MOVEMENT AND OVERWINTERING BEHAVIOR OF STERNOTHERUS MINOR PELTIFER (STRIPE-NECKED MUSK TURTLE) IN WHITEOAK CREEK, HOUSTON AND HUMPHREYS COUNTIES, TENNESSEE

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A. Floyd Scott, Major Professor

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A Thesis

Presented for the

Master of Science Degree

Austin Peay State University

Joshua R. Ennen

August 2005

DEDICATION

This thesis is dedicated to

Mr. Tom Johnson and family, Mr. John Cook, Mr. Randy Norfleet, Mr. Fred Payne, and

Ms. Susan Gilmore, the landowners

who allowed me to conduct research on their land.

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Finally, I extend my sincere appreciation to my family for their unwavering support throughout this project and in every life decision I have made so far.

ABSTRACT

Little information is available on the movement behavior of any of the subspecies of *Sternotherus minor*. Most published studies on the species focus on other aspects of its life history and phylogeny. This paper presents the findings of an investigation begun in May 2004 of movements, overwintering strategy, and diel activity of a population of *S. minor peltifer* in Whiteoak Creek, a tributary to Kentucky Lake (impounded Tennessee River) in Houston and Humphreys counties, Tennessee. Using radio telemetry and Geographic Information System (GIS) technologies, 14 individuals (6 males, 8 females) were relocated once weekly for periods ranging from 9 to 50 weeks. Their movements were plotted in relation to assorted physical and biological features in and along the stream. Movements over the 24-hour cycle were also monitored on 7 occasions. Data obtained suggests a linear-shaped home range (mean 341.4 m) extending along stream reaches with ample shoreline cover. Mean length of home ranges of males (335 m) was not significantly different from that of females (346 m). Of 7 distinct microhabitats utilized overall, submerged limestone bluffs and vegetated limestone outcrops were the most frequented accounting for 58.0% and 16.0%, respectfully, of all initial captures and relocation points. During winter months (December - March), however, only 5 microhabitats were used, with limestone bluffs at 72.4% and vegetated limestone outcrops at 20.4% topping the list. Frequency of usage by males and females also differed throughout the year. The mean depth of relocation points throughout the study was 0.88 m with depths for females exceeding that of males. Seven turtles were essentially inactive between December and March, while 4 individuals remained minimally active. Movements observed over the 24-hour cycle suggest a nocturnal

pattern of behavior especially among females and during the months of July and August. During the fall months, no preference was exhibited for any particular part of the 24-hour cycle.

TABLE OF CONTENTS

LIST OF TABLES

Tables | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Little to nothing has been published about the overwintering behavior, movement, and diel activity of *Sternotherus minor* (Stripe-necked Musk Turtle), and the information that is available does not identify which subspecies (*S. m. minor* or *S. m. peltifer*) was examined when it was obtained. In their account for *S. minor*, Ernst et al. (1994) mention that 1) activity occurs both day and night with peaks in the morning, 2) soft bottom, submerged rock cervices, or muskrat bank burrows are utilized as hibernacula, and 3) hibernation occurs December through February in the northern portions of it's range. Studies of these life history aspects via radio telemetry in other members of the genus are also limited. Dodd et al. (1988) studied movements using radio telemetry, but determined diel behavior of *S. depressus* in Alabama by capture data. Other diel behavior studies conducted within the genus involved *S. odoratus* (Smith and Iverson, 2004; Bancroft et al., 1983; Graham and Hutchinson, 1979; Lagler, 1943; Ernst, 1986; and Mahmoud, 1969) and *S. carinatus* (Mahmoud, 1969). The role of temperature in determining levels of activity in *S. minor* has not been investigated.

Considering the paucity of basic information on the ecology and behavior of *S. m. peltifer*, this study focused on several aspects (overwintering behavior, movement patterns, and diel rhythm) of the life cycle of this aquatic turtle. The data obtained can be used by resource managers in both public and private sectors to help ensure that this and related species remain a part of the biota of Tennessee and the southeastern United States.

Literature Review

Overwintering Behavior in Turtles

Ultsch (1989) suggested that the hibernacula of turtles overwintering in water are often found in hypoxic environments and that selection of anaerobic or hypoxic hibernacula will produce physiological adaptations. For example, selecting anaerobic hibernacula causes turtles to utilize glycolysis for ATP production (Gatten, 1987). The physiological adaptations to overwintering will unequivocally influence ecological and life history aspects of the organism (Gregory, 1982). Conversely, aspects of the ecology and life history of an organism, such as overwintering strategies and movements, will influence the physiological adaptations of the organism as well. Therefore, overwintering microhabitat selection plays an extremely important role in survival.

Overwintering is the widely accepted term used to describe the response behavior of reptiles in colder environments (Gregory, 1982; Ultsch, 1989). This and similar response behaviors to environmental changes allow reptiles to survive the winter and other harsh conditions like drought and lack of resources (Ultsch, 1989). Mortalities in aquatic turtles have been shown to increase when the environmental conditions are colder (Ultsch, 1989), thus demonstrating the importance of selecting overwintering habitat. Overwintering is probably influenced by three factors: climate, body size, and food supply (Gregory, 1982), with the latter having the most dramatic influence. Some reptiles, including turtles, living in higher latitudes (North or South) spend the majority of the year in an overwintering state (Ultsch, 1989), thus increasing the importance of selecting appropriate hibernacula to increase survival.

In selecting an aquatic hibernaculum, two factors (freezing and desiccation) are alleviated that would be problems in terrestrial hibernation (Ultsch, 1989). Overwintering in the running water of streams or deep waters of lakes is adaptively advantageous because freezing rarely occurs (Ultsch, 1989). Aquatic hibernacula present oxygen-availability issues because of the anoxic environment on the bottom and ice cover above, which prevents turtles from reaching the surface (Ultsch, 1989). Other problems associated with turtles using aquatic hibernacula involve maintaining water balance, ionic balance, and avoiding predation (Ultsch, 1989).

Movement and Diel Patterns in Turtles

Life history and ecology are intimately related to an organism's movement patterns (Gibbons et al., 1990). Movement data (home range and diel) of any species will elucidate the habitat requirements needed (basking sites, feeding, cover, and mating) in the species' aquatic ecosystem. Home ranges and movement are intimately connected to the daily and seasonal habitat needs of the species. Turtle movement can be classified into two categories: spatial and temporal (Gibbons et al., 1990). Spatial movements can be further classified as intrapopulational (short-range) or extrapopulational (long-range), and temporal movements can be partitioned as daily (diel), seasonal, or sporadic (Gibbons et al., 1990).

All movements require the expenditure of energy to acquire necessary resources to survive and increase reproductive success. Data on movement patterns (daily and seasonal) lead to an understanding of the cost and risk of acquiring energy, the total energy budget, and the benefits of movement (Rowe and Moll, 1991). Short-range (intrapopulational) movement patterns are important for ectothermic organisms in thermoregulation (basking or thermal regulating behavior), feeding (to acquire energy for maintenance, growth, reproduction, and storage), dormancy, courtship, and predator avoidance (Gibbons et al., 1990; Gouley, 1979). Studying seasonal or long-range (extrapopulational) movements provides information on breeding patterns (e.g. mate seeking), nesting habits, habitat usage over the annual cycle, foraging patterns, dispersal of young, and migration associated with overwintering and aestivation (Gibbons et al., 1990).

Information on an organism's diel patterns, which are a component of short-range movements, reveals the nature of its activity over the 24-hour cycle. This activity can be characterized as nocturnal, diurnal, or crepuscular. A species' diel behavior could be adaptive to maximize efficiency for physiological processes or the result of competition in an ecosystem (Gourley, 1979). Competition for the same resource could spatially separate species in an ecosystem but could also create a temporal separation resulting in different diel behaviors among the species with similar resource requirements (Gourley, 1979).

The Study Animal

Taxonomy and Nomenclature

A member of the family Kinosternidae, *Sternotherus minor* was first described by Agassiz (1857) from Mobile County, Alabama, under the name *Goniochelys minor*. In 1862 the name was changed by Strauch to *Armochelys minor* (Iverson, 1977b). The currently accepted binomial, *Sternotherus minor*, was provided by Stejneger (1923). *Sternotherus minor* includes two recognized subspecies: *Sternotherus minor minor* and

Sternotherus minor peltifer (Tinkle and Webb, 1955), the latter being the focus of this study.

The family Kinosternidae has a controversial phylogeny that is still being deciphered (Iverson, 1998). Many studies have attempted to determine the phylogeny and relationships between the members of the family and for the genus *Sternotherus* (Seidel and Lucchino, 1981; Seidel et al., 1986; Ernst et al., 1988; Iverson, 1991; Iverson, 1998). Seidel and Lucchino (1981) used an electrophoretic analysis to determine that *S. depressus* and *S. minor* are genetically distinct sister species. Iverson's (1977a and 1998) and Tinkle's (1958) findings supported the conclusions of Seidel and Lucchino (1981). While using a different approach to the question (shell morphology), Ernst et al. (1988) determined that *Kinosternon minor peltifer* (today know as *S. m. peltifer*) growth curve was significantly different than the other species in the complex (*Sternotherus*). This suggests that *S. m. peltifer* and *S. depressus* are distinct species. The phylogenetic controversy lies in the separation of *Kinosternon* to create *Sternotherus* (Seidel et al., 1986; Iverson, 1998; Iverson, 1991). Seidel et al. (1986) and Iverson (1991) concluded there was not enough evidence to support the split of *Sternotherus* from *Kinosternon*. However, Iverson (1998) provided ample genetic evidence for the monophyly of the genus *Sternotherus* and its resurrection from the synonymy of *Kinosternon*.

Life History

Sternotherus minor peltifer has not been thoroughly studied. In most studies that mention or include *S. m. peltifer*, the turtle is not the main target taxon. A diet assessment (Folkerts, 1968) and two population analyses (Guyer and Herndon, 1992; Williamson, 2001) are the only studies that focus directly on the subspecies. More recent literature on *S. m. peltifer* has involved reports of new county records from Tennessee (Scott et al., 2000) and Mississippi (Jones et al., 1993). In addition, one master's thesis has been written (Williamson, 2001) providing substantial data on the structure, habitat, and distribution of the Whiteoak Creek population, but limited information on movements.

<u>Geographic Distribution</u>

The range of *Sternotherus minor* (Figure 1) includes all or portions of seven southeastern states: Florida, Georgia, Alabama, Mississippi, Tennessee, North Carolina, Virginia (Iverson, 1977b; Ernst et al., 1994; Conant and Collins, 1998). The subspecies *S. minor minor* occurs throughout most of Georgia, the northern half of Florida's peninsula and all of its panhandle, and in southeastern Alabama westward to the Mobile Delta. *Sternotherus m. peltifer* ranges from the panhandle of Florida westward to eastern Mississippi and northward through most of Alabama and northwestern Georgia to eastern Tennessee and extreme southwestern Virginia (Ernst et al., 1994; Iverson, 1977b; Conant and Collins, 1998). Ranges of the two subspecies are sympatric over most of the Florida panhandle and southeastern Alabama. A population discovered by Scott et al. (2000) in the Whiteoak Creek drainage (tributary to Tennessee River) of Houston and Humphreys counties, Tennessee, is 120 km north of the nearest known population in Landerale County, Alabama (Mount, 1975).

<u>Other Related Literature</u>

Additional references relevant to this project and to *S. minor* or closely related taxa follow and are listed by subject: Distribution – Warton and Howard (1971), Tinkle

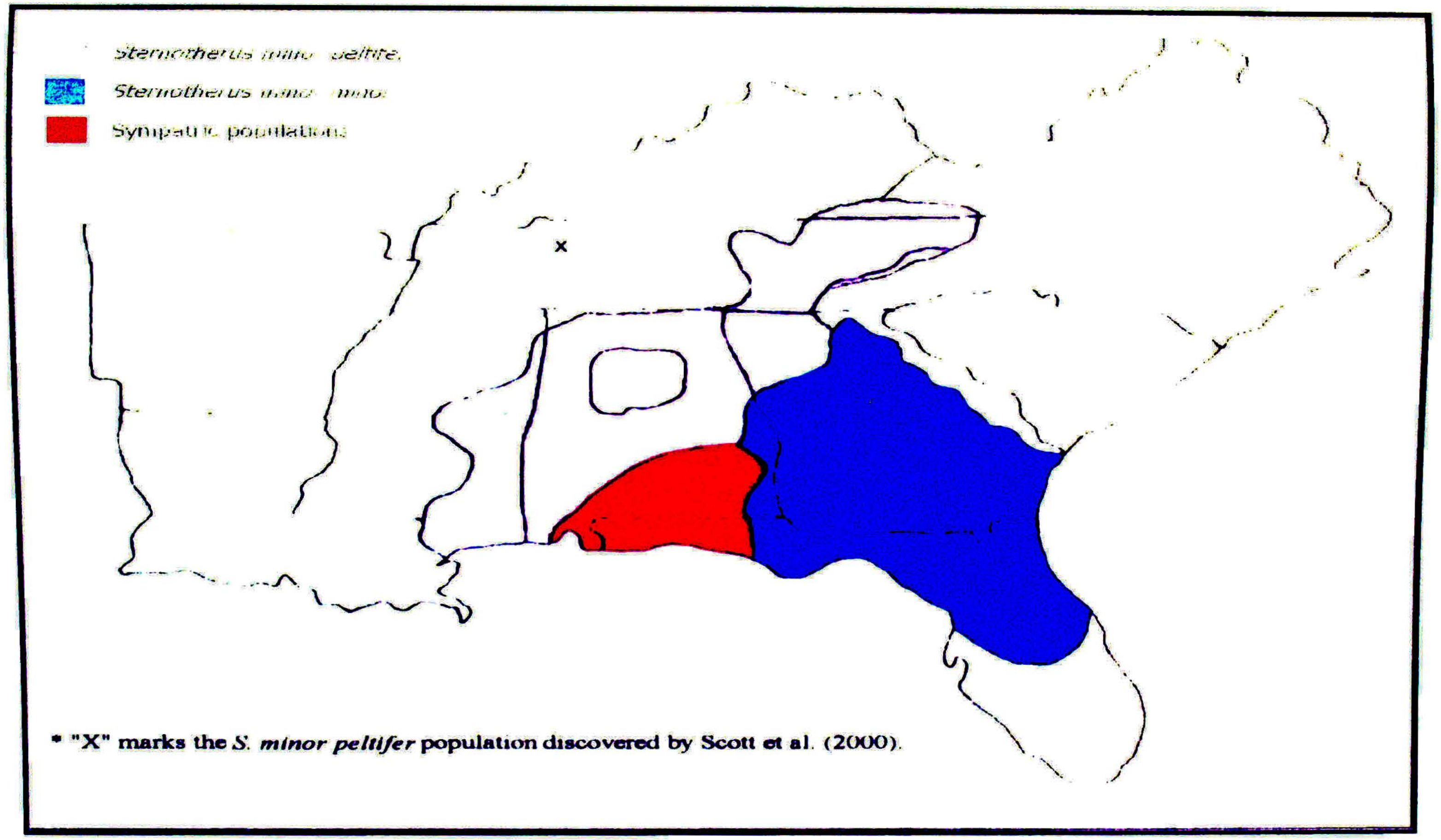

Figure 1. The distributions of *Sternotherus minor minor* and *Sternotherus minor peltifer* are allopatric except in parts of southern Alabama and the panhandle of Florida. Map adapted from the one by Conant and Collins (1998).

