the more detailed

third order selection, in which habitat types in each home range are compared to habitat

cover types observed at telemetered turtle locations. The third order habitat selection is

also referred to as "fine-scale" habitat selection in this study.

Compositional analysis (Aebischer *et al.* 1993) was used in this study as the

method to analyze coarse- and fine-scale habitat selection, and is a statistical tool that is

closely related to Johnson's (1980) ranked-based analysis of habitat selection at different

spatial scales. However, unlike Johnson's (1980) method, which uses the difference in

ranks of used and available habitat to measure habitat preference, compositional analysis

uses log-ratio analysis $(\ln[X_{U2}/X_{U1}] - \ln[X_{A2}/X_{A1}]$, where X_{U1} and X_{U2}, are proportions of

habitats used and X_{A1} and X_{A2} are proportions of available habitat). When describing the

proportional habitat available within a given area, the proportional data must sum to 1,

which is known as the unit-sum constraint (Aebischer *et al.* 1993). A consequence of this

constraint is that the preference for any one habitat type leads to an apparent avoidance of

other habitats (Aebischer *et al.* 1993). Use of log-ratio analysis of proportional data

allows detection of habitat use that may overlooked due to zero proportions by

substituting some small value for zero, which increase sensitivity of the detection of

habitat use (Aebischer *et al.* 1993). Johnson's method does not substitute values for

proportions of habitats used or available that have zero values, which may lead to a loss

of information and sensitivity (Alldredge and Ratti 1986, Aebischer *et al.* 1993). The

compositional analysis method considers each radio-tagged turtle as a sampling unit, and

uses the proportion of locations in each habitat type in the analyses. Log-ratios of

available and used habitat are calculated from the proportional habitat data. Then, the

differences in the log-ratios are calculated and analyzed using multivariate analysis of

variance (MANOVA), and based on the results of the MANOVA, Wilk's lambda is used

to assess whether habitats are used in proportion to their availability at each level

(Aebischer *et al.* 1993).

I used the compositional analysis module of Resource Selection (Leban 1999) to

perform the compositional analysis to assess second- and third-order habitat selection at

each of the three study sites, and to rank habitat types in order of preference at the two

spatial levels. The second level analysis ranked the turtle's coarse-scale habitat use from

its home range within the study site. The third level selection ranked the fine-scale or detailed habitat use at radio locations with available habitat in the individual's home range. At Site 1, where the number of habitat types exceeded the number of samples, habitat types with similar structure and density were combined for the analyses to reduce the overall number of habitat types and allow the analysis of within-site habitat use. The habitat types were combined because the compositional analysis module would not perform the MANOVA at Site 1 due to the small sample size ($n = 5$), which would result in a greater number of variables than samples.

At each radio location, I measured eight structural microhabitat variables to the nearest 0.01 m. Five of the variables described the distance of the telemetered turtle from the nearest water (DH2O), upland (DUP), woody vegetation (DWOOD), herbaceous emergent vegetation (DEVG), and basking site (DBASK). A basking site was the nearest structure (*e.g.*, roots, logs, hummocks, tussocks, shoreline, or beaver dam) to the turtle location that provided an opportunity for basking. Also, I measured the height of the tallest vegetation (VEGHT) within a 5 m radius of the turtle or random location. Average water (AVEWAT) and sediment (AVESED) depths were measured (nearest 0.01 m) at each of the four cardinal direction points 5 m from the turtle's location using a 2.5 m wooden dowel, and averaged with a depth measurement taken at the center of the plot. Water depth was defined as the distance from the surface to the transition zone of the sediment and substrate. Sediment depth was measured by pushing the dowel until it could not continue into the substrate (Carter *et al.* 1999).

Multivariate analyses were used to examine the eight structural microhabitat variables collected at each radio and random location to assess whether Blanding's turtles

select areas with specific characteristics or behave randomly, and whether males and females were found in areas with similar habitat characteristics. MANOVA was performed on the structural microhabitat variables to detect whether the telemetered turtles displayed random habitat use, and to determine whether the habitat variables measured at male and female locations were significantly different. Further, the multiple contrasts were performed assess which individual structural microhabitat variables could be used to predict where males and females were located.

Discriminant Function Analysis (DFA) was used to further examine which structural microhabitat variables are important to Blanding's turtles, and which variables explain the differences in male and female habitat use. This analysis facilitates the extraction of components that represent the majority of the variation in the data to search for potential explanations for the observed distribution of data between male and female turtles within and across the three study sites. By extracting the main sources of variation in a multivariate dataset, the effects that may not stand out may be detected because they are disassociated with another variable. Statistical analyses and tests on the structural microhabitat variables were performed using SAS (SAS Institute Inc. 2005).

RESULTS

A total of 23 adult (>17 years old) Blanding's turtles including 5 turtles from Site 1 (3 males (M):2 females (F)), 7 from Site 2 (7 F), and 11 from Site 3 (3 M: 8 F) were radio-tagged and used in the habitat use analyses. Each of the turtles were located between 10 and 35 times ($\bar{x} = 24 \pm 9.2$) between May and November 2004.

Based on the land cover GIS layer, available habitat at each of the three study areas was primarily upland (78%) due to the inclusion of locations associated with female

nesting movements within the boundaries of the study areas (Table 1). This was also the case for the proportion of each cover type estimated within the home ranges at each site (Table 2). Overall, the proportion of locations in each cover type varied between the sites (Table 3.).

Due to an inadequate number of telemetered turtles (n = 5) at Site 1, the number of turtles were equal to the number of habitat types (n = 5), which would not allow compositional analysis to be performed. Therefore, the shrub swamp and woody emergent habitat cover type categories were combined because both habitat types at this site possessed similar structural characteristics, including height, root configuration (buttressed), and density. Also, because the habitat types were combined, these data could not be compared to those from other sites for the second order analysis. Compositional analysis of the second order selection of the proportion of the four habitat cover types available at Site 1 did not differ from the habitat types used by turtles within their MCP home ranges (Wilk's lambda (λ) = 0.436, df = 3, p = 0.245). Consequently, compositional analysis did not produce a ranking of habitat preference at this spatial scale. However, compositional analysis of the third order selection indicated that the proportions of habitat types used were significantly different from the proportions available within the home ranges (λ = 0.141, df = 3, p = 0.005). The overall ranking of the habitat types at Site 1 in order of preference was forested swamp > shrub swamp/woody emergent > herbaceous emergent > upland (Table 4).

The number of telemetered turtles at Site 2 and Site 3 allowed the habitat use analysis to include all five habitat cover types. However, the sites were not combined for any analyses due to differences in overall area, proportion of habitat types (Table 3), and

51

geographic location. Compositional analysis revealed a significant difference between the home range habitat types used and the available habitat in the study area at Site 2 ($\lambda = 0.011$, df $= 4$, $p < 0.0001$) and Site 3 ($\lambda = 0.802$, df $= 4$, $p < 0.0001$). The second order selection of habitats ranked upland as most preferred and shrub swamp as least preferred at Site 2, and herbaceous emergent as most preferred and upland as the least preferred habitat for Site 3 (Table 4). A significant difference was also found between the habitats used at radio locations and habitat types available in the home ranges for both Site 2 ($\lambda = 0.082$, df $= 4$, $p < 0.005$) and Site 3 ($\lambda = 0.086$, df $= 4$, $p < 0.0001$). The third order ranking of habitat use at Site 2 indicated that herbaceous emergent was most the preferred habitat and upland was the least preferred habitat. The results of the third order selection for Site 3 ranked woody emergent habitat as most preferred and forested swamp as least preferred (Table 4).