(1959); Reproductive cycle – Cox and Marion (1978), Etchberger and Ehrhart (1987), Iverson (1978), Etchberger and Stovall (1990); Growth model – Cox et al. (1991); Physiology – Hutchison et al. (1966), Goin and Jackson (1965); Behavior – Jackson (1969), Berry (1975); Phylogeography – Walker and Avise (1998); Movement (in *S. depressus*) – Dodd et al. (1988); General – Ernst et al. (1994), Ernst and Barbour (1989).

Objectives

The objective of this study was to obtain basic information on the following aspects of the life history of *S. m. peltifer*: 1) the overwintering strategy in terms of microhabitat preferences and movements, 2) home range characteristics in terms of size and general habitat requirements, 3) seasonal and diel activity patterns, and 4) the influence of water temperature on movement and habitat selection.

CHAPTER II

STUDY AREA

Whiteoak Creek flows some 42 km through Houston and Humphreys counties before emptying into Kentucky Lake (impounded lower reaches of the Tennessee River) at river mile eighty-two (Figure 2). The area drained by Whiteoak Creek is part of the Western Highland Rim ecoregion, which is part of the Interior Plateau (Arnwine et al., 2000). The Interior Plateau (designated ecoregion 71) extends from Ohio to the northern tip of Alabama, and includes 5 Level IV ecoregions: Western Pennyroyal Karst (71e), Western Highland Rim (71f), Eastern Highland Rim (71g), Outer Nashville Basin (71h), and Inner Nashville Basin (71i) (Arnwine et al., 2000).

The Western Highland Rim covers 13.9% of Tennessee's land area (Arnwine et al., 2000) and is underlain mainly by bedrock of Mississippian Age, plus smaller amounts of Pennsylvanian and Devonian Age (Quarterman and Powell, 1978). The bedrocks are carbonate in composition and include limestones of the St. Louis and Warsaw series. Ridges contain dolostones and cherty Cretaceous gravel; slopes consist of Fort Payne Chert (Quarterman and Powell, 1978; Chester and Ellis, 1989). Carbonate rock, which releases calcium carbonate into water, aids in the natural buffering system of streams and groundwater, thus stabilizing the pH of the waters and resulting in healthy aquatic ecosystems (Etgen et al., 2002). The Tennessee Stream Condition Index (TSCI) for the Western Highland Rim has a mean score of 31.9 with a rating of good (Arnwine et al., 2000). With the diversity of fish being highest in the Ecoregion and the TSCI scores classified as good, the study stream appears to be in healthy condition.

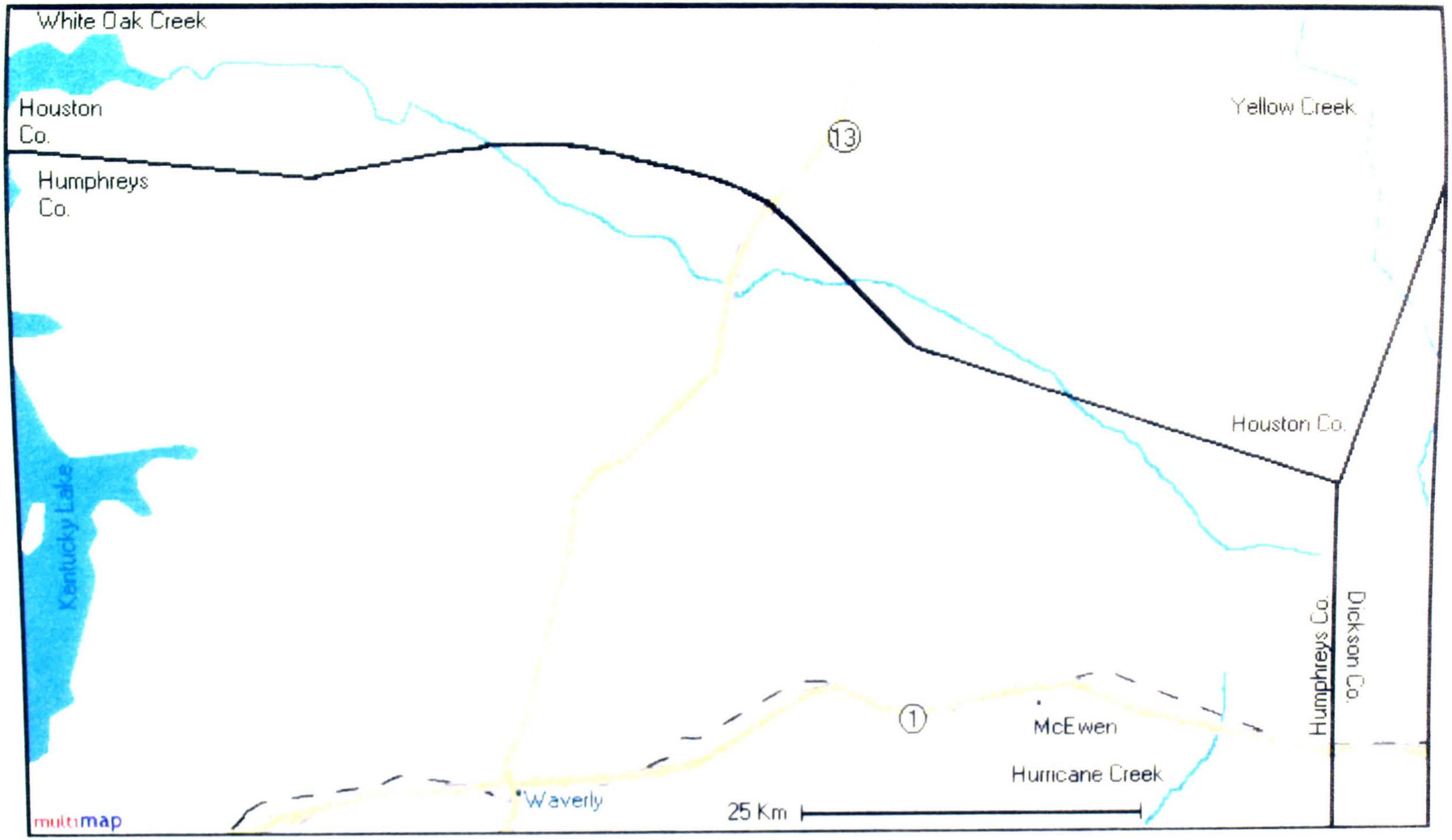

Figure 2. The 42-km path of Whiteoak Creek in Houston and Humphreys counties, Tennessee in relation to county boundaries, major roads, and Kentucky Lake (impounded Tennessee River). Map adapted from Multimap.

The study area soils are a mixture of acidic and low to moderate fertile red and yellow podsols (Arnwine et al., 2000; Chester and Ellis, 1989). Baxter, Brandon, Dickson, Ennis, Hawthorne, Mountview, Saffell, and Sulphura are the soil types found throughout Houston and Humphreys counties (Wildermuth and Odom, 1958; Welles et al., 1946). Today, the area is dominated by oak-hickory forests with all counties found within the Western Highland Rim having at least 50% of the land covered by secondary forests (Chester and Ellis, 1989). Chester and Ellis (1989) describe the forests as being dominated by four genera: *Acer*, *Carya*, *Quercus*, and *Ulmus*.

The nearest location to the study area with historic climatologic data is in Erin, Tennessee in Houston County. Erin is located 12.5 km from Gander Bridge site and 13.5 km from Spout Spring site. The mean annual temperature is 13.9 °C with July (26 °C) being the warmest month and January (1 °C) being the coolest month. Annual mean precipitation is 113 mm with the month of March (137.2 mm) being the wettest and the month of October (89.2 mm) being the driest. All climatic data were obtained from the following website: www.weather.com.

CHAPTER III

MATERIALS AND METHODS

Primary Collection Locations

Three sites (Spout Spring- 36° 15' 07"N, 87° 48' 56"W; Rushing Bluff- 36° 14' 58"N, 87° 48' 45"W; and Gander Branch- 36° 13' 30"N, 87° 46' 18"W) along Whiteoak Creek served as the main source of study specimens. These locations were chosen because of ease of their access, permission by landowners to access them, and the known numbers of *S. m. peltifer* previously captured at each (Williamson, 2001). All three are similar by having limestone bluffs and several fallen trees. Two stream assessments adapted from the Red River Watershed Association Site-Specific Stream Visual Assessment Protocol were conducted at Gander Bridge and at a location between Spout Springs and Rushing Bluff. The stream assessment assigns a rating between 10 and 40, the latter being the highest for quality. The final rating is derived from evaluations of eight stream features: riparian zone (rate each bank), bank stability (rate each bank), canopy cover, aquatic insect/invertebrate habitat, riffle and pool sedimentation, water appearance/characteristics, nutrient enrichment, and channel condition. Each feature is scored on a scale from 1 to 4, with riparian zone and bank stability receiving scores for each bank. The Gander bridge site scored 28, while the stream site between Spout Springs and Rushing Bluff scored 30. Both sites had erosion problems on one bank due to trampling by cattle.

Capture and Tracking Methods

Recent attempts to capture *S. minor peltifer* with funnel traps in Whiteoak Creek yielded only individuals of larger aquatic turtle species (Williamson, 2001). Wading and snorkeling were very effective. The latter of the two techniques was used in this study. All turtles were marked for identification using a modification to Cagle's (1939) method.

To document movements, habitat use, and duration of overwintering time, radio transmitters (Wildlife Materials International model: SOPB-2190) originally designed for small birds (quail and parrots) were affixed to 15 individuals (6 males, 8 females). This particular model was selected for its compact size (33 mm x 13 mm x 8 mm), weight (4.6 – 5.0 g), and battery longevity (~248 days). Radio signals emitted from the transmitters were picked up by a telemetry receiver (LA12-DS) and antenna (M-Yagi) purchased from AVM Instruments Company, Ltd. The LA12-DS telemetry receiver and SOPB-2190 transmitter functioned at a low frequency range of 49.000 to 49.999.

Monitoring Thermal Relationships

In addition to the SOPB-2190 transmitter, an iButton® Thermochron (Model DS 1921G-F5) thermal sensor was also attached to the carapace of each study animal. These dime-sized (~ 17 mm diameter x 6 mm height and ~ 3.1grams weight) thermometers log temperature (accurate 0.1 °C) and time (± 2 seconds per month). Angilletta and Krochmal (2003) evaluated the performance of a similar model, the iButton® Thermochron (Model DS 1921-F51), and found the instrument to be accurate to 0.3 °C in a libratory test and 0.3 ± 0.1 °C when submerged underwater for 7 days. The iButton® Thermochron products can be programmed to log temperature at intervals from 1-255 readings per minute. This allows water temperature to be compared to the habitat being selected by an individual turtle, and to see the relevance of temperature in relation to movements. In this study, the iButton® Thermochron was programmed to take one temperature reading every 180 minutes (3 hours) for a total of 256 days.

Waterproofing and Affixing Transmitters and Sensors

Transmitters came pre-sealed with a waterproofing material. The iButtons® were guaranteed waterproof only at depths of less than one meter, so they were encased in a waterproofing substance (PC-Superepoxy®) after being attached to each specimen. Both the thermal sensors and transmitters were applied to the carapace with the PC-Superepoxy® adhesive. Before application, a section of the carapace was cleaned (i.e. removal of dirt and algae), dried, and scuffed via sandpaper. Then the epoxy was applied and the transmitter and thermal sensor set into place. The transmitter and thermal sensor were held in place with rubber bands for at least 12 hours in order to dry. The total package weight (8 grams) ranged from 3.2 % to 7.6 % of the individual turtle's mass. Six individuals (5.1 %, 5.2 %, 5.5 %, 5.8 %, 7.3 %, and 7.6 %) violated the 5 % package to mass ratio.

Sampling Schedule

During the study, which extended from May 2004 to April 2005, each site was visited once a week to relocate study specimens and to acquire data on habitat and abiotic conditions. Some weeks the sites could not be sampled due to elevated waters. Once specimens were fitted with transmitters and thermal sensors and released, the number of days spent tracking was determined by the longevity of the transmitters. During the time turtles were active, 7 days were spent monitoring 10 individuals (5 males: 5 females) from the Gander Branch site for diel behavior. This site was selected because of the number of individuals in close proximity to one another. The total number of days spent monitoring each individual's diel behavior was determined by the time of capture and duration of transmitter life. Six individuals were monitored for 7 days, one for 6 days, one for 5 days, and two for 4 days each. This effort involved obtaining radio fixes of each individual on an every-other-hour basis over the 24-hour cycle. Once the position of a turtle was determined, it was recorded with a Tremble™ GPS receiver and a Trimble Survey Controller™.

Five days (16 August, 2 September, 23 September, and 4 November) were sampled on even hours, while 2 days (27 July and 12 August) were sampled on odd hours. This change was due to delays in my arrival time at the creek caused by traffic congestion. On 27 July and 12 August no data were take between 0700 and 0900 hours; on 16 August and 2 September no data were obtained between 0600 and 0800 hours.