The habitat variables measured at the three study sites were significantly different from those at random points (MANOVA, F $= 0.498$, df $= 2$, $p < 0.0001$). Although the overall model indicated that the habitat variables measured at the three sites were different, the MANOVA tests for specific differences in the measured variables between sites indicated the three study sites possessed similar ($p > 0.05$) average water and distances from woody vegetation and distances from basking sites (Table 5). Conversely, sediment depths and the distances from turtles to herbaceous emergent vegetation, upland, and water and tallest vegetation within the location-centered plot differed significantly between the three sites (Table 5). The among-site differences between the above habitat variables may have been an effect of site-specific habitat composition

including vegetation type, density, and age, or differences in the structural microhabitat use of males and females.

In addition to the differences between the structural microhabitat variables at the three sites, MANOVA also revealed that an overall difference existed between the structural microhabitat variables measured at male, female, and random locations from all sites combined (F = 5.71, df = 1, p = 0.0036). Based on the results of multiple contrast tests, the only difference between the structural microhabitat habitat variables measured at the random and male locations was sediment depth. Specifically, the contrast between males and random locations indicated that males select areas with deeper sediment depths that were significantly different than random locations (F = 6.67, df = 1, p = 0.0102) (Table 6). In addition, the contrasts indicated that there was a biologically significant difference between the sediment depths measured for males and females (F = 3.56, df = 1, p = 0.059), however, the borderline result of this test did not indicate which sex was selecting areas with deeper sediment. (Table 6). The contrast tests comparing the data from the females to males and random locations also showed that females were locating in areas near vegetation with heights that were significantly shorter than random locations (F = 6.67, df = 1, p = 0.0102) (Table 6). A MANOVA performed without random points produced a biologically significant difference between the microhabitat variables at male and female locations (F = 5.70, df = 1, p = 0.0796). The post-hoc contrast tests of microhabitat variables indicated that females were found in areas with significantly deeper sediment depths than males (F =5.50, df = 1, p = 0.0284) (Table 6).

DFA emphasized the relationship between sediment depth and vegetation height where male and female turtles were located. The DFA model including nine fine-habitat

variables (Site, VEGHT, DBASK, DUP, DH2O, DWOOD, DEHV, AVEWAT and AVESED) significantly discriminated male and female locations (Roy's Greatest Root =0.055, F = 2.26, p = 0.0178) and indicated that 70.95% of the variation between the measured habitat variables at male and female and female locations was explained by the following equation:

$$Z1 = 0.055 + 0.053X_1 - 0.003\ X_2 + 0.003X_3 - 0.001X_4 - 0.001X_5 - 0.001X_6 - 0.002X_7 - 0.001X_8 + 0.162X_9$$

where X_1 = Site, X_2 is VEGHT, X_3 is DBASK, X_4 is DUP, X_5 is DH2O, X_6 -is DWOOD, X_7 is DEHV, X_8 is AVEWAT, and X_9 is AVESED

The second axis explained only 29.05 % of the variability between male and female habitat data:

$$Z2 = 0.023 + 0.051X_1 + 0.001X_2 - 0.004X_3 + 0.001X_4 - 0.001X_5 - 0.001X_6 - 0.001X_7 - 0.001X_8\ \ -0.341X_9$$

The variation in the model is driven primarily by average sediment depth and the height of the tallest vegetation within the 10 m plot. Average sediment depth loaded highest on both axis of the DFA, followed by vegetation height. Based on the sign of these variable, female Blanding's turtles were typically found in areas with deeper sediment and shorter vegetation, while male turtles were found more often in areas with shallower sediment (or upland) with taller vegetation than females. The DFA output suggested that males behave randomly, and that female habitat use is more predictable. Specifically, males displayed a graphical distinction from females and did not display a clustered grouping around any one variable in the DFA output, where females were grouped around average sediment depths and average vegetation heights.

DISCUSSION

This study showed that a multi-scale approach to assessing habitat use is important in understanding what habitat types are important to Blanding's turtles. St. Lawrence County, New York State may be one of the few locations in the state where it is possible to examine habitat use by Blanding's turtles in a relatively undisturbed, large-scale landscape with limited development pressure. This study showed that Blanding's turtles did not use habitats in proportion to their availability and showed a preference for different habitats between sites. Second order selection at the Sites 2 and 3 ranked upland and herbaceous emergent marshes as the most preferred habitat type at each site, and shrub swamp and upland as least preferred at this scale. The differences observed between coarse-scale habitat use by Blanding's turtles at Site 2 and Site 3 were likely related to the inclusion of nesting movements in the analyses. Nesting areas were located closer to wetland habitats at Site 3 than Site 2, which caused a reduced proportion of upland in home ranges at Site 3. In addition, a greater number of radio-tagged females nested at Site 2 than Site 3, which may have resulted in the smaller proportion of upland habitat included in the turtle home ranges at Site 3. Thus, relative habitat preference appears to be greatly affected by the proportion of upland area available at a site or within home ranges. The high proportion of upland habitats estimated in both the turtle home ranges and overall study areas supports the findings of other studies that upland areas are an important habitat component used for the annual activities of Blanding's turtles (Piepgras and Lang 2000, Joyal *et al* 2000, Hamernick 2000). Joyal *et al.* (2000) also observed extensive use of uplands by Blanding's turtles associated with nesting movements of females and basking by both sexes up to 40 m from the nearest wetland.

In my study, compositional analysis of the third order habitat selection available within Blanding's turtle home ranges identified different preferred habitats at each site. Forested swamp, herbaceous emergent swamp, and woody emergent swamp were the most preferred habitat types at the three sites, while upland and forested swamp were the least preferred. The analysis of habitat use at this level is more representative of Blanding's turtle habitat use reported in other studies than the results of the second order selection of habitat use. Blanding's turtles have been reported as being associated with shallow water habitats with emergent vegetation (Congdon *et al.* 1983, Rowe and Moll 1991, Pappas and Brecke 1992, Hamernick 2000) and deep organic sediments (Ernst *et al.* 1994, Ross and Anderson 1990), and using permanent pools (Joyal *et al.* 2000), marshes, sloughs, and bays (Vandewalle and Christiansen 1996), shrub swamps (Piepgras and Lang 2000), lakes, rivers, and pond, and areas with darkly colored shallow water and living sphagnum mats (McMaster and Herman 2000). Thus, use of different habitat vegetation types appears to be regionally specific, or may follow a latitudinal trend. Piepgras and Lang (2000) and Kiviat (1993) noted extensive use of shrub swamp habitats, and Kiviat (1993) highlighted buttonbush (*Cephalanthus occidentalis*) as a specific indicator species of Blanding's turtle habitat for populations in Dutchess County, New York. Although the general compositions of available habitats at the home range and site scales were very similar in the sense that the proportions of each cover type were similarly distributed, compositional analysis produced different preference rankings. These differences in habitat preference suggest that Blanding's turtles in northern New York may not select habitat based entirely on general vegetative cover type alone, and that other factors such as structural microhabitat features may influence habitat selection.

Many studies have described the general habitat characteristics of sites occupied by Blanding's turtles, including the dimensions of aquatic features and the occurrence of habitat types, or average depths of aquatic features such as lakes and ponds. However, few studies have used microhabitat variables at turtle-centered locations to explain which variables within the specific habitat types influence habitat selection. Although many of the microhabitat variables measured in this study fluctuate seasonally, it is important to examine these variables as potential predictors of Blanding's turtle presence or absence. These types of data can be useful in habitat management plans, and for comparisons of habitat selection across the species' geographic range. Carter *et al.* (1999) demonstrated that bog turtles (*Clemmys mulenbergii*), a related emydid, exhibit a greater response to structural components than to vegetation type, and suggested that selection of a habitat type may be related to structural characteristics such as water and sediment depth. Based on the findings of this study and review of other studies, it is likely that Blanding's turtle habitat preference is also related to structural habitat characteristics. Kofron and Schreiber (1985) found that Blanding's turtles in northeastern Missouri hibernated in water depths ranging from 9.5-21 cm and mud cover to 15 cm, and Kiviat (1993) reported that pools at sites with Blanding's turtles in Dutchess County, New York had winter and springtime maximum water depths ranging from 50-120 cm. Ross and Anderson (1990) measured water depths of pond, marsh, and stream/ditch habitat at a study site in Wisconsin. They found that ponds in their study area possessed a mean depth of 65 cm, while water depth in marsh habitats was 18 cm, and stream/ditch habitat was 35 cm. The water depths in the aquatic habitat types in the Wisconsin study ranged from 3-210 cm, however; depths were described for the study area only, and were not

reported at turtle-centered locations. In this study, the average water depths measured at radio locations at the three study sites ranged from 16-182 cm and average sediment depths ranged from 6-21 cm. These findings are similar to those described by Kiviat (1993), Kofron and Schreiber (1985), and Ross and Anderson (1990) and could be incorporated into management plans in which water level management is a factor.

Other important structural microhabitat variables in this study included the measured distances from radio-located turtles to the nearest basking site and woody vegetation, which were similar between the three study sites. Radio-tagged turtles were usually located within 1.0 m of the nearest basking site and within 2.8 m of the nearest woody structure. The combined proportion of forested swamp, woody emergent swamp, and shrub swamp habitat types observed at turtle centered locations at each of the sites were 65.4% at Site 1, 74.4% at Site 2, and 63.0% at Site 3 (Table 3). Thus, turtles were found most often in aquatic areas containing some sort of woody vegetation or debris with relatively thick density that provided structure for cover or provided basking opportunities within 1.0 m. This finding is consistent with the description of habitat structure described by Kiviat (1997), where turtles were found to be associated with areas with a dense cover of shrubs with a tree fringe around the aquatic habitats.

Conversely, vegetation height and the distances of turtles from the nearest emergent herbaceous vegetation, upland, and water differed among the three sites, which suggests that these variables may be structural microhabitat features that are not general predictors of habitat preference of Blanding's turtles. These results expand on the results of the second order habitat analysis, where the habitat preferences at each of the sites differed based on availability. The differences in the structural microhabitat variables for

58

turtle locations at the three sites can be attributed to the configuration of the wetlands with respect to uplands, and density of patches of each habitat cover type available within the overall site. Sites 2 and 3 possessed a more linear configuration (based on the presence of roads and uplands) than Site 1, which resulted in shorter distances between turtles and upland areas. In addition, the different distances to water between the sites was affected by the inclusion of the higher numbers of nesting females at Site 2, which traveled longer distances overland to nest than females from Sites 1 and 3. The configurations of the sites also affected the distance between turtles and herbaceous emergent vegetation at each of the sites. At Site 2, herbaceous emergent vegetation was restricted to the periphery of a large willow-dominated pool, whereas the boundaries of this vegetative type were not as easily delineated at Site 1 because it was not confined to specific areas and was interspersed throughout the other aquatic habitats. Areas with herbaceous emergent vegetation were larger and better defined at Site 3 than the other two sites. Similarly, the site configuration and vegetative composition affected the height of the tallest vegetation found at turtle locations. Because Sites 2 and 3 were more elongated than Site 1, they tended to possess taller vegetation, consisting of trees or shrubs near the transition zones on the fringe between wetland and uplands. Based on the field observations of this study, the elongated wetlands had a greater abundance of shallow water along the periphery of the wetlands, which would allow the vegetation to grow taller due to aerobic conditions. Thus, vegetation height and distances to the nearest water, upland, and emergent vegetation at a site affect how habitats are used, and thus these variables appear to be site-specific and do not serve as general indicators of

habitat types or structural microhabitat features that could be used to predict where unknown Blanding's turtle populations are found.

Male and female Blanding's turtle habitat use differed in only two of the 13 structural microhabitat features measured. Female Blanding's turtles selected areas with deeper sediment and shorter vegetation, while male turtles selected areas with shallower sediment (or upland) with taller vegetation than females. Average sediment depth appeared to be a strong predictor of how males and females utilized available microhabitat habitat for life activities, and was not site-specific. Further, although the mean height of the tallest vegetation measured differed between the three sites, this variable appeared to be important in predicting where males and females are located within a given habitat type based. Selection of deeper sediments and shorter vegetation by females could be explained by a need to need to meet specific biological requirements such as thermoregulation or development of eggs. Shorter vegetation provides increased opportunity for basking and increased line of sight to for predator avoidance. Deeper sediment provides a more stable temperature regime, and may aid in gestation of eggs by females, or provide a different food or nutrient source than areas with shallower sediment. During this study, males made sporadic movements and used forested swamps and alder-dominated shrub swamps more than females. These habitats possessed taller vegetation heights and shallower sediments than the willow-dominated woody emergent swamps where females were most often located. Again, these observations can be attributed to behavioral differences between males and females, with males making unpredictable movements associated with mate-searching and foraging, and females tending to exhibit fidelity to specific areas and exhibit more predictable movements

throughout the active season . Site fidelity in females and frequent movements by males have been documented in Minnesota (Piepgras and Lang 2000) and Maine (Joyal *et al.* 2000), where adult Blanding's turtles move to multiple bodies of water throughout the active season, presumably to locate food or a mate.

This study confirms that Blanding's turtles require a mosaic of upland and several different wetland habitat types, although they were associated primarily with wetlands containing an abundance of woody vegetation and structure with relatively shallow water depths and deep sediments. Blanding's turtles exhibit fidelity to nesting areas and primary use wetlands (Ernst *et al.* 1994). Thus, upland areas serve as an important component of the overall habitat types required for life activities by providing linkages between adjacent wetlands and nesting sites. In addition, wetlands must possess a range of vegetation heights to provide suitable areas for males and females. Further exploration of sex-specific microhabitat selection may help to explain sex ratio trends for Blanding's turtles. Studies have found that female-skewed sex ratios are common, while juveniles are rarely captured (Ross and Anderson 1990, Rowe and Moll 1991, Hamernick 2000, Piepgras and Lang 2000). I found the same trend while trapping at sites in northern New York. The lack of male and juvenile captures may be related to trapping techniques, where a minimum water depth is required for the use of hoop traps, which restricts the placement of traps to areas with water deep enough for their use to allow turtles to enter the traps. Therefore, future studies should consider employing traps that can be used in areas with shallower water to determine whether the lack of male and juvenile captures is due to low numbers of these demographic groups due to mortality or a lack of recruitment, or simply trapping methods. In addition, due to their tendency to make

frequent movements, captures of more males that leave their primary use wetlands in search of mates during the mating season and use of radio telemetry may lead researchers to wetland areas supporting additional populations of Blanding's turtles that have not been identified.

MANAGEMENT IMPLICATIONS

Blanding's turtle populations are declining throughout their range (New York Natural Heritage Program 2008). In New York State, there currently are 64 extant Blanding's turtle occurrences reported in Dutchess, Saratoga, St. Lawrence, Jefferson, Niagara, and Erie counties (New York State Natural Heritage Program 2008). However, self-sustaining populations have been identified only in Dutchess, Saratoga, St. Lawrence, and Jefferson Counties (New York State Natural Heritage Program 2008). Each of the regions exhibits a variety of different aquatic and upland habitat types and vegetative species composition. Therefore, it is important to identify the microhabitat requirements and habitat signatures for this species so that additional populations may be documented, and develop conservation and habitat management plans to address potential habitat loss or isolation due to development.