Geographical Information System Technologies and Analysis

The home range size, distance traveled, and diel movements were analyzed by GIS software ESRI ArcGIS 9, ArcView 3.2, and an online distance calculator found at the following web address: http://grapevine.abe.msstate.edu/~fto/calculator/converte.html. Digital maps were created of all three sites using ESRI ArcGIS 9, the Tremble™ GPS receiver, and a Trimble Survey Controller™ (Figures 3 and 4). Animal Movement Analyst Extension (AMAE) Version 2.0 (Hooge and Eichenlaub, 2000) in ArcView 3.2 calculated the 100% minimum convex polygon (White and Garrott, 1990), and the shape file was imported into ArcGIS 9 for analysis. In home range studies, the minimum convex polygon (MCP) historically has been the most commonly incorporated method in the analysis (White and Garrott, 1990), but the MCP has limitations. The area calculated may include and exclude areas traversed and not traversed by the organism, thus limiting the accuracy of

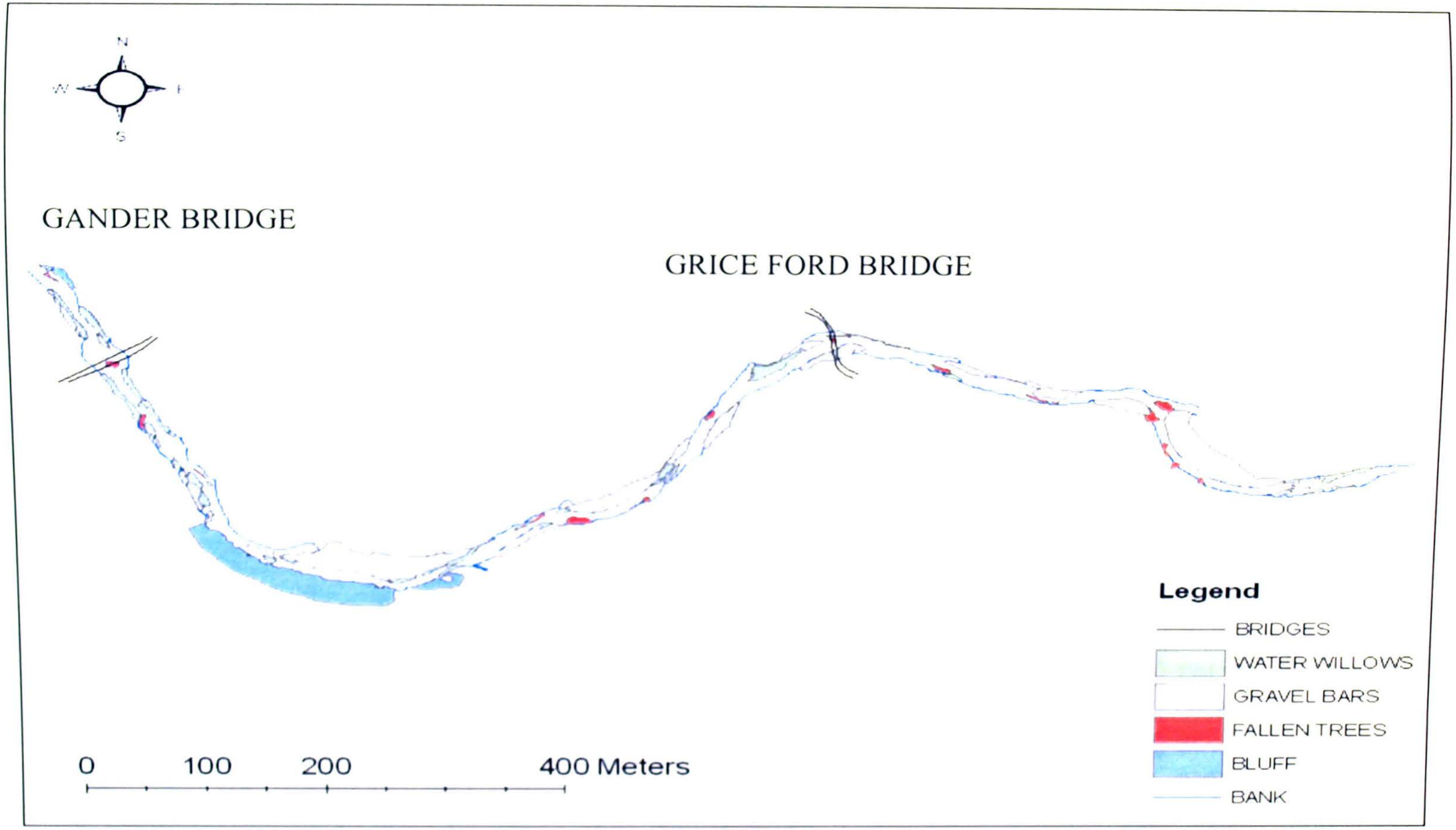

Figure 3. Gander Branch digital map created using ESRI ArcGIS 9 software and Tremble™ GPS receiver and a Trimble Survey Controller™.

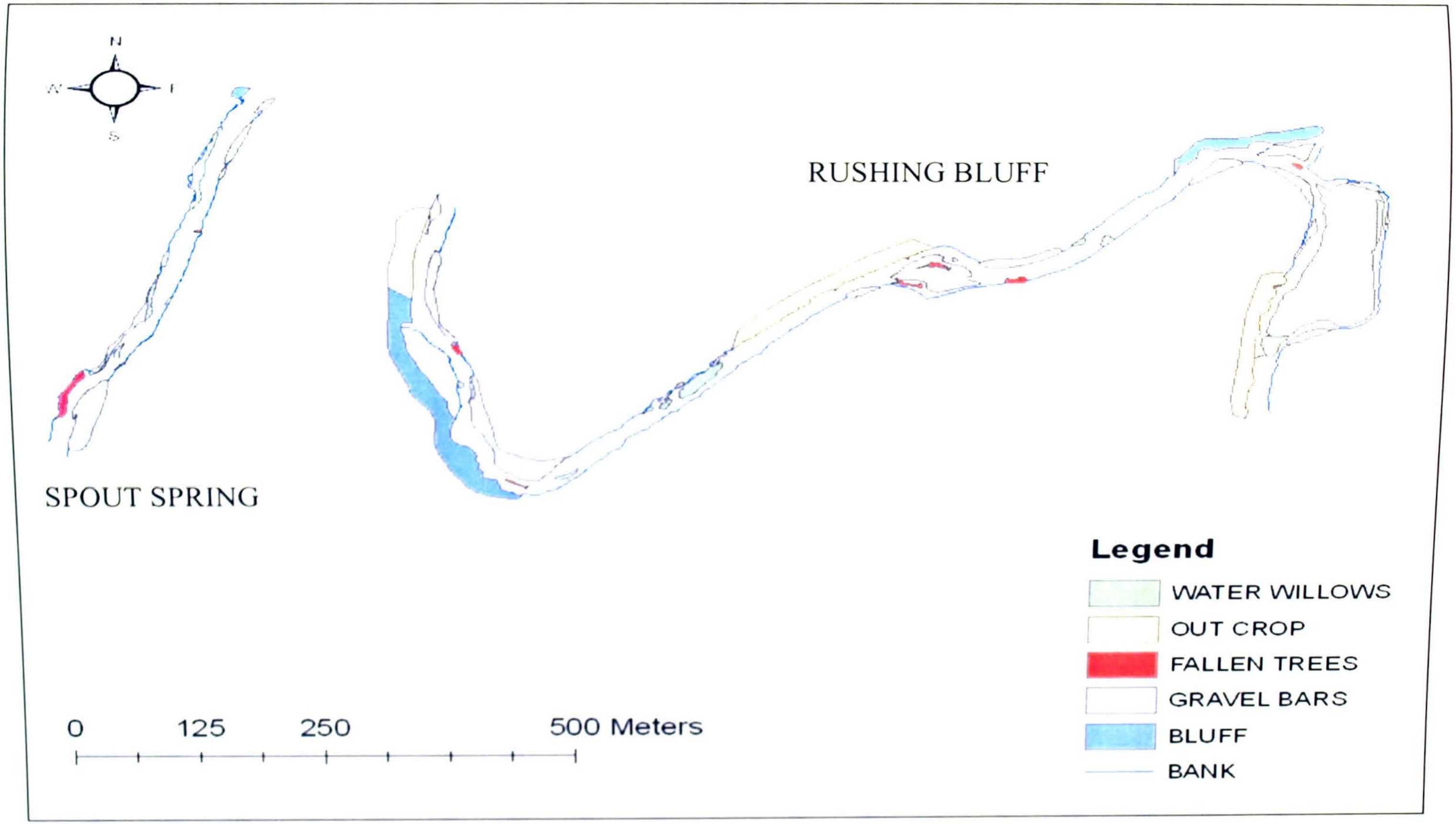

Figure 4. Spout Spring and Rushing Bluff digital maps created using ESRI ArcGIS 9 software and Tremble™ GPS receiver and a Trimble Survey Controller™.

the home range analysis (Figure 5). These limitations appear to magnify in regards to fresh-water, stream-dwelling turtle species. With increased sinuosity of the stream, accuracy of the calculation of home-range area decreases when using the minimum convex polygon method because it includes terrestrial habitats (cattle pastures, wood ridges, and habitat adjacent to large vertical bank cuts) not likely to be traversed and excludes aquatic habitats that are likely utilized. Plummer and Shirer (1975) mentioned the same issues with the MCP in a study on *Apalone muticus*. Because of this, the linear home range distance and aquatic surface area (100% minimum convex polygon) was the best estimation of actual home range dimensions. Burt (1943) defines an animal's home range as the area an individual occupies during the collection of food, mating and parental care. For this study, home range was defined by all the relocation points and any area traversed by the animal during the study period.

The use of the Tremble™ GPS receiver and a Trimble Survey Controller™ allowed the construction of digital site maps used in the analysis of home range characteristics and microhabitat preferences. The hibernacula and microhabitat preference within a home range were described for the following variables: cover/substrate, depth, and temperature. Cover/substrate included the following categories: submerged limestone bluffs, vegetated rocky outcrops, bank with exposed root system, woody debris (includes fallen trees, snags, and log jams), unconsolidated bank, water willow, and open waters. In the analysis of the diel behavior, the U.S. Naval Observatory Astronomical Applications Department website (http://aa.usno.navy.mil) was consulted when determining precise times of daylight and darkness.

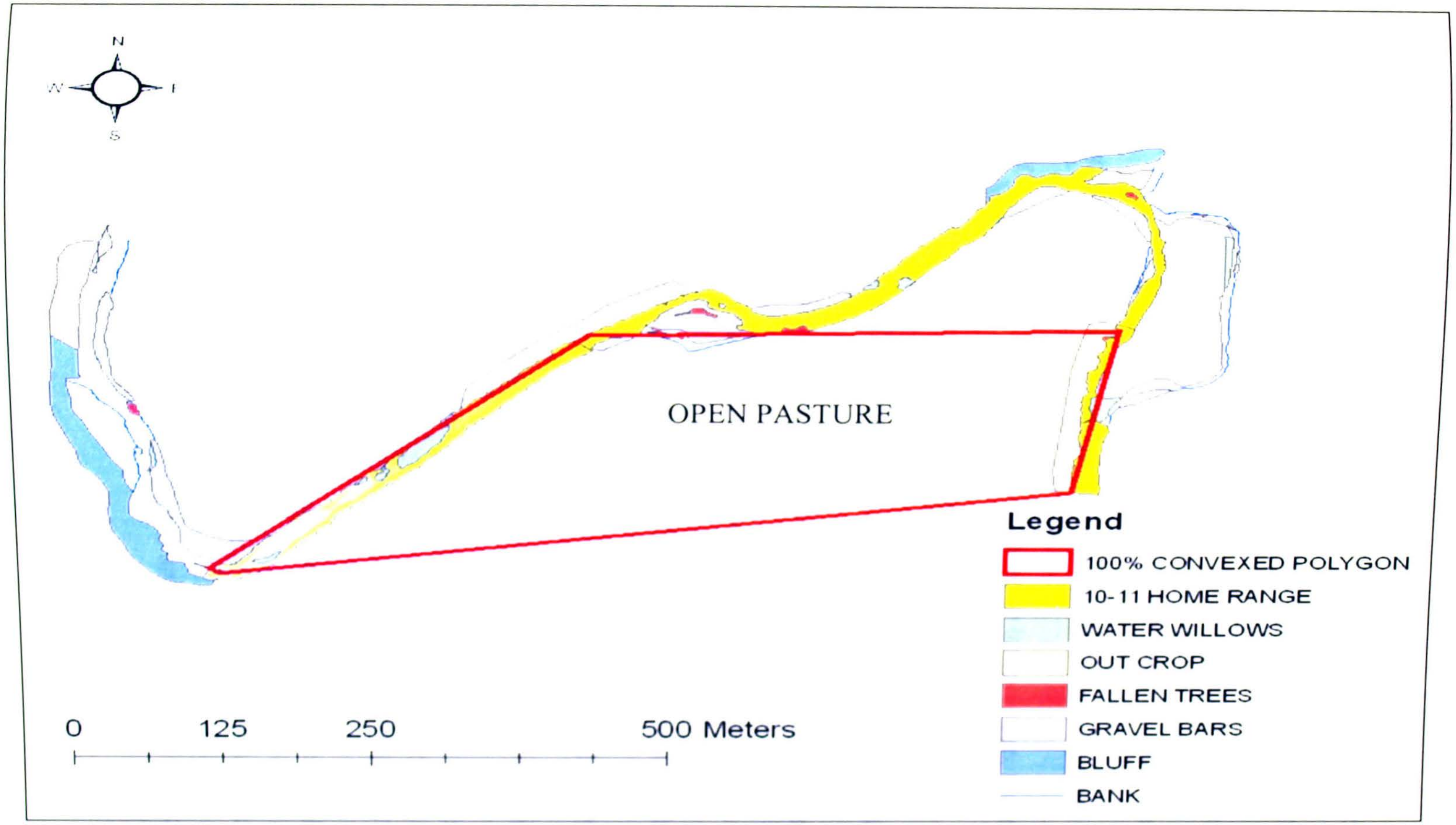

Figure 5. Male turtle 10-11 home range (yellow) with an overlay of the minimum convex polygon to illustrate how certain parts of the true area normally traversed by the animal are excluded, while other areas outside its habitat are included.

Statistical Analysis and Software

MINITAB® version 14.13 statistical software was used for all statistical analyses except for the Chi-square analyses which were preformed in KeyStat 1.5. All analyses used an alpha of 0.05. Home range and depth analyses between the genders and the analysis of home range length between violators and non-violators of the 5% package weight to body ratio used a Mann-Whitney Test. Microhabitat data were analyzed using Chi-square goodness of fit, and a Chi-square test of independence was used on the sex microhabitat comparison. Linear regression was used in comparing mass of an individual turtle to home range length, creek temperature to turtle temperature, mean monthly distance traveled to creek temperature, and mean monthly depth to creek temperature. Mean monthly distance and depth were analyzed with a General Linear Model (GLM) to incorporate the repeated measures nature of the design, and a Tukey's test at a 95% confidence level was preformed to determine which months significantly differ from one another. Diel movements used logistic regression and GLM analyses, taking into account the repeated measures design. Logistic regression was used to analyze frequency data for darkness and daylight movements, movements within individual 2-hour intervals, and between the sampling episodes to determine a behavioral shift. To account for the zeros and lessen the skewness, individual turtle's mean distances were calculated by first summing distance within an interval, and then mean distances were calculated for each 2-hour interval, dark hours, and daylight hours for a given day. The non-parametric nature of the data was due to the large number of times animals exhibited no movements, thus skewing the data

CHAPTER IV

RESULTS

Home Range and Overwintering Behavior

The mean linear home range size for all (N = 14) turtles studied was 341.4 m, and there was no significant difference between the sizes of home ranges of individuals whose package weight to body weight was above and below 5% (W = 36.0, $P = 0.273$). Also, no correlation ($r^2 = 0.729$, $P = 0.35$) was found between the mass of the individuals and the mean length of their home ranges (Figure 6). The individual home-range lengths were extremely variable ranging from 35 to 1283.2 m (Table 1). Male (335.0 m) and female (346.0 m) linear home ranges were comparable in length and did not differ significantly (W = 37.0, $P = 0.333$) from one another. Eleven out of 14 turtles (4 males: 7 females) moved a distance of at least 100 m on one or more occasions between relocation points. Of the 3 turtles that never traversed a distance of 100 m or greater, two were males and one was female. Most turtles displayed a strong site fidelity returning periodically to the same general area (main activity center) within the home range (Table 2 and Appendix). Over half (64.5%) of the relocations for each individual turtle, on average, was within 10.8 m of each other (Table 2). Site fidelity data were pooled only for summer and autumn months when turtles were most active. Throughout the study, 47.0% of all relocation points were located at the prior week's relocation point for an individual turtle. Home ranges overlapped among and between the sexes. There was no instance where separation was evident, thus turtles showed no evidence of territoriality (Figures 7 and 8).

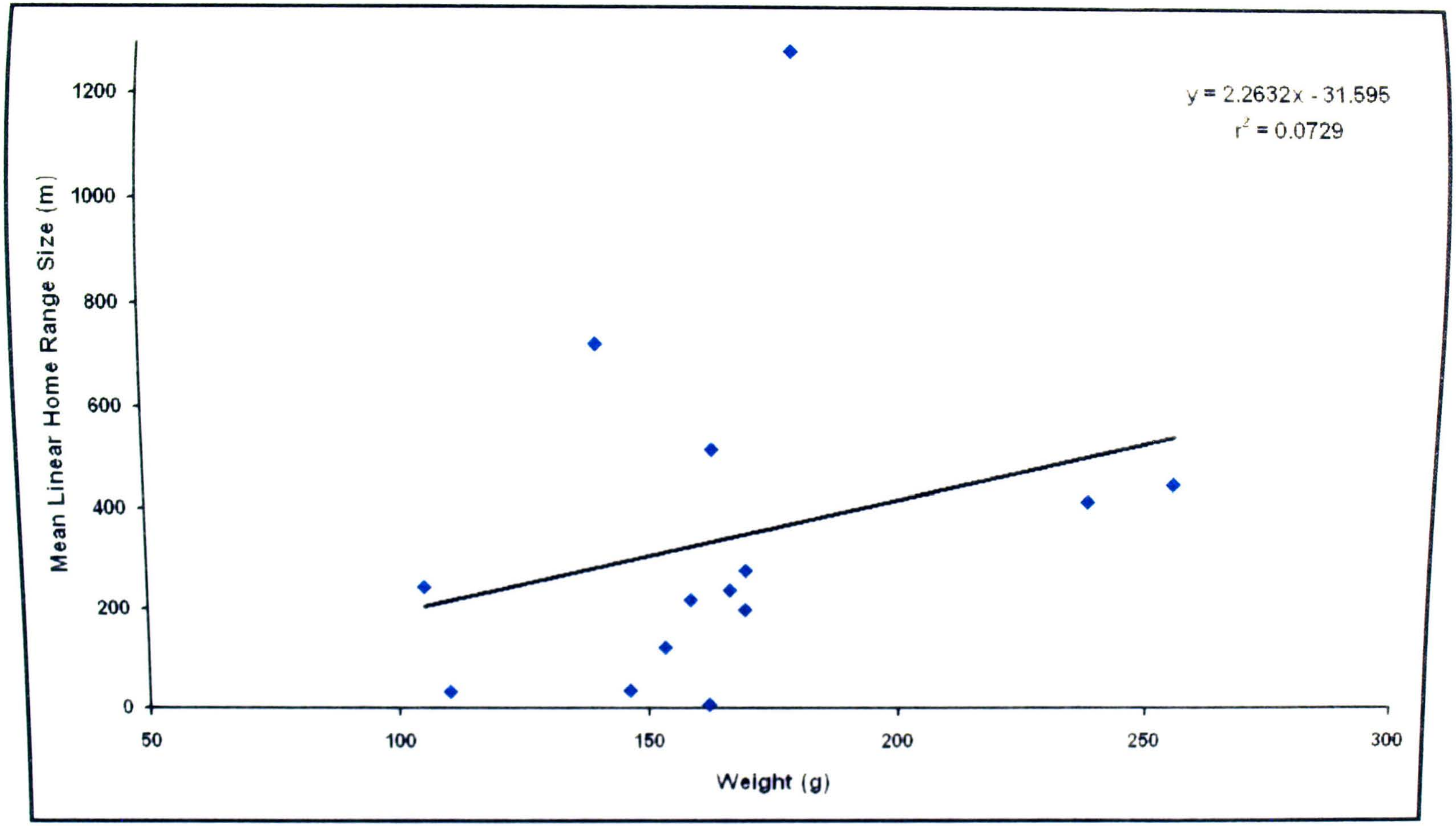

Figure 6. Relationship between mean linear home range size and mass of individual *S. m. peltifer* tracked in Whiteoak Creek, Humphreys and Houston counties, Tennessee, from May 2004 to April 2005.

Table 1. Data on mass, telemetry to mass ratio, and home range size for 14 individual *S. m. peltifer* tracked in Whiteoak Creek, Houston and Humphreys counties, Tennessee, from May 2004 to April 2005.

Individual ID(sex)	Mass (g)	Telemetry Package to Turtle Mass Ratio	Home range		
			Lenght (m)	Area (sq m)	Area (ha)
0-8 F	254	3.2	450.8	8949.0	0.895
2-9 F*	139	5.8	723.9	13545.5	1.355
11-3 F*	146	5.5	37.9	89.6	0.009
1-11 F	237	3.4	416.1	4900.0	0.490
10-8 F	162	4.9	518.0	5813.5	0.581
9-0 F*	153	5.2	122.8	1318.3	0.132
6-0 F*	158	5.1	219.0	3182.5	0.318
2-8 F	169	4.7	279.5	3737.4	0.374
10-11 M	177	4.5	1283.2	22324.0	2.232
2-1 M	169	4.7	199.0	2981.5	0.298
11-10 M*	110	7.3	35.0	242.6	0.024
2-2 M*	105	7.6	245.5	2676.1	0.268
8-8 M	162	4.9	7.8	162.1	0.016
8-1 M	166	4.8	240.4	2623.3	0.262
Mean ± SE	164.8 ± 10.8	5.1± 0.32	341.4 ± 90.3	5182 ± 1645	0.518 ±0.17

*Individuals whose telemetry package weight exceeded 5% of body weight

Table 2. Total number of relocation points and length of total home range for each study animal compared to the longest dimension of the main activity center, the number of relocation points therein, and the percent of all relocation points recorded in the main activity center in Whiteoak Creek, Humphreys and Houston counties, Tennessee, from May 2004 to April 2005.

Individual's	Total Home Range		Main Activity Center Within Home Range		
ID(sex)	No. Relocation Points	Home Range Length (m)	Longest Dimension (m)	No. Relocation Points	% of Total Relocation Points
0-8 F	26	450.8	3	24	92.3
2-9 F	19	723.9	21	13	68.4
11-3 F	31	37.9	5	21	67.7
1-11 F	18	416.1	4	5	27.8
10-8 F	19	518.0	2	13	68.4
9-0 F	9	122.8	8	8	88.9
6-0 F	34	219.0	14	29	85.3
2-8 F	24	279.5	17	16	66.7
10-11 M	12	1283.2	34	5	41.7
2-1 M	16	199.0	6	12	75.0
11-10 M	34	35.0	7	20	58.8
2-2 M	21	245.5	12	9	42.9
8-8 M	10	7.8	0	5	50.0
8-1 M	13	240.4	18	9	69.2
Mean ± SE	20.4 ± 2.25	341.4 ± 90.3	10.8 ± 2.49	13.5 ± 2.02	64.5 ± 5.0

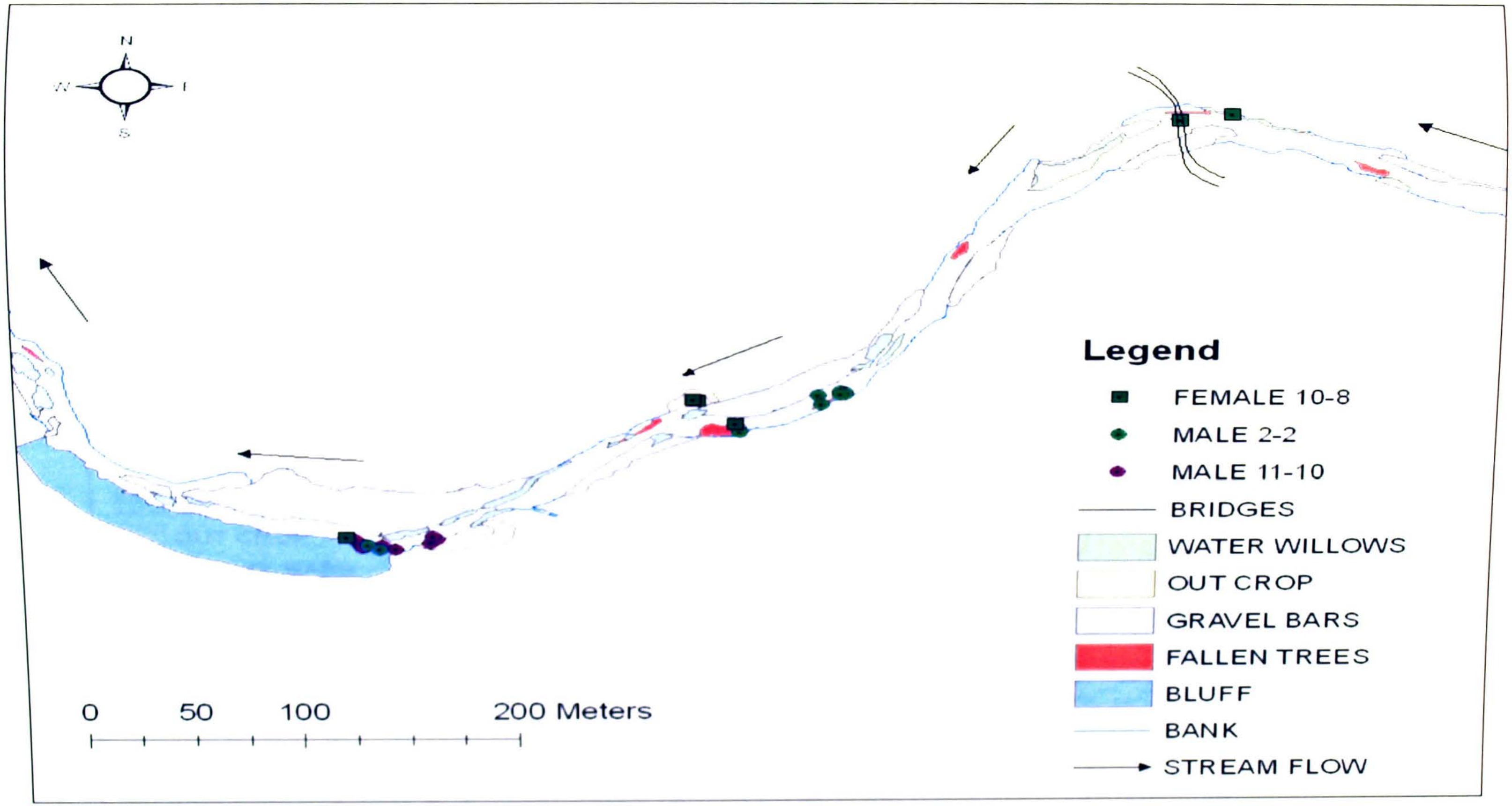

Figure 7. Example of home range overlap and microhabitat sharing by two male and one female *S. m. peltifer* in Whiteoak Creek at the Gander Branch site, Humphreys County, Tennessee.

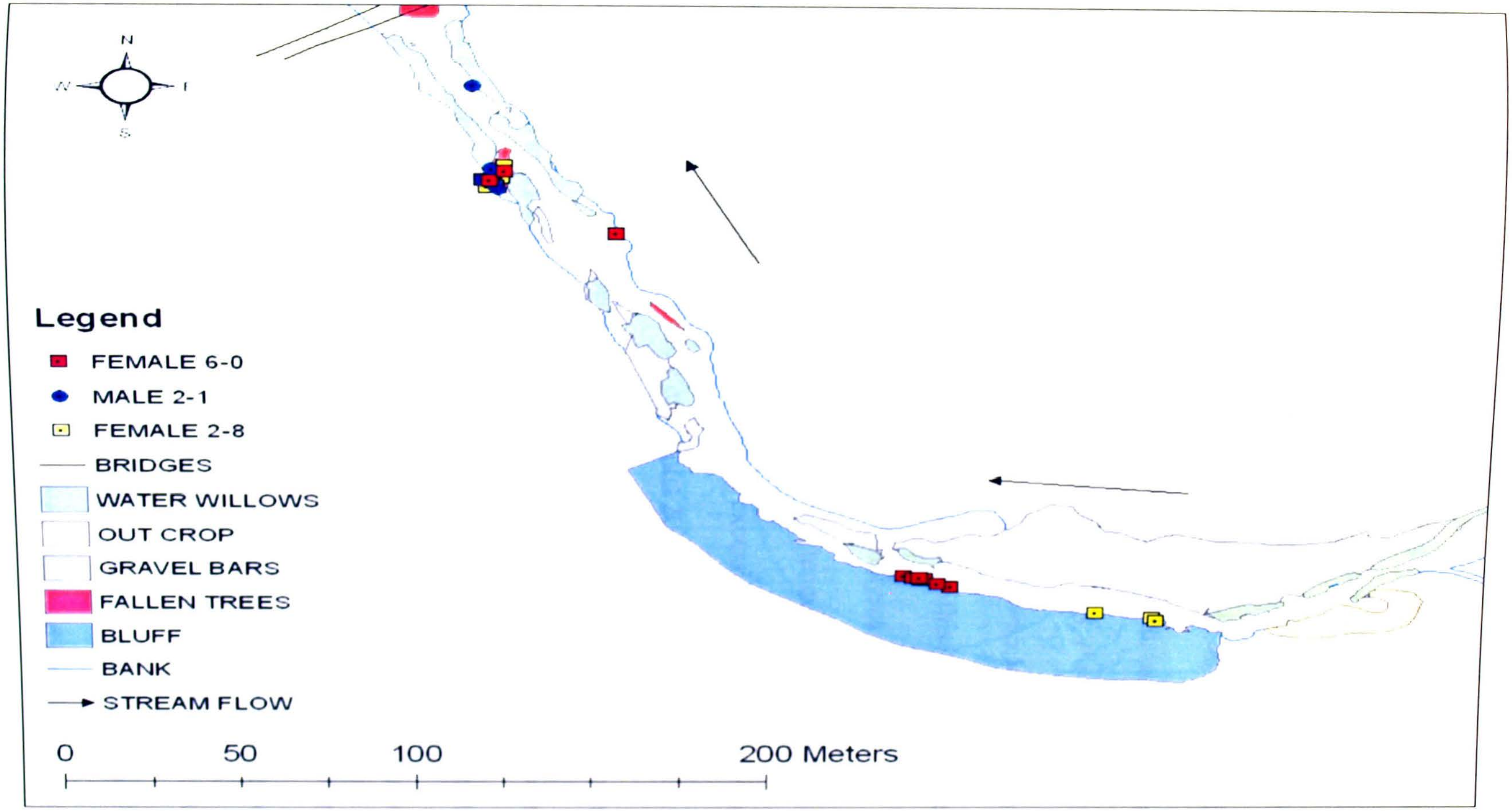

Figure 8. Example of home range overlap and microhabitat sharing by two female and one male S. *m. peltifer* in Whiteoak Creek at the Gander Branch site, Humphreys County, Tennessee.

The overall mean distance moved for all turtles varied throughout the study, and differed significantly (F = 2.44, $P = 0.010$) among months (Figure 9). Distances moved were noticeably greater from April through November with a spring peak in June and a fall peak in October. In December, the length of travel dropped off sharply and remained at its lowest point through March. Using Tukey's method at a 95% confidence interval, significant differences were revealed between the mean distance moved in June and January (t = 3.46, $P = 0.038$), June and February (t = 3.5, $P = 0.034$), and June and March (t = 3.38, $P = 0.047$). Female 2-9 was only relocated twice between October and December due to equipment problems and because of this it was excluded from these months in the mean monthly distance and depth analyses.