Use of multiple habitat types at different scales by Blanding's turtles emphasizes the need to consider a multi-level approach to assess areas that must be protected. For example, if the coarse scale level of habitat use is ignored, the importance of upland habitat may not be detected, even though it is an important habitat requirement. If upland linkages to nesting sites and other wetlands are lost to development, populations may become isolated and experience reduced fitness. Thus, upland buffer areas of a minimum of 100 m should be placed around primary use aquatic habitats and travel corridors

between adjacent aquatic habitats and nesting areas. In southern Maine, Blanding's turtles basked up to 40 m from wetlands (Joyal *et al.* (2000), and upland forest habitat was used during periods of relative dormancy in the late summer at distances up to 110 m from wetlands. During the spring season in Illinois, upland forest was used when water temperature was low (Rowe and Moll 1991). Long-distance overland travel to nesting areas and between aquatic habitats up to 1.4 km by Blanding's turtles has been well documented (Ernst *et al.* 1994). Although the specific characteristics of upland travel corridors have not been described, the observation that uplands around aquatic habitat provide additional options for thermoregulation and serve as travel corridors indicate that upland habitats should be included in conservation plans, along with wetland habitats and nest sites. Further, based on the use of multiple habitat types within and between sites, protection of wetland mosaics is necessary to protect populations of Blanding's turtles. Conservation efforts in New York should focus on identifying the detailed distribution and population densities of Blanding's turtles to determine the overall population trends. Regional-specific habitat cover types that serve as indicators of where Blanding's turtles may occur should be identified (e.g. willow- or buttonbush-dominated shrub swamp or emergent marshes), and search efforts should focus on areas within habitats that possess water depths ranging from 16-182 cm and average sediment depths between 6-21 cm. In northern New York, the region-specific habitat type appears to include shrub swamps influenced by beaver activity that are dominated by willow interspersed with sedges, with permanent deep (30- 180 cm) open pools connected by shallow (16 – 40 cm) channels with abundant root structure at the base of the shrubs and a tree or shrub fringe. Identification of region-specific Blanding's turtle habitat will allow more efficient

distribution surveys. Once surveys identify sites occupied by Blanding's turtles, additional studies should assess the extent of upland and adjacent aquatic habitats that require immediate protection from development pressure.

Another factor that should be considered for Blanding's turtle conservation is the lack of movement between local populations. Both male and female radio-tagged turtles at all three study areas exhibited fidelity to nesting areas and regular activity areas throughout this study, and did not emigrate to other wetlands where Blanding's turtles were captured. Several of the trap sites were located approximately 1 km from the sites selected for the radio telemetry study in habitat types similar to those of the study areas, and Blanding's turtles were captured and marked at each of these areas. However, we did not recapture marked turtles at adjacent trap sites, nor did we observe any movements of the radio-tagged turtles to the adjacent sites. This suggests that populations of Blanding's turtles in northern New York may be characterized as metapopulations, with larger populations that exhibit consistent recruitment being restricted to wetland complexes with an abundance of suitable habitat and little human influence (e.g. roads, agriculture, and housing), and little movement (immigration or emigration) to other sites. Several of the trap sites produced only one to three turtles. These sites were historically contiguous with the larger wetland complexes, but eventually became disconnected from these areas due to alteration of surface water from beaver and beaver dam removal, agriculture, and housing developments. As a result, these smaller, relatively isolated wetlands may become population sinks that may receive few immigrants from adjacent populations, and may be more susceptible to habitat alteration and development than populations inhabiting larger wetland complexes. Therefore, management plans should

also address connectivity between populations of Blanding's turtles to provide a means for migration to facilitate overall population stability and genetic diversity in northern New York and other regions where this species is found.

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Table 1. Habitat cover types available at three study sites in St. Lawrence County, New York (based on interpretation of 2003 aerial photography and ground truthing).

	Site 1	Site 2	Site 3
Cover Type	%	%	%
Forested Swamp	12.6	0.3	3.1
Herbaceous Emergent	6.4	2.4	5.3
Shrub Swamp	13.1	16.7	2.2
Upland	62.1	74.3	73.3
Woody Emergent	5.9	6.2	16.2
Total	100	100	100

Table 2. Habitat cover types calculated within Blanding's turtle home ranges (MCP) at three study sites in St. Lawrence County, New York.

	Site 1	Site 2	Site 3
Cover Type	%	%	%
Forested Swamp	2.0	1.3	0.4
Herbaceous Emergent	3.8	0.7	2.0
Shrub Swamp	12.9	7.9	7.9
Upland	78.0	84.4	73.3
Woody Emergent	3.3	5.6	16.4
Total	100	100	100

Table 3. Habitat cover types at telemetered Blanding's turtle locations at three study sites in St. Lawrence County, New York.

	Site 1	Site 2	Site 3
Cover Type	%	%	%
Forested Swamp	4.6	5.8	12.8
Herbaceous Emergent	32.7	14.5	34.3
Shrub Swamp	43.9	11.4	12.9
Upland	1.8	1 1.1	2.2
Woody Emergent	16.9	57.3	37.9
Total	100	100	100

Table 4. Habitat preference rankings based on compositional analysis of all turtles at Sites 1, 2, and 3 during 2004.

Second Order[1]
  Site 1   no difference in preference detected
  Site 2   upland > woody emergent > herbaceous emergent > forested swamp > shrub swamp
  Site 3   herbaceous emergent > forested swamp > shrub swamp > woody emergent > upland

Third Order[2]
  Site 1   forested swamp > shrub swamp/woody emergent > herbaceous emergent > upland
  Site 2   herbaceous emergent > forested swamp > shrub swamp > woody emergent > upland
  Site 3   woody emergent > upland > shrub swamp > herbaceous emergent > forested swamp

[1]Second Order = Site vs. MCP home range
[2]Third Order = MCP home range vs. telemetry locations.

Table 5. Means and results of MANOVA for males, females, and random points at three study sites in northern New York in 2004, all values are in meters.

Variable	Site 1 Mean(SD)	Site2 Mean(SD)	Site3 Mean(SD)	P
AVGWAT[1]	0.16(0.12)	1.82(22.59)	0.26(0.26)	0.59
AVGSED[2]	0.21(0.17)	0.06(0.08)	0.12(0.12)	<0.001
DBASK[3]	0.70(2.05)	1.05(2.40)	0.70(1.05)	0.29
DWOOD[4]	0.83(1.17)	2.83(23.49)	0.63(0.88)	0.47
VEGHT[5]	2.95(0.27)	8.62(7.29)	4.11(2.57)	<0.001
DUP[6]	63.53(36.89)	13.27(17.93)	22.17(19.85)	<0.001
DH2O[7]	1.50(6.49)	9.39(19.23)	1.90(4.49)	<0.001
DEHV[8]	0.21(1.30)	2.706.81)	1.39(3.98)	<0.001

[1]AVGWAT = average water depth;
[2]AVGSED = average sediment depth;
[3]DBASK = distance to nearest basking site;
[4]DWOOD = distance to nearest woody vegetation.
[5]VEGHT = height of tallest vegetation;
[6]DUP = distance to upland;
[7]DH2O = distance to water;
[8]DEHV = distance to nearest herbaceous emergent vegetation.

Table 6. Means of measured microhabitat variables for males, females, and random points combined at three study sites in northern New York, all values are in meters.

Variable	N	Female Mean(SD)	N	Male Mean(SD)	N	Random Mean(SD)
VEGHT[1]	17	3.79(1.57)	6	4.15(2.11)	356	7.73(6.51)
DBASK[2]	17	1.16(1.12)	6	1.42(1.55)	356	0.84(2.18)
DUP[3]	17	27.02(11.69)	6	2.07(10.06)	356	34.20(36.94)
DH2O[4]	17	1.11(2.69)	6	0.82(1.23)	356	5.60(14.91)
DWOOD[5]	17	0.97(0.86)	6	1.31(0.99)	356	1.80(16.78)
DEHV[6]	17	0.53(0.88)	6	0.33(0.39)	356	1.63(5.27)
AVGWAT[7]	17	0.33(0.14)	6	0.37(0.11)	356	1.01(16.10)
AVGSED	17	0.14(0.06)	6	0.27(0.23)	356	0.12(0.15)

[1] VEGHT = height of tallest vegetation;
[2] DBASK = distance to nearest basking site;
[3] DUP = distance to upland;
[4] DH2O = distance to water;
[5] DWOOD = distance to nearest woody vegetation;
[6] DEHV = distance to nearest herbaceous emergent vegetation;
[7] AVGWAT = average water depth;
[8] AVGSED = average sediment depth.