Attempts were made to monitor the creek temperature throughout the study. Twice the temperature senor was lost during excessive flooding. However, temperature data were obtained for the months of August 2004 through April 2005. A linear regression analysis was used to examine the relationship between mean creek temperatures and mean distances traveled for those months. Results revealed that the mean distance traveled was significantly correlated in a positive manner to the mean monthly temperature ($r^2 = 0.526$, $P = 0.027$) (Figure 10). Only one iButton® was retrieved from of a study turtle (female 9-0) with a functioning transmitter. Unfortunately this turtle was discovered dead in an open field, rendering the temperature data unusable for the purposes of this study. Another iButton® with temperature data extending from July 2004 to April 2005 was removed from male 8-9 at Gander Branch. This turtle's transmitter however, failed two days after being deployed resulting in no data on its where abouts during most of the periods. Still, as revealed in Figure 11, the temperature

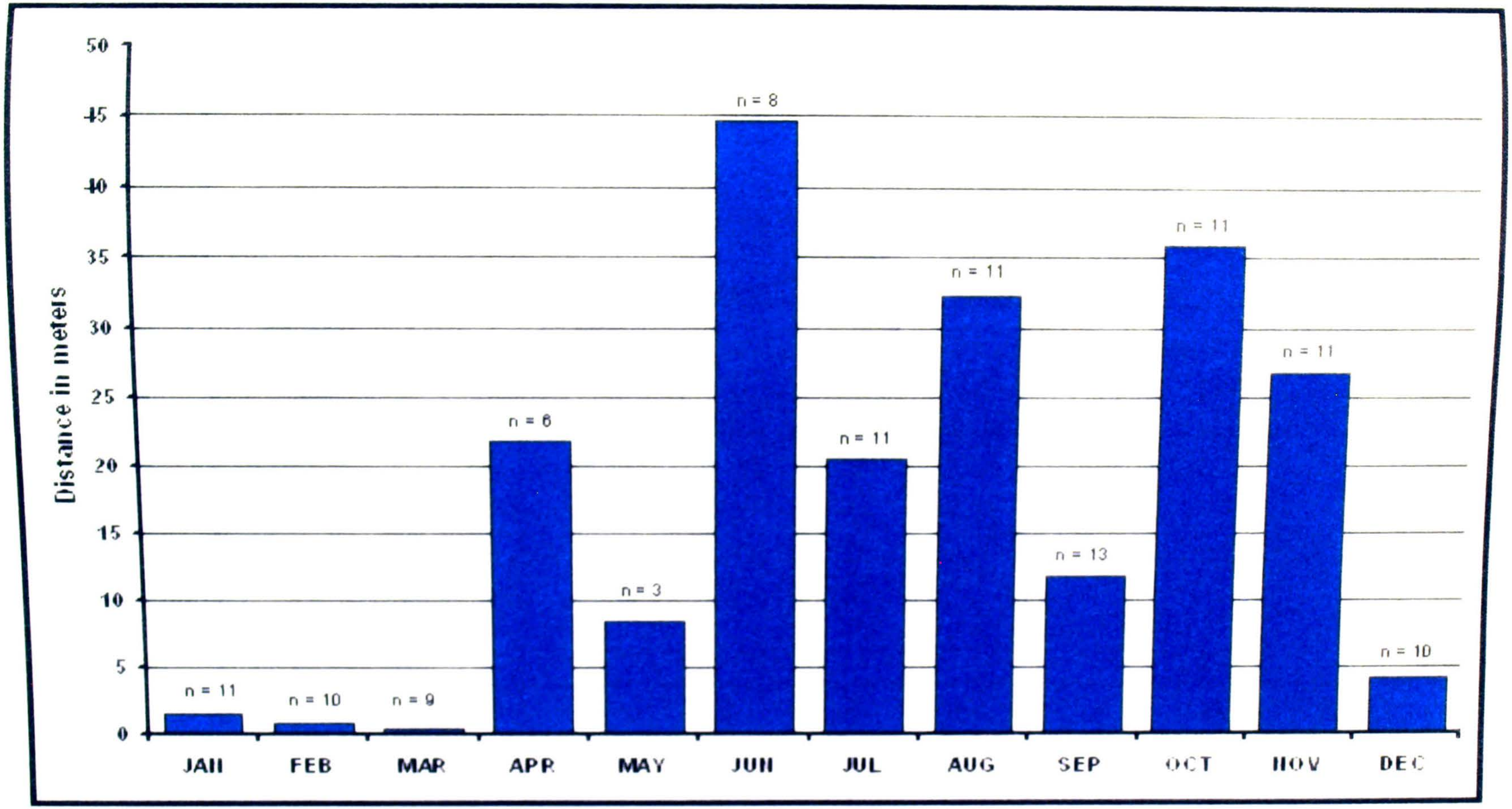

Figure 9. Mean distance moved each month by *S. m. peltifer* being tracked in Whiteoak Creek, Houston and Humphreys counties, Tennessee, from May 2004 to April 2005.

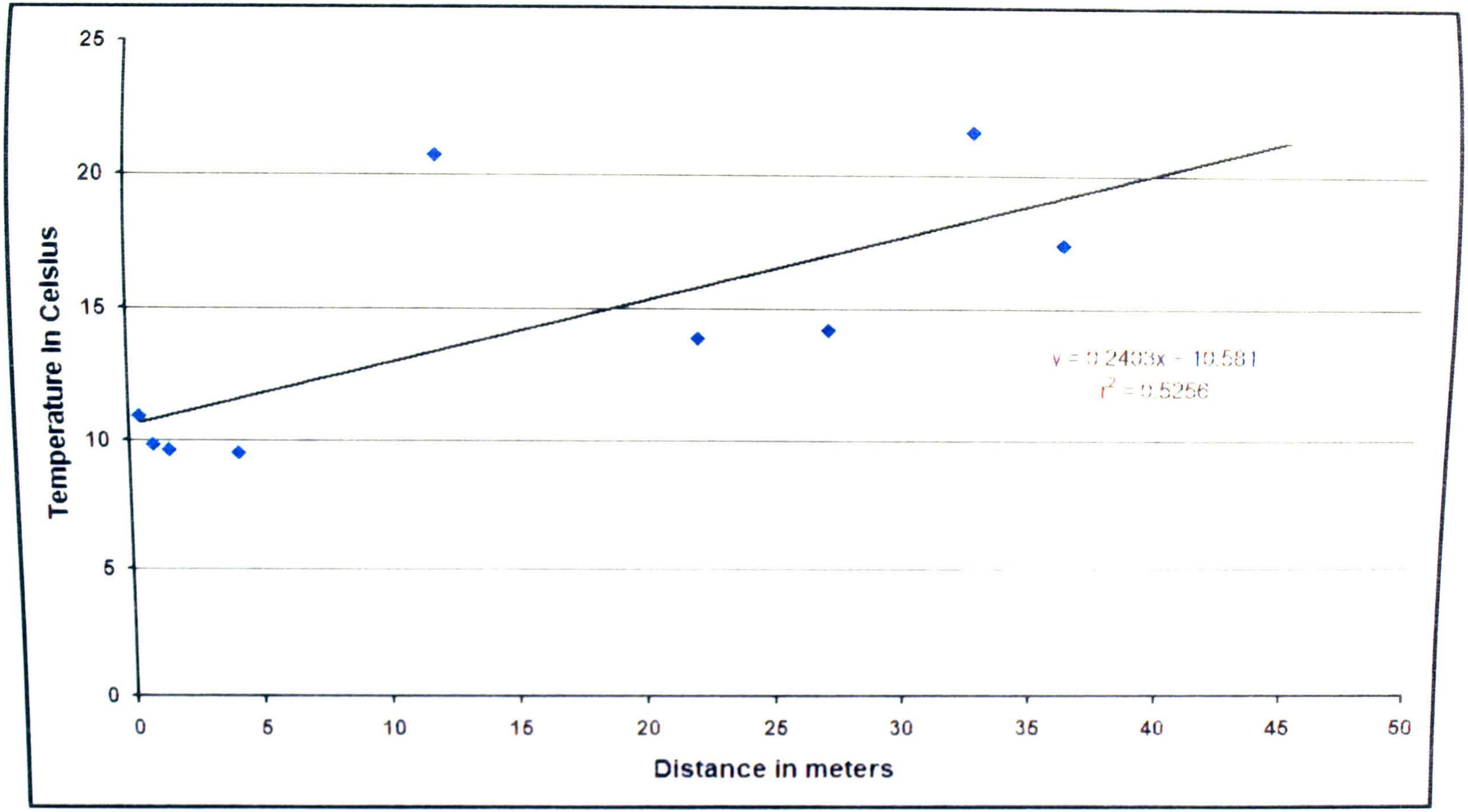

Figure 10. Mean distance moved each month by *S. m. peltifer* being tracked from May 2004 to April 2005 and the means of temperatures collected by an iButton® in Whiteoak Creek, from July 2004 through April 2005.

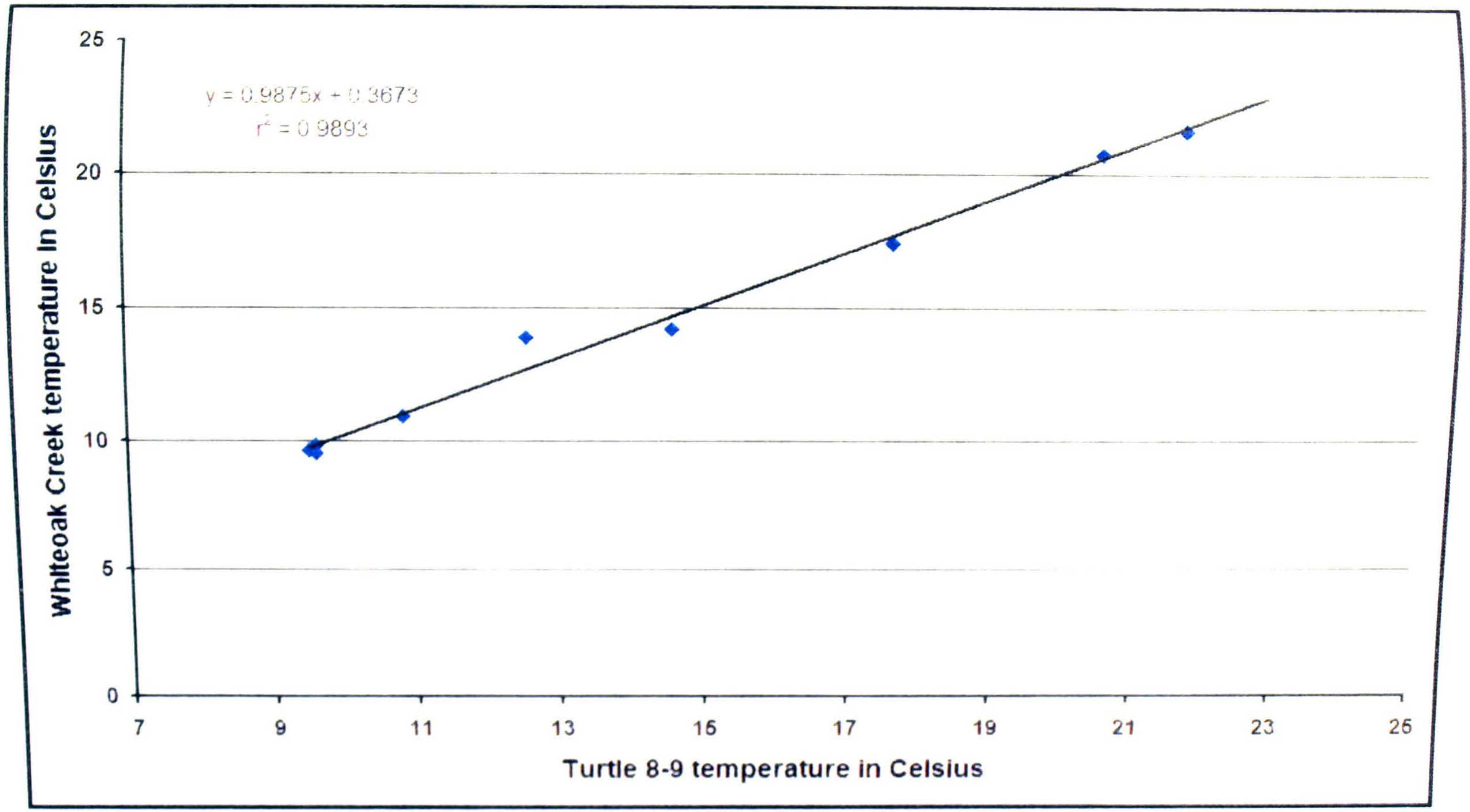

Figure 11. Mean monthly temperatures in Whiteoak Creek, from July 2004 through April 2005 based on data collected from 2 iButtons®, one deployed directly in stream, the other attached to the carapace of study animal 8-9.

regime from the iButton® on male 8-9 was positively correlated ($r^2 = 0.989$, $P = 0.000$) with that of the iButton® placed directly in the creek at the Gander Branch site. Therefore, it seems reasonable to conclude that the creek and turtle temperatures fluctuated in a relatively consistent manner throughout the tracking area over the study period.

Data on overwintering behavior were collected on only 11 of the 14 turtles because the transmitters on the other three (male 8-8, female 9-0, and female 10-8) failed. Seven turtles (4 males: 3 females) revealed no activity throughout the winter, while four (1 male: 3 females) were active to varying degrees. Exactly when turtles entered the inactive period varied with the individual but occurred mainly between 11 November and 12 December. The mean distance moved by turtles that remained active during the winter was minimal (Figure 9). The resurgence of movement in spring occurred over a more contracted time period than the fall slow-down leading up to winter. Turtles began moving within a two week time period between 31 March 2005 and 19 April 2005. Due to transmitter failure in the winter months, only 5 of the 7 turtles that were inactive during the winter were documented emerging from dormancy. Only 2 turtles (males 2-1 and 2-2) moved outside of their known home range to over-winter (Figure 12 and 13). Like all other turtles, females 11-3 and 6-0 remained in the area where they were active during summer and fall (Figure 14). Three male turtles (2-2, 2-1, and 10-11) traversed distances downstream of 184 to 200 m to overwintering habitats. Male 2-1 traveled 193 m from 16 November to the 21 November 2004, where he remained sedentary until 11 April 2005 (Figure 12). Male 2-2 moved 200 meters between 22 October and 29 October 2004, and then 2 weeks later moved a short distance downstream to remain sedentary for the remainder of the transmitter's battery life (Figure 13). Male 10-11