Legend

Upland

Forested Swamp

Herbaceous Emergent Marsh

Shrub Swamp

Woody Emergent Swamp
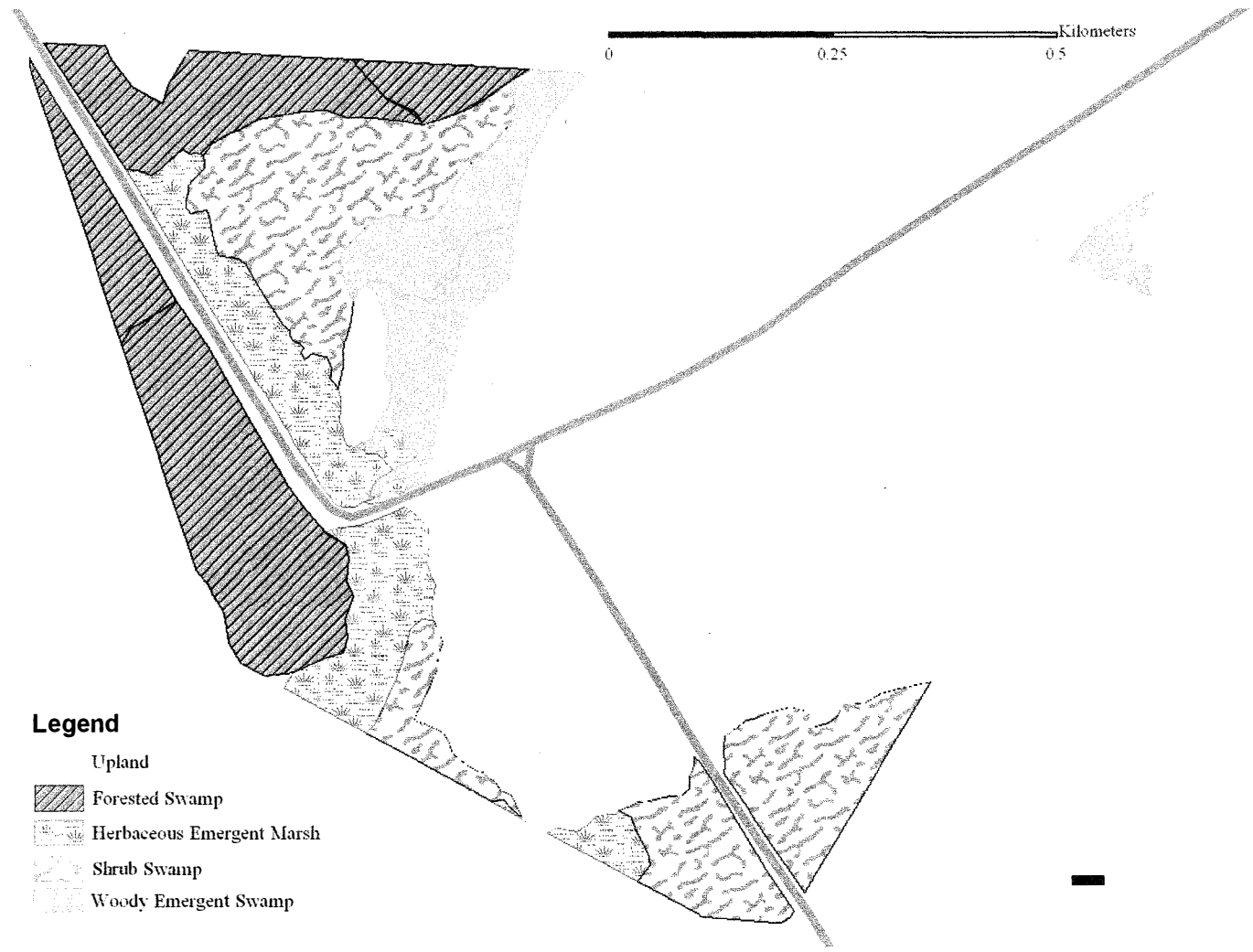
Figure 1. Habitat cover type map of the area within the 100% minimum convex polygon home range of all telemetered turtle locations at Site 1 in 2004.

Legend

    Upland

    Forested Swamp

    Herbaceous Emergent Marsh

    Shrub Swamp

    Woody Emergent Swamp
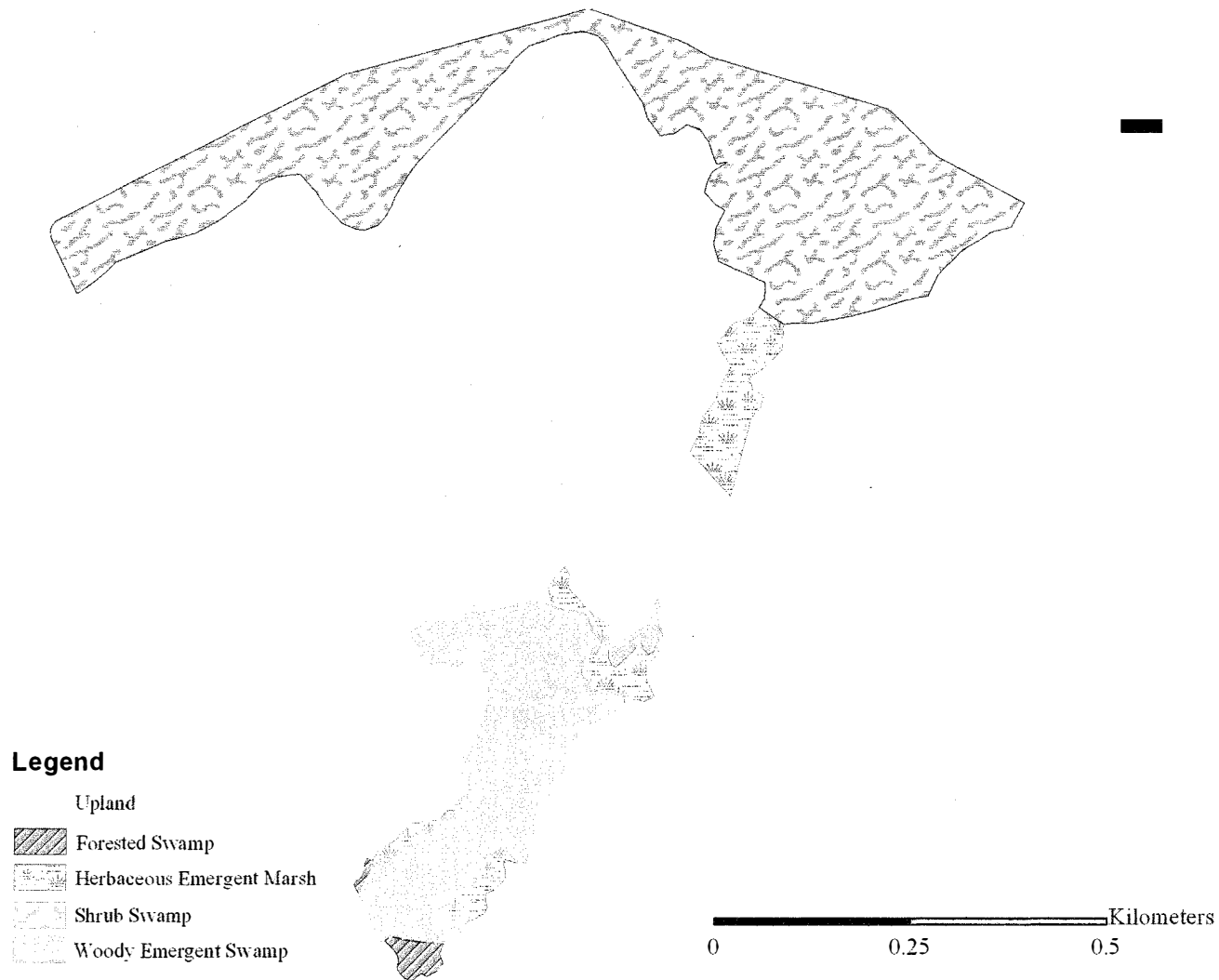
Figure 2. Habitat cover type map of the area within the 100% minimum convex polygon home range of all telemetered turtle locations at Site 2 in 2004.

Legend

- Upland
- Forested Swamp
- Herbaceous Emergent Marsh
- Shrub Swamp
- Woody Emergent Swamp

Kilometers
0   0.25   0.5

Figure 3. Habitat cover type map of the area within the 100% minimum convex polygon home range of all telemetered turtle locations at Site 3 in 2004.

APPENDICES

Appendix I. Measurements of juvenile Blanding's turtles captured in traps and by hand from May 2003- September 2004 in at 22 study sites in northern New York.

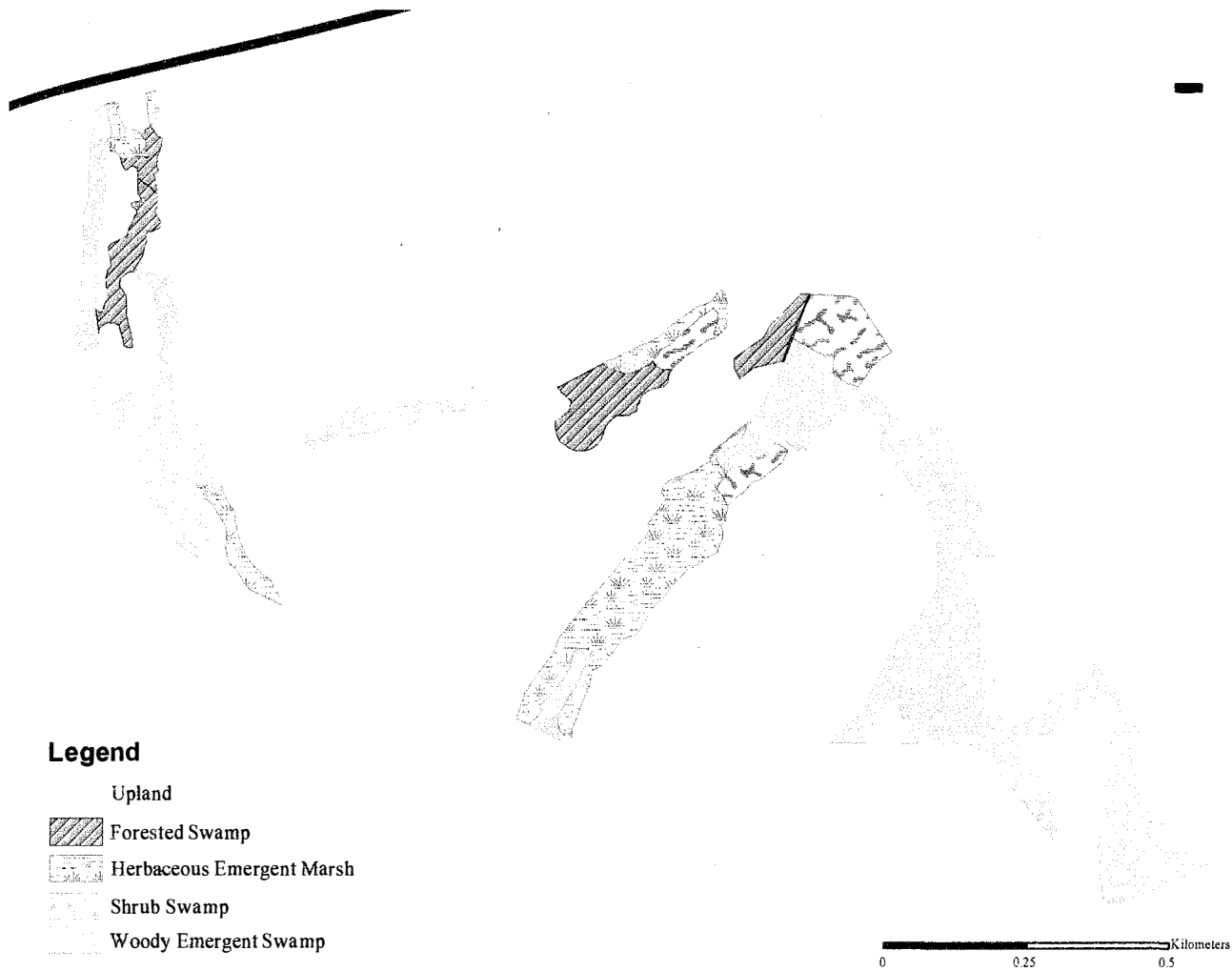| Sex	Weight (g)	Carapace Length (mm)	Carapace Width (mm)	Plastron Length (mm)	Plastron Width (mm)	Carapace Height (mm)
Juvenile	26	55.9	46	49.9	29	21
Juvenile	66	77	61	73	40.5	31
Juvenile	295	124	87	121	64	51
Juvenile	195	102	85	101	57	43
Juvenile	273	129	92	124	68	49
Juvenile	207	110	80	104	56	82
Juvenile	750	174	117	169	87	69
Juvenile	260	122	88	114	63	48
Juvenile	133	146	101	140	75	58
Juvenile	173	104	78	102	56	44
Juvenile	163	105	76.5	102	55.1	41
Juvenile	336	134	97	131	75	52
Juvenile	280	122	90	121	65	50
Juvenile	400	139	99	135	73	57
Juvenile	590	157	110	158	83	60
Juvenile	257	125.2	89.5	124.3	66	48
Juvenile	346	138.1	99	134	73	51.1
Juvenile	-	179	122	177	96	77
Juvenile	480	152	118	79	151	61
Juvenile	785	177	118	174	87	70
Juvenile	656	172	109	168	87	64
Juvenile	750	175	118	174	88	68
Juvenile	638	160	112	160	86	63
Juvenile	600	157	113	157	83	59
Juvenile	265	120	83	117	65	46

Appendix II. Measurements of female Blanding's turtles captured in traps and by hand from May 2003- September 2004 in at 22 study sites in northern New York.

Sex	Weight (g)	Carapace Length (mm)	Carapace Width (mm)	Plastron Length (mm)	Plastron Width (mm)	Carapace Height (mm)
Female	680	171	115	168	84	65
Female	1350	208	142	206	116	81
Female	925	184	119	179	94	73
Female	1420	211	138	203	112	82
Female	940	191	127	174	91	71
Female	1040	201	127	196	113	76
Female	1320	210	139	201	106	85
Female	1000	195	127	198	100	78
Female	1100	194	134	192	101	76
Female	1780	231	159	226	119	86
Female	1142	203	134	201	102	77
Female	1400	216	140	213	109	83
Female	880	185	129	182	96	71
Female	1280	194	148	200	113	84
Female	1514	218	147	216	116	81
Female	1490	222	150	220	115	87
Female	940	228	151	227	118	87
Female	1345	204	137	204	109	85
Female	1600	218	146	216	113	86
Female	1540	222	153	224	122	86
Female	1800	236	156	226	119	89
Female	1830	234	156	235	120	91
Female	1552	228	146	218	115	87
Female	-	224	149	218	114	91
Female	1250	207	138	205	109	81
Female	1220	217	136	215	119	83
Female	1510	229	145	218	116	88
Female	1580	217	147	216	118	89
Female	1700	227	157	223	119	86
Female	1690	232	143	221	109	88
Female	1350	209	136	206	111	87
Female	1510	217	152	216	117	87
Female	1840	210	140	202	112	82
Female	1298	207	148	207	110	79
Female	1466	222	146	220	122	86
Female	1920	243	155	234	122	97
Female	1542	221.5	152	221	123	86
Female	1600	225	156	217	120	87
Female	1490	222	158	220	117	90
Female	1880	223	158	223	120	88
Female	1610	221	153	222	115	89
Female	840	175	116	173	87	74
Female	1710	227	155	225	121	91
Female	1650	220	149	225	114	93