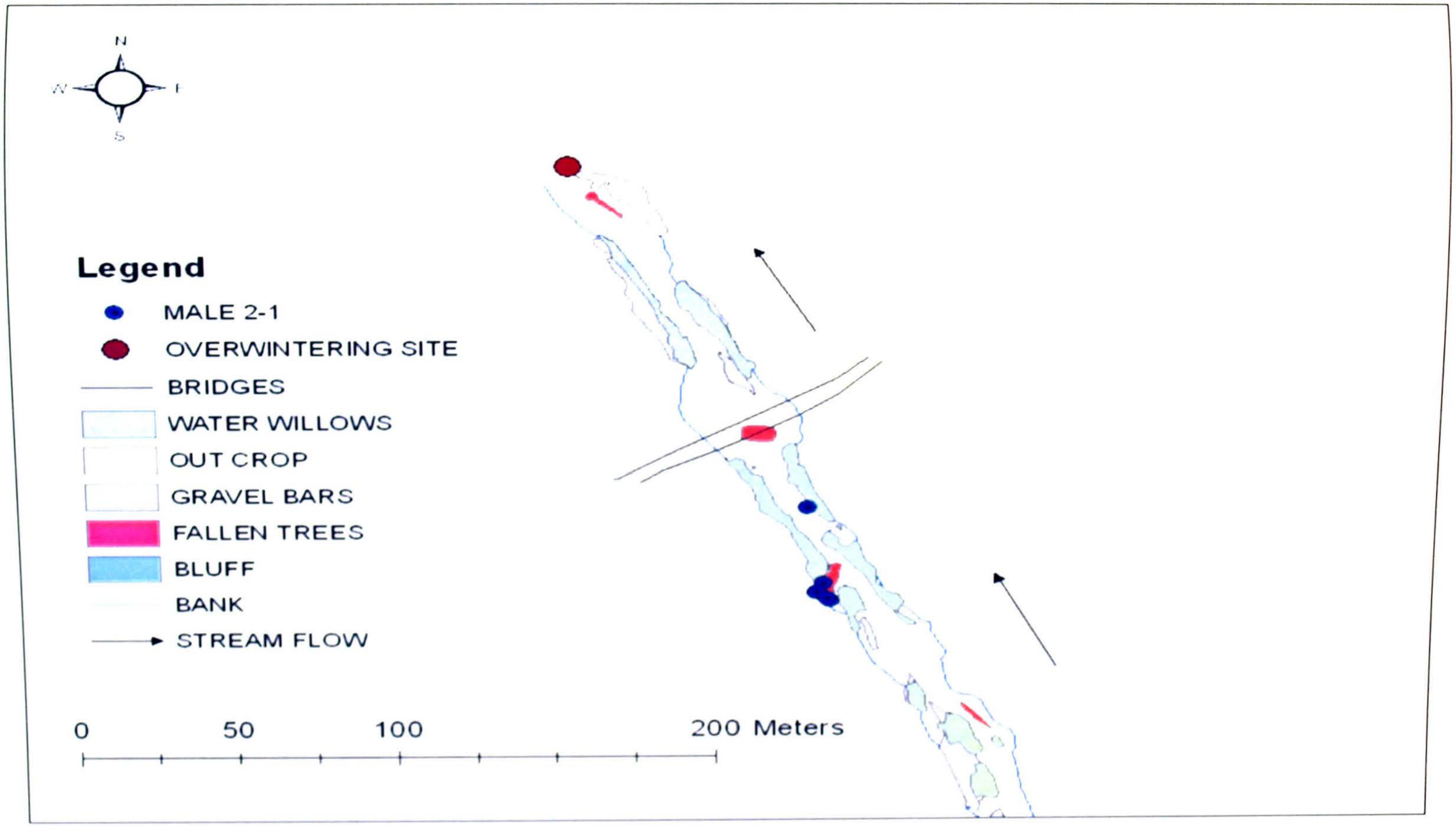

Figure 12. Map of the Gander Branch site on Whiteoak Creek showing distance (193 m) and direction (downstream) moved by male 2-1 from its summer and fall activity area (small blue circles) to its overwintering location (large red circle).

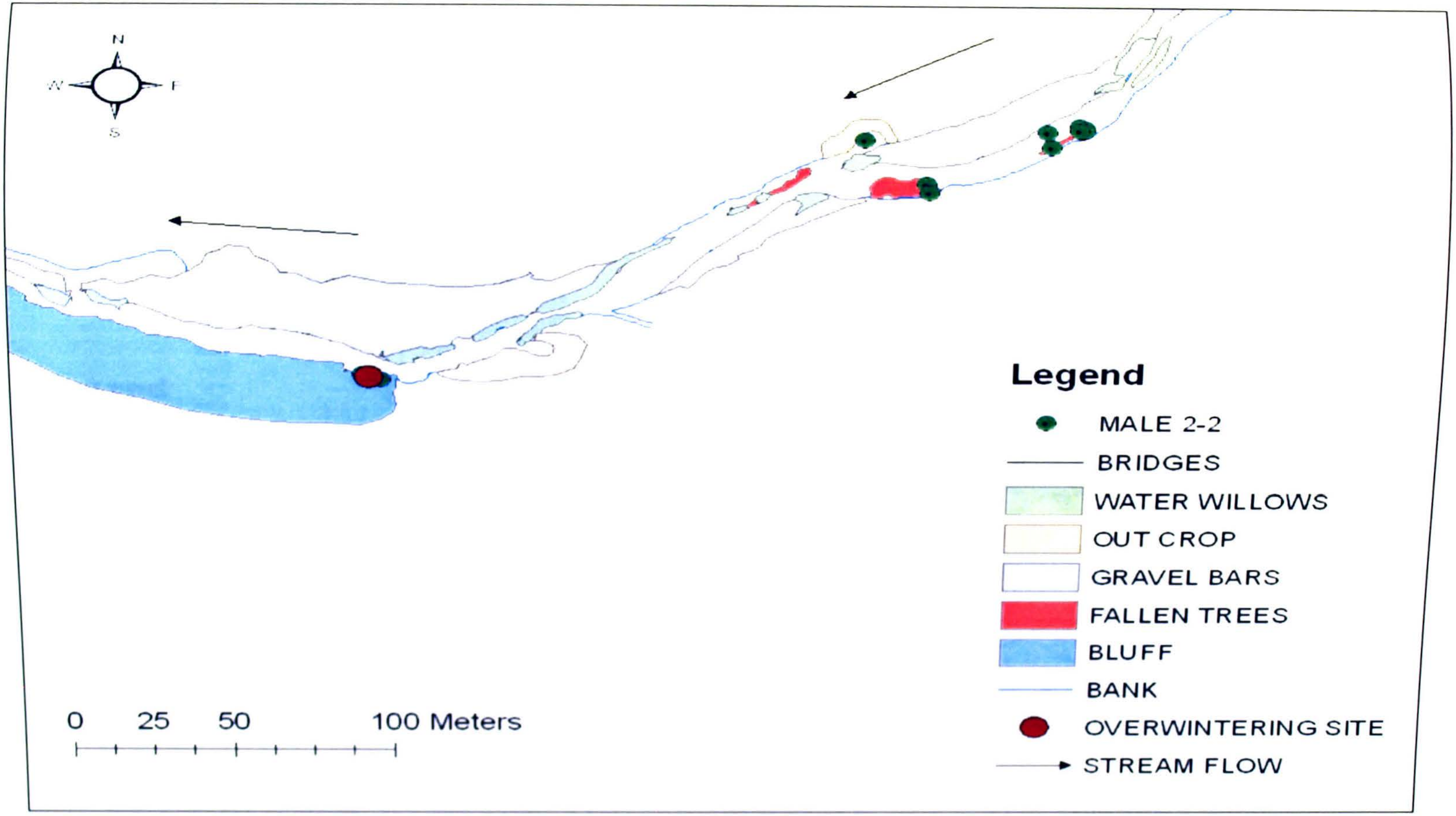

Figure 13. Map of the Gander Branch site on Whiteoak Creek showing distance (200 m) and direction (downstream) moved by male 2-2 from its summer and fall activity area (small green circles) to its overwintering location (large red circles).

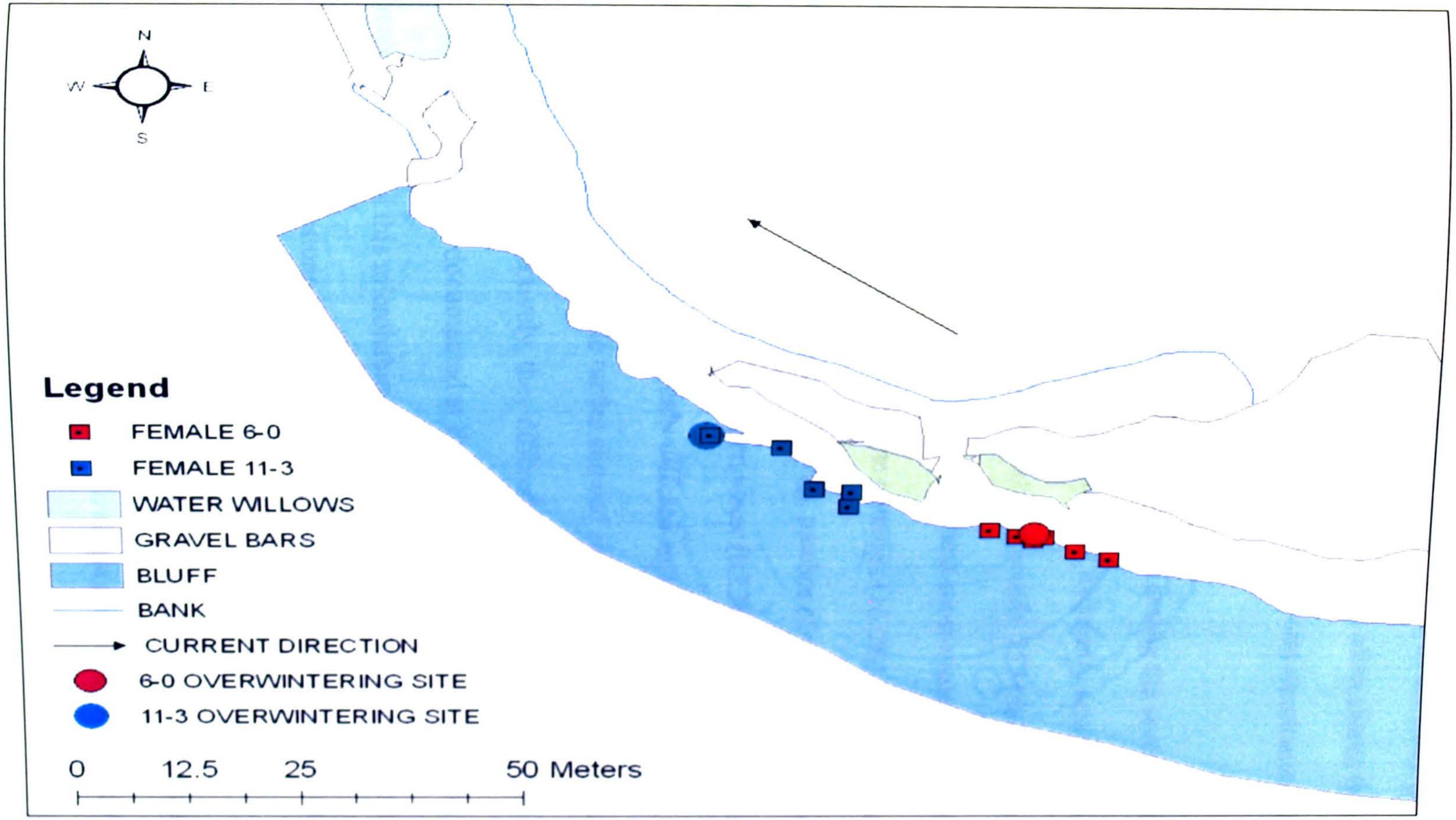

Figure 14. Map of Gander Branch site on Whiteoak Creek showing overwintering areas for females 6-0 (red circle) and 11-3 (green circle), which were within their summer and fall activity centers (red and green squares, respectively).

traveled 184 m between 16 November and 21 November 2004, then a week later moved a short distance upstream to remain sedentary until the end of the study (Figure 15). Four turtles (3 male: 1 female) overwintered within 37 m and often shared the same relocation points, but turtles never occupied the same relocation point simultaneously (Figure 16).

Habitat Preference

Habitat usage was not uniformly distributed among the seven available microhabitats ($X^2 = 766.28$, $P < 0.001$). The most frequently selected microhabitat was submerged limestone bluffs. Of 443 relocations records, 257 (58.0%) were for turtles associated with this geo-physical feature. The next-most-visited microhabitat was shoreline areas below vegetated limestone outcrops (16.0%). After this came woody debris (15.1 %), tangled root systems (5.6%), patches of water willow (0.68%), banks of unconsolidated material (4.1%), and open water (0.23%) (Table 3). Male and female habitat utilization throughout the study differed significantly ($X^2 = 52.11$, $P < 0.001$). Although both male and female turtles showed similar preference for woody debris 14.9% and 15.3%, respectively, they differed in the selection of the other microhabitats (Table 3). Males were documented at limestone bluffs 43.4% of the time, where as females frequented this microhabitat 67.5% of the time. After limestone bluffs, males chose vegetated limestone outcrops (30.9%), while females visited this microhabitat only 6.3% of the time (Table 3).

Out of 14 turtles being monitored, 6 were found in 4 microhabitats, 4 in 3 microhabitats, 3 in 2 microhabitats and 1 in a single microhabitat (Table 4). All but one was found in association with woody debris, 9 along limestone bluffs,8 by rocky outcrops, 5 in root systems, 3 each in water willow and along unconsolidated bank, and 2

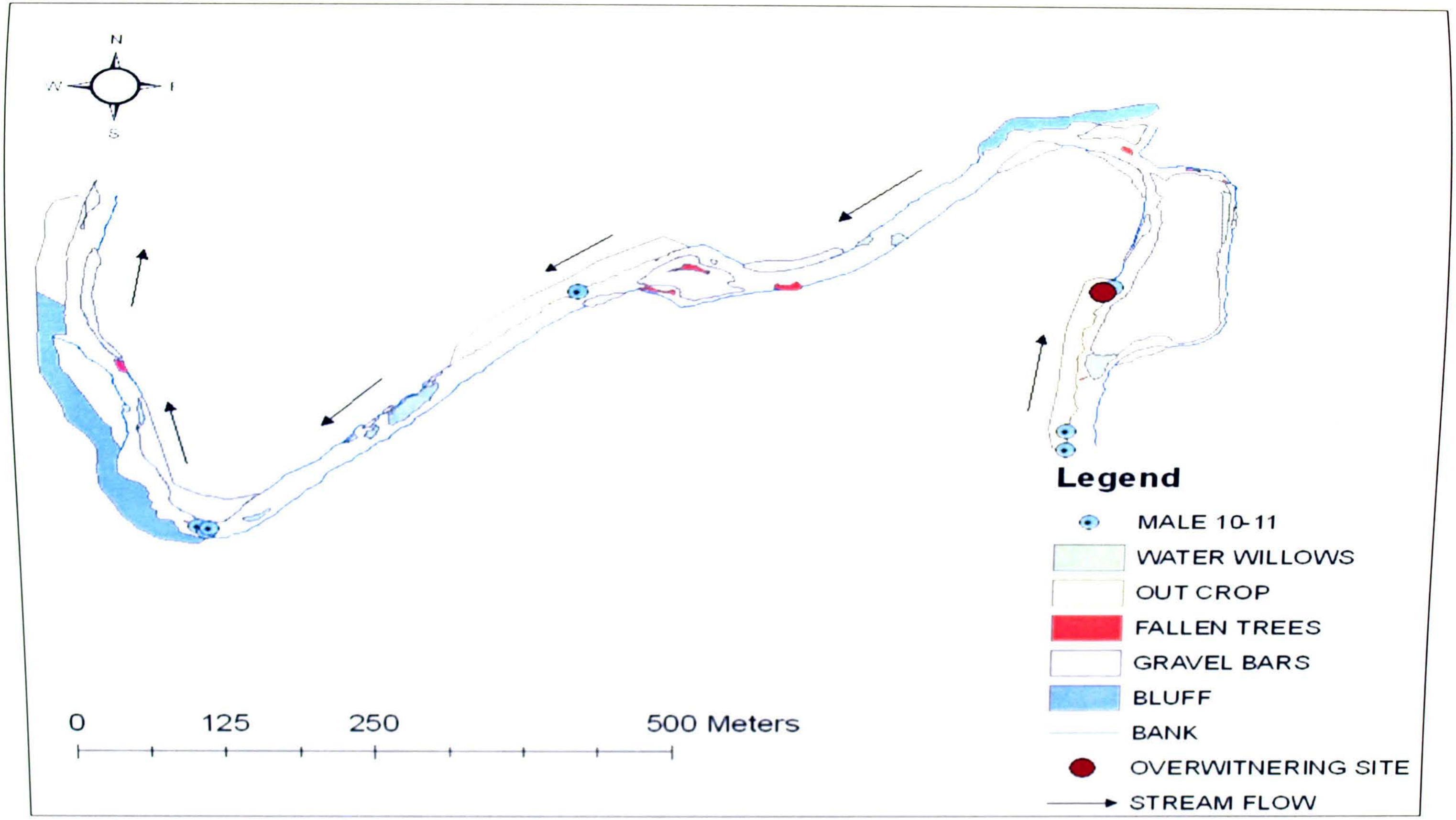

Figure 15. Map of the Rushing Bluff site on Whiteaok Creek showing location of overwintering site (red circle) of male 10-11 within its summer and fall activity area. Its last move before ceasing activity for the winter was downstream for a distance of 184 m.

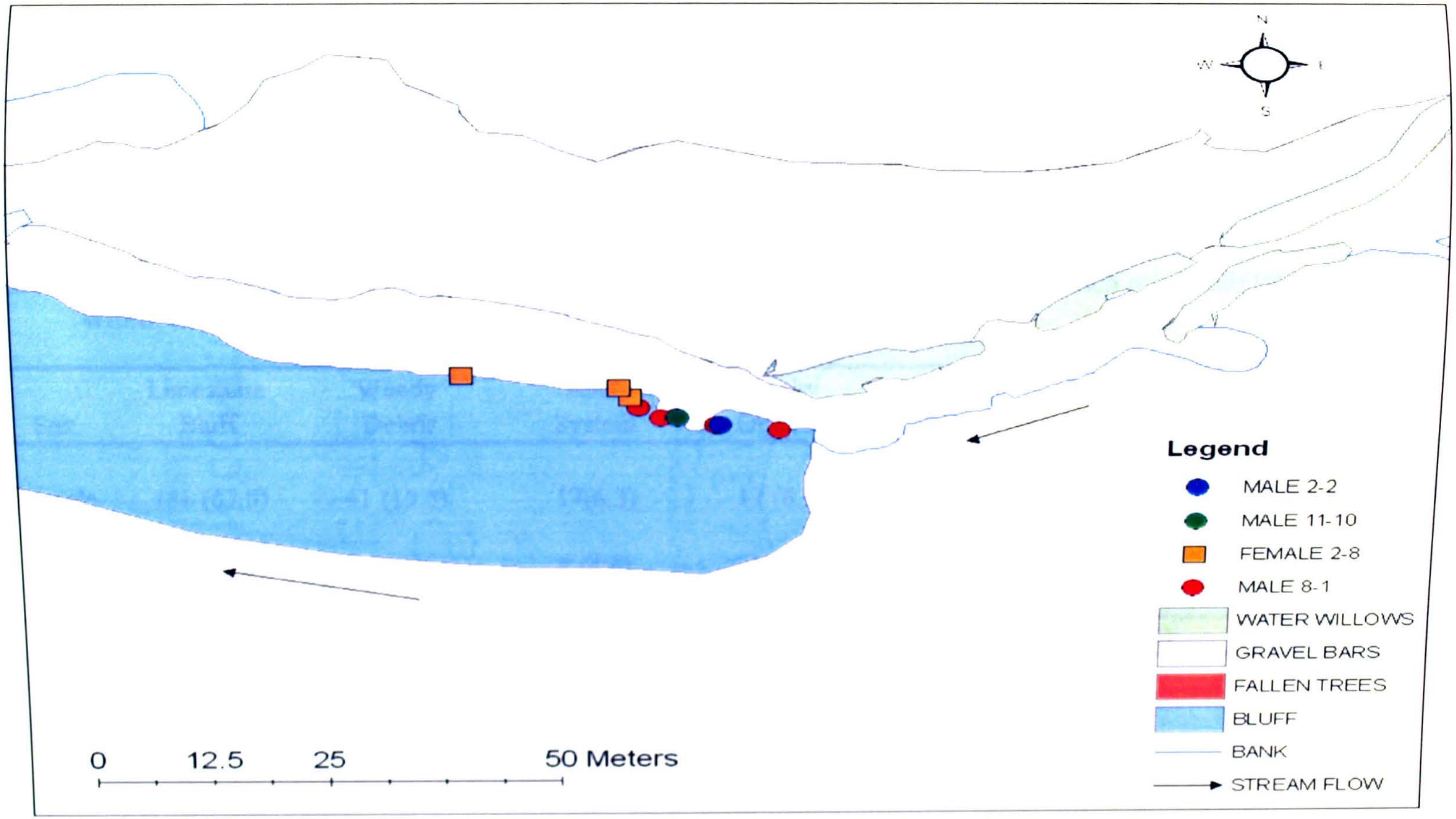

Figure 16. Example of hibernacula overlap and microhabitat sharing by three male and one female S. *m. peltifer* in Whiteoak Creek at the Gander Branch site, Humphreys County, Tennessee.

Table 3. Frequency (and percent) of relocation points, overall and by sex, recorded for each microhabitat identified within the study area.

Sex	Limestone Bluff	Woody Debris	Root System	Rocky Outcrop	Water Willow	Unconsolidated Bank	Open Water	Totals
Female	181 (67.5)	41 (15.3)	17(6.3)	17 (6.3)	1 (0.37)	10 (3.7)	1 (0.37)	268 (100)
Male	76 (43.4)	26 (14.9)	8 (4.6)	54 (30.9)	2 (1.1)	8 (4.6)	1 (0.57)	175 (100)
Totals	257 (58.0)	67 (15.1)	25 (5.6)	71 (16.0)	3 (0.68)	18 (4.1)	2 (0.23)	443 (100)

Table 4. Presence (X) and absence (-) of microhabitats in home ranges of each study animal, and the total number of turtle home ranges that included each microhabitat.

	Microhabitats							
Turtle ID(sex)	Limestone Bluff	Woody Debris	Root System	Rocky Outcrop	Water Willow	Unconsolidated Bank	Open Water	Total Habitats Used
9-0 F	-	X	X	X	-	X	-	4
1-11 F	-	X	X	-	-	X	X	4
11-3 F	X	-	-	-	-	-	-	1
10-8 F	X	X	-	X	X	-	-	4
2-8 F	X	X	-	-	-	-	-	2
2-9 F	X	X	X	X	-	-	-	4
6-0 F	X	X	X	-	-	-	-	3
0-8 F	X	X	-	-	-	-	-	2
8-8 M	-	X	-	-	X	X	-	3
10-11 M	-	X	-	X	-	-	-	2
2-1 M	-	X	X	X	X	-	-	4
11-10 M	X	X	-	X	-	-	-	3
8-1 M	X	X	-	X	-	-	-	3
2-2 M	X	X	-	X	-	-	X	4
Total Turtles	9	13	5	8	3	3	2	

in open water. home ranges including woody debris and vegetated limestone out crops (Table 4). Only one turtle's home range was lacking all microhabitats except limestone bluff (Table 4).All other turtle home ranges incorporated at least 2 microhabitats (Table 4).

Usage of microhabitats by *S. m. peltifer* during winter months (December – March) was also disproportionate ($X^2 = 452.02$, $P < 0.001$) and did not involve any water willow patches or open water (Table 5). Unlike overall microhabitat usage, it was limited mainly to areas beneath limestone bluffs (72.4%) and vegetated rocky outcrops (20.4%) with minimal use of the other features. Male and female overwintering behavior involved significantly different selections of microhabitats ($X^2 = 52.68$, $P < 0.001$) (Table 5). Relocations for male turtles were distributed somewhat evenly between limestone bluffs (54.4%) and vegetated limestone outcrops (45.6%). In contrast, 86.9% of relocations for females were beneath limestone bluffs, with the remaining 13.1 % representing woody debris (1.2%), root system (4.8%), and unconsolidated banks (7.1%).

The mean depth at relocation points for all turtles over the study ranged from 0.2 m to 3.6 m and averaged 0.88 m. A general linear model revealed the monthly means for depth of relocation points to be significantly difference ($F = 2.06$, $P = 0.032$), but a Tukey's test at a 95% confidence interval did not reveal any monthly differences in depth. There was a trend towards deeper waters from January through April as compared to the rest of the year (Figure 17). Depth of relocation points for males and females did not differ significantly overall ($W = 40.0$, $P = 0.56$) (Figure 18). There was a significant negative correlation between creek temperature and depth of relocation points for which these data were available ($r^2 = 0.577$, $P = 0.0018$) (Figure 19).

Table 5. Frequency (and percent) of relocation points for males and females as recorded for each microhabitat during the winter inactivity period (December – March).

	Winter Microhabitats					
Sex	Limestone Bluff	Woody Debris	Root System	Rocky Outcrop	Unconsolidated Bank	Totals
Female	73 (86.9)	1 (1.2)	4 (4.8)	0	6 (7.1)	84 (100)
Male	37 (54.4)	0 (0)	0 (0)	31 (45.6)	0 (0)	68 (100)
Totals	110 (72.4)	1 (0.66)	4 (2.6)	31 (20.4)	6 (3.9)	152 (100)

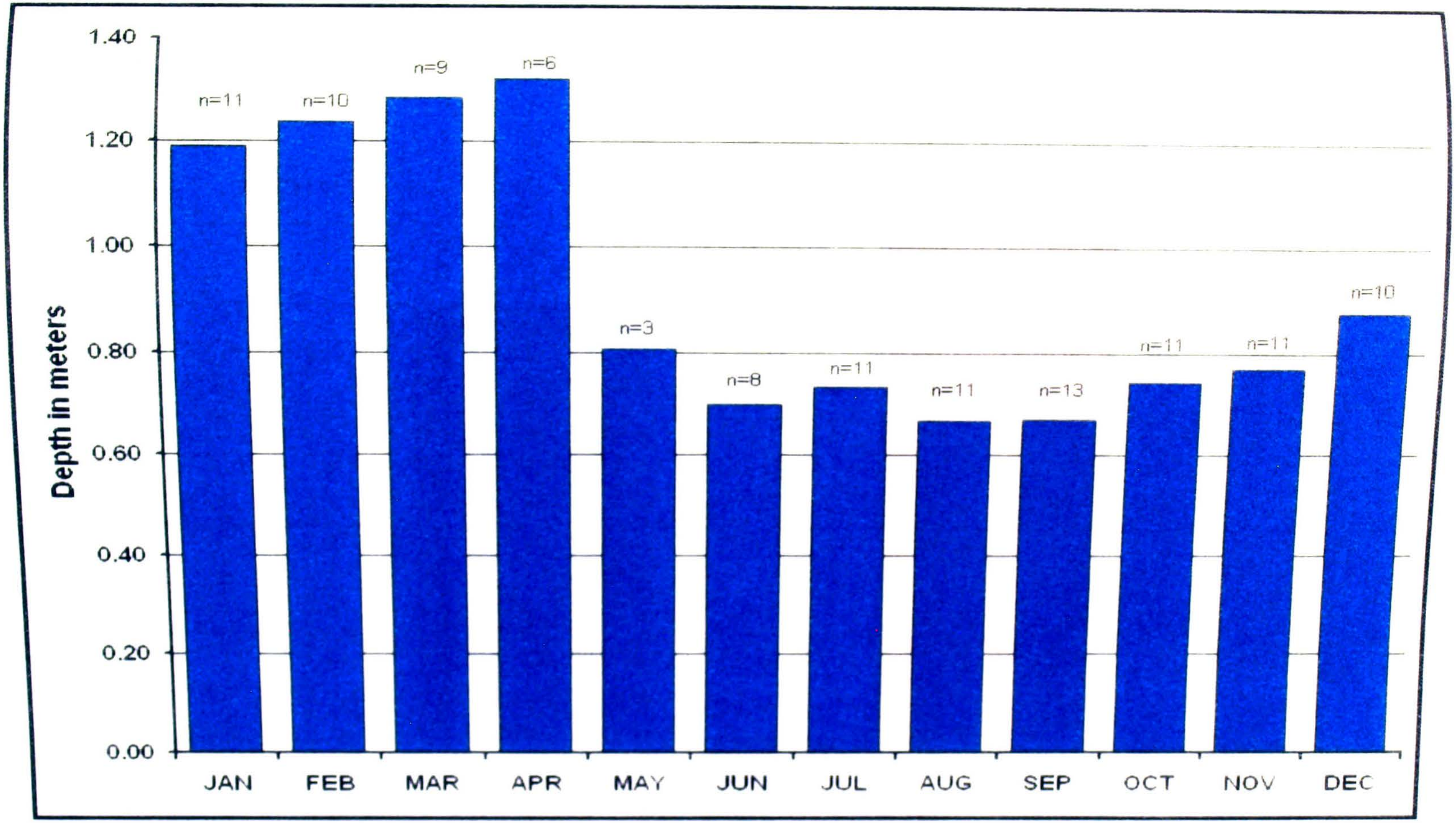

Figure 17. Mean monthly depths for relocations points for *S. m. peltifer* tracked in Whiteoak Creek, Houston and Humphreys counties, Tennessee, from May 2004 to April 2005.