Appendix III. Measurements of male Blanding's turtles captured in traps and by hand from May 2003- September 2004 in at 22 study sites in northern New York.

| Sex	Weight (g)	Carapace Length (mm)	Carapace Width (mm)	Plastron Length (mm)	Plastron Width (mm)	Carapace Height (mm)
Male	1298	221	134	206	102	79
Male	1512	221	149	207	106	81
Male	1500	226	154	211	110	86
Male	1684	229	147	220	118	89
Male	1840	236	153	217	119	87
Male	2000	230	159	218	115	92
Male	1345	214	148	213	111	83
Male	1742	237	158	221	120	89
Male	1780	235	154	206	117	86
Male	1600	230	151	216	111	79
Male	1380	214	145	196	119	82
Male	1522	223	145	217	112	82
Male	1490	218	147	202	112	83
Male	1520	227	143	207	108	81
Male	1480	222	146	208	109	77
Male	1506	222	147	206	108	84
Male	2150	250	161	237	119	98
Male	980	236	156	213	113	87
Male	1540	229	147	207	111	84
Male	1480	230	153	212	106	85
Male	1775	225	156	217	115	84
Male	1720	233	161	214	128	88
Male	1540	218	150	200	110	88
Male	1660	280	147	214	113	87
Male	1810	238	157	218	112	89
Male	1940	237	159	227	114	92
Male	1820	239	154	219	118	89
Male	1610	222	146	200	112	83
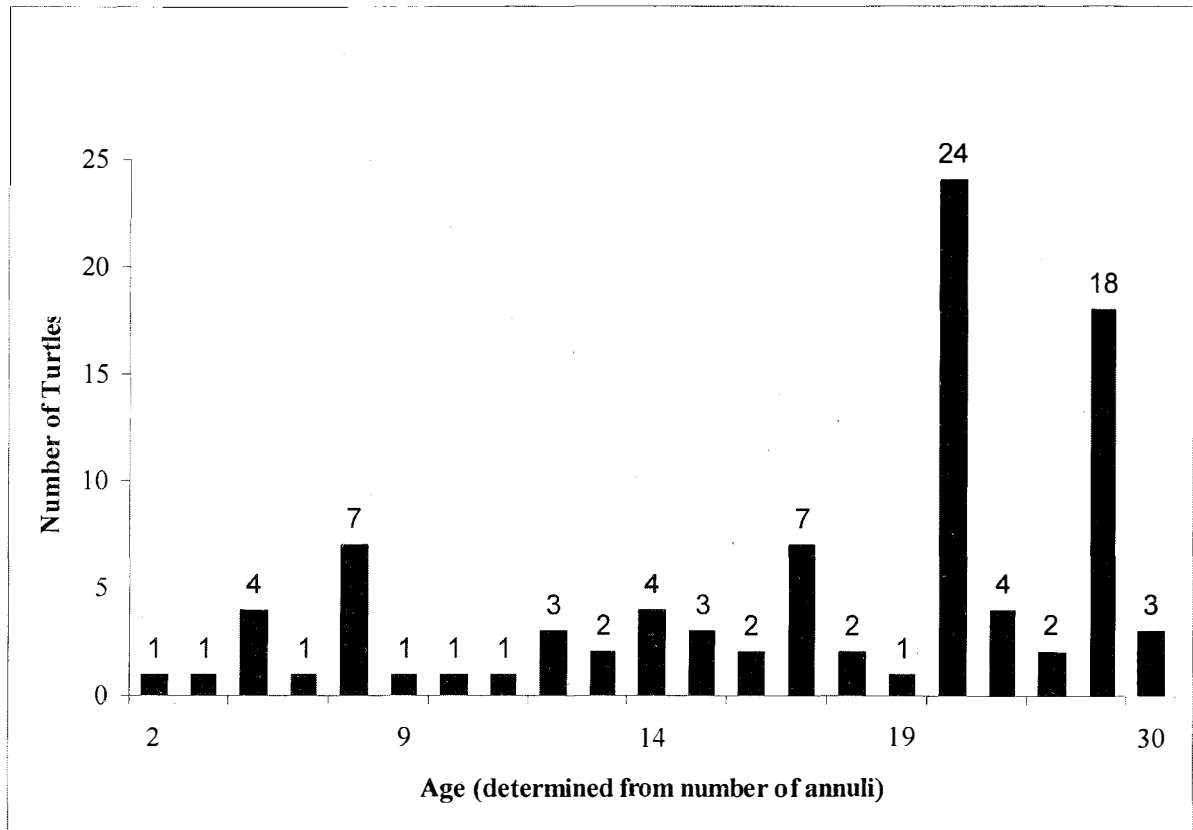
Appendix IV Age distribution (in years) of Blanding's turtles (n = 99) captured by hand or in traps in 2003 and 2004 in northern New York State.
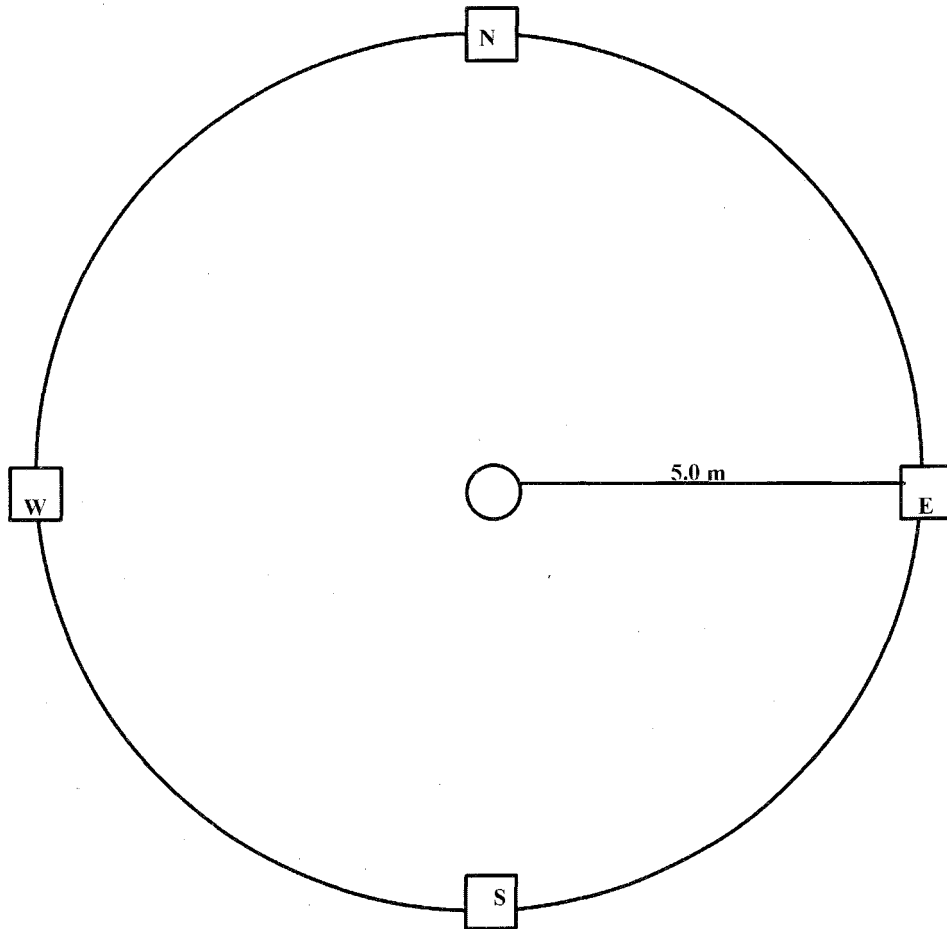
Appendix V. Overhead layout of water and sediment depth sampling protocol for turtle centered and random locations.
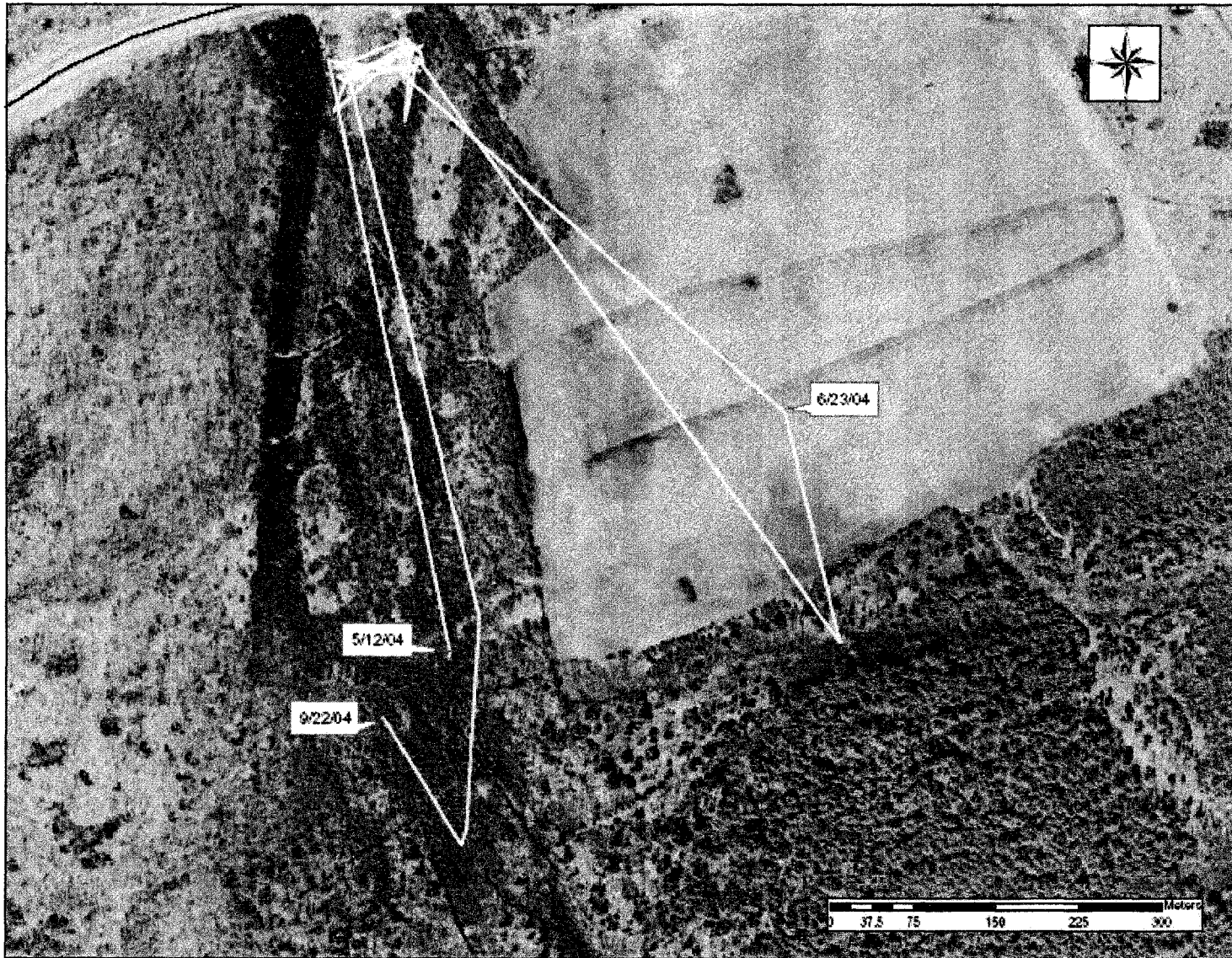
Appendix VI. Example of the movements of a female Blanding's turtle in northern New York.
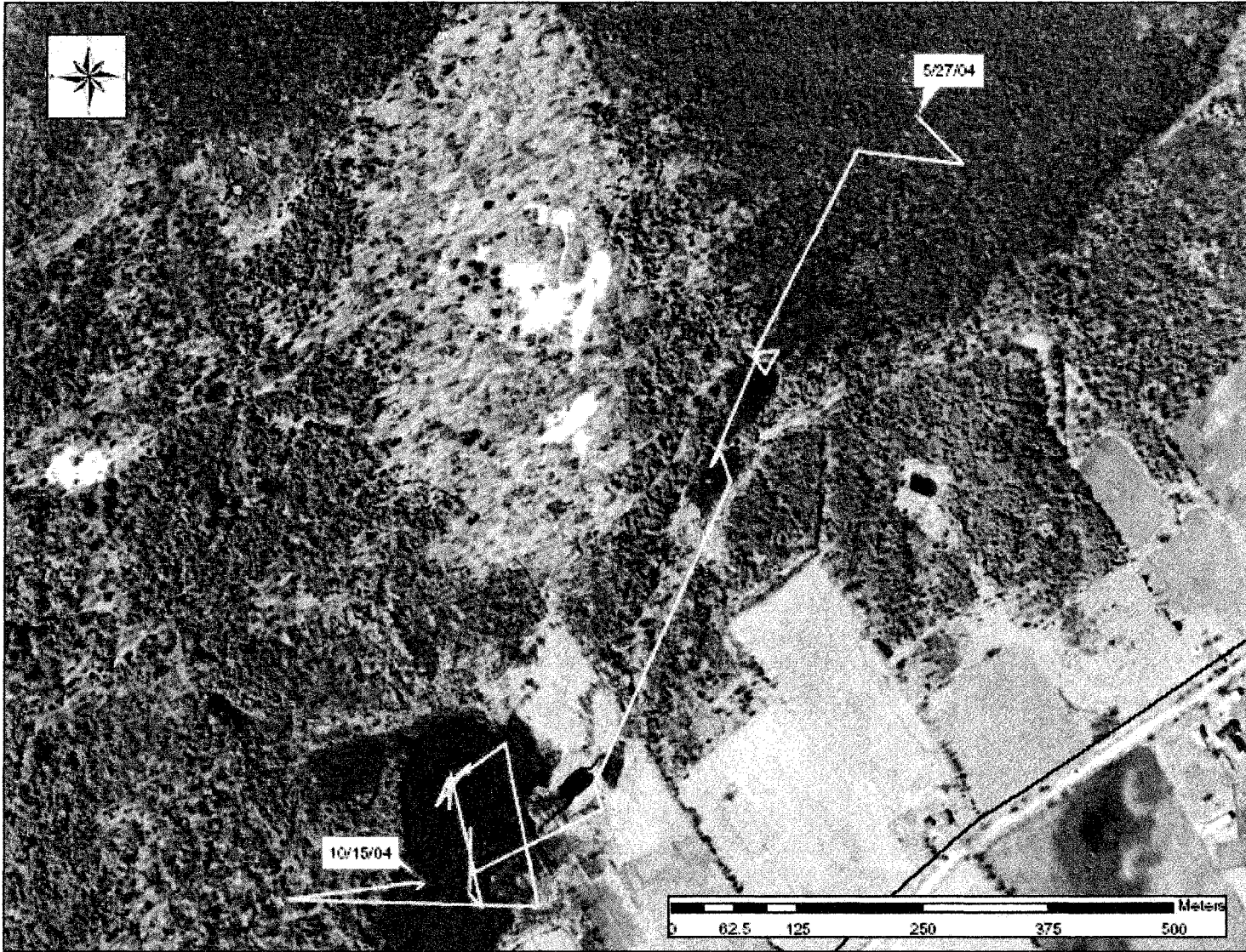
Appendix VII. Example of the movements of a male Blanding's turtle in northern New York.