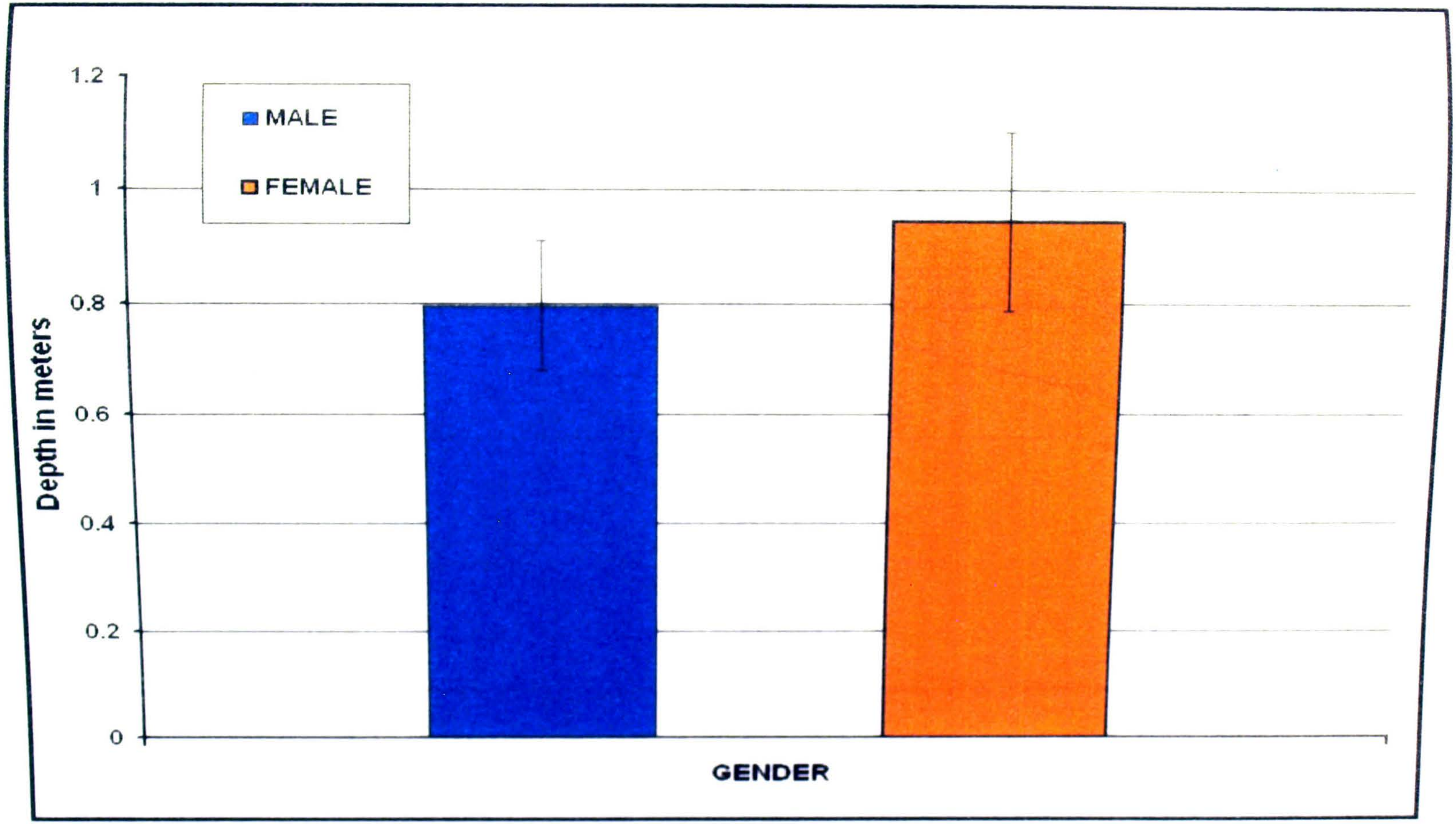

Figure 18. Mean overall depth of relocation points for male (N = 6) and female (N = 8) *S. m. peltifer* tracked in Whiteoak Creek, Houston and Humphreys counties, Tennessee, from May 2004 to April 2005.

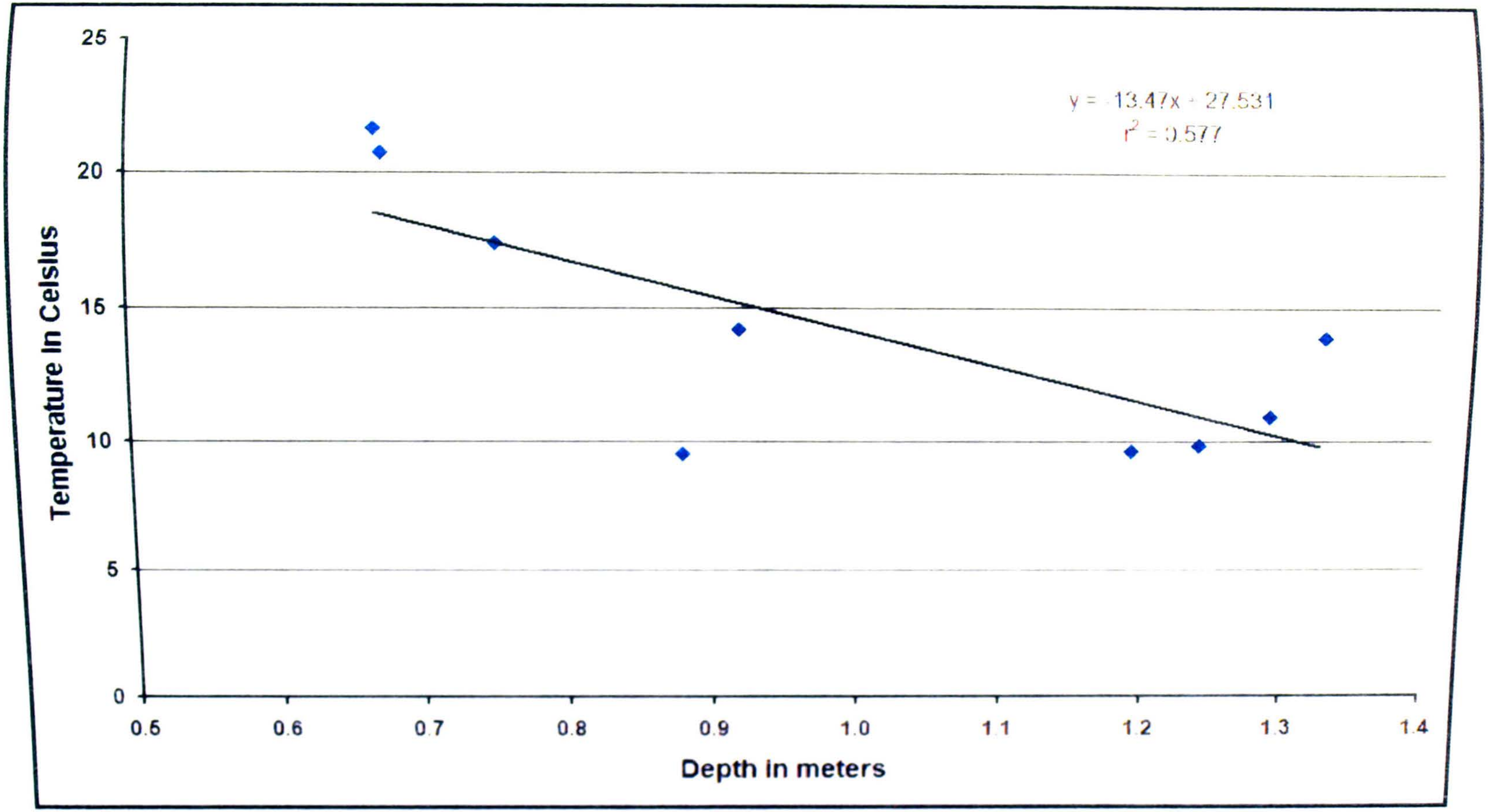

Figure 19. Relationship between mean monthly depths of relocation points for all study animals and the mean monthly temperature of Whiteoak Creek at Gander Branch study site.

Diel Behavior

Overall, the study animals exhibited a preference for darkness over light ($Z = -3.07$, $P = 0.002$) (Figure 20). Male turtles moved more frequently during daylight hours than females ($Z = 2.12$, $P = 0.034$) (Figure 21). The population's diel behavior (frequency) shifted with the changing seasons ($Z = 2.15$, $P = 0.032$). The months of July and August saw the highest levels of nocturnal behavior, while during September, October, and November no preference for light or dark was apparent (Figure 20). Turtles did not move more frequently during any particular 2-hour interval when checks were begun in even hours ($Z = 0.00$ to -1.33, P-values ranging from 0.21 to 1.00), nor was there any significant difference in the distance traveled per interval ($F = 0.78$, $P = 0.659$) (Figure 22). In contrast, data from two 24-hour samples during which checks were begun on each odd hour, there seemed to be a trend toward progressively more and longer movements from 1700 hours through 0100 hours (Figure 23). This observation, however, cannot be supported statistically because of the small sample size.

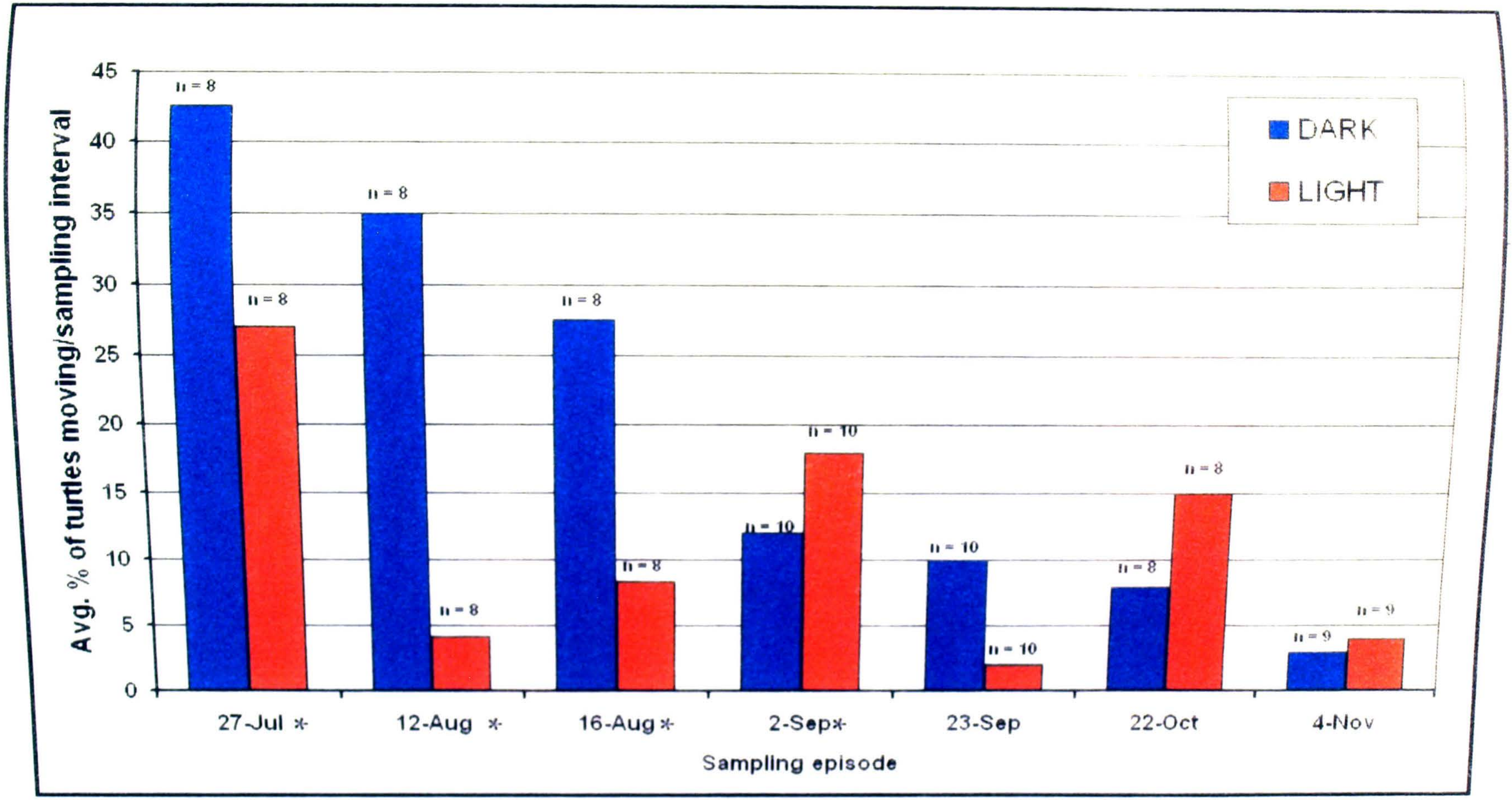

Figure 20. Average percent of radio-tagged *S. m. peltifer* moving during light and dark parts of 24-hour cycle based on checks made every 2 hours on 7 occasions from July to November 2004 in Whiteoak Creek, Humphreys County, Tennessee. An asterisk identifies sampling episodes during which data are lacking for a single 2-hour interval.

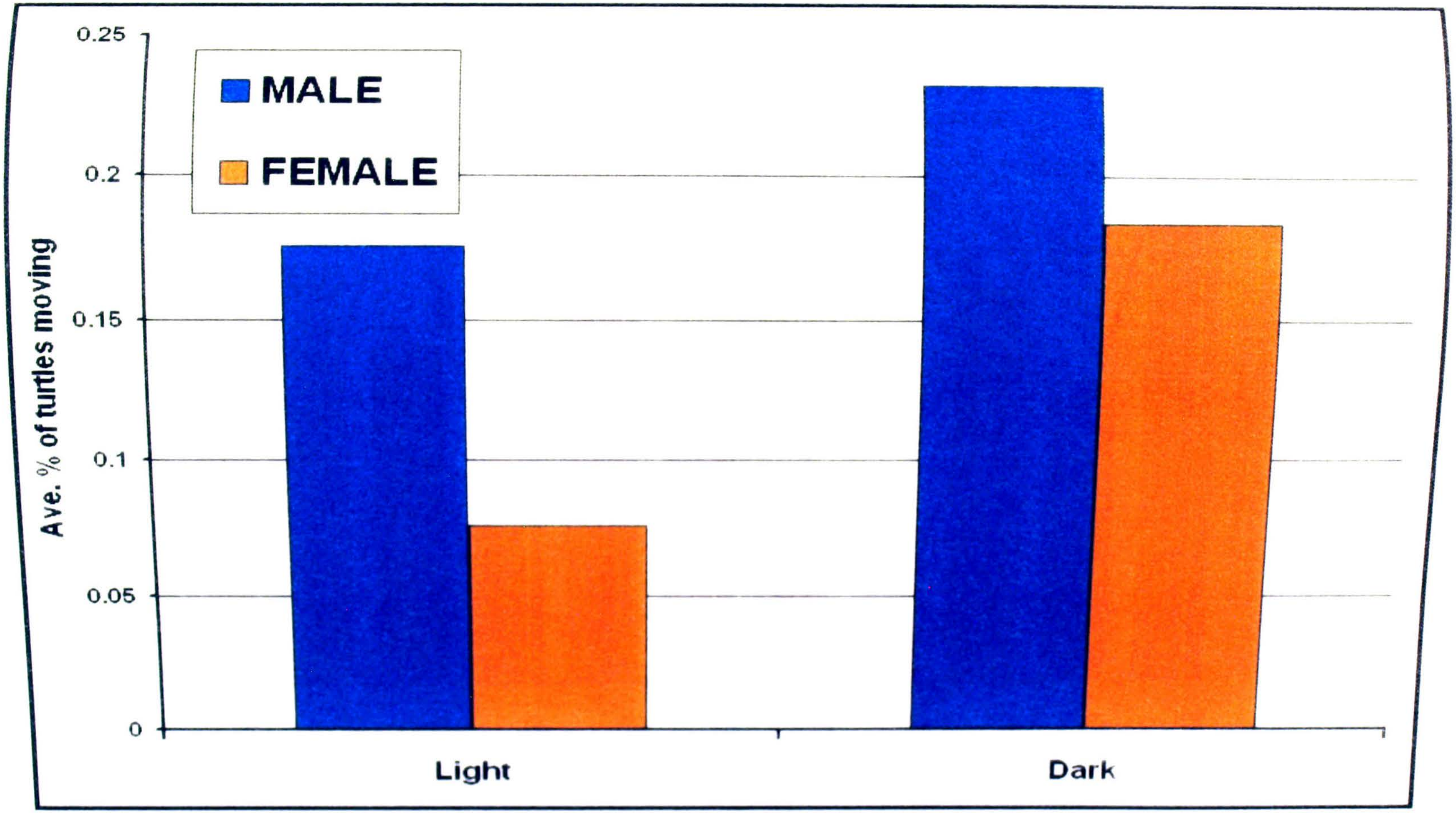

Figure 21. Average percent of radio-tagged male and female *S. m. peltifer* moving during light and dark parts of the 24-hour cycle based on checks made every 2 hours on 7 occasions from July to November 2004 in Whiteoak Creek, Humphreys County, Tennessee.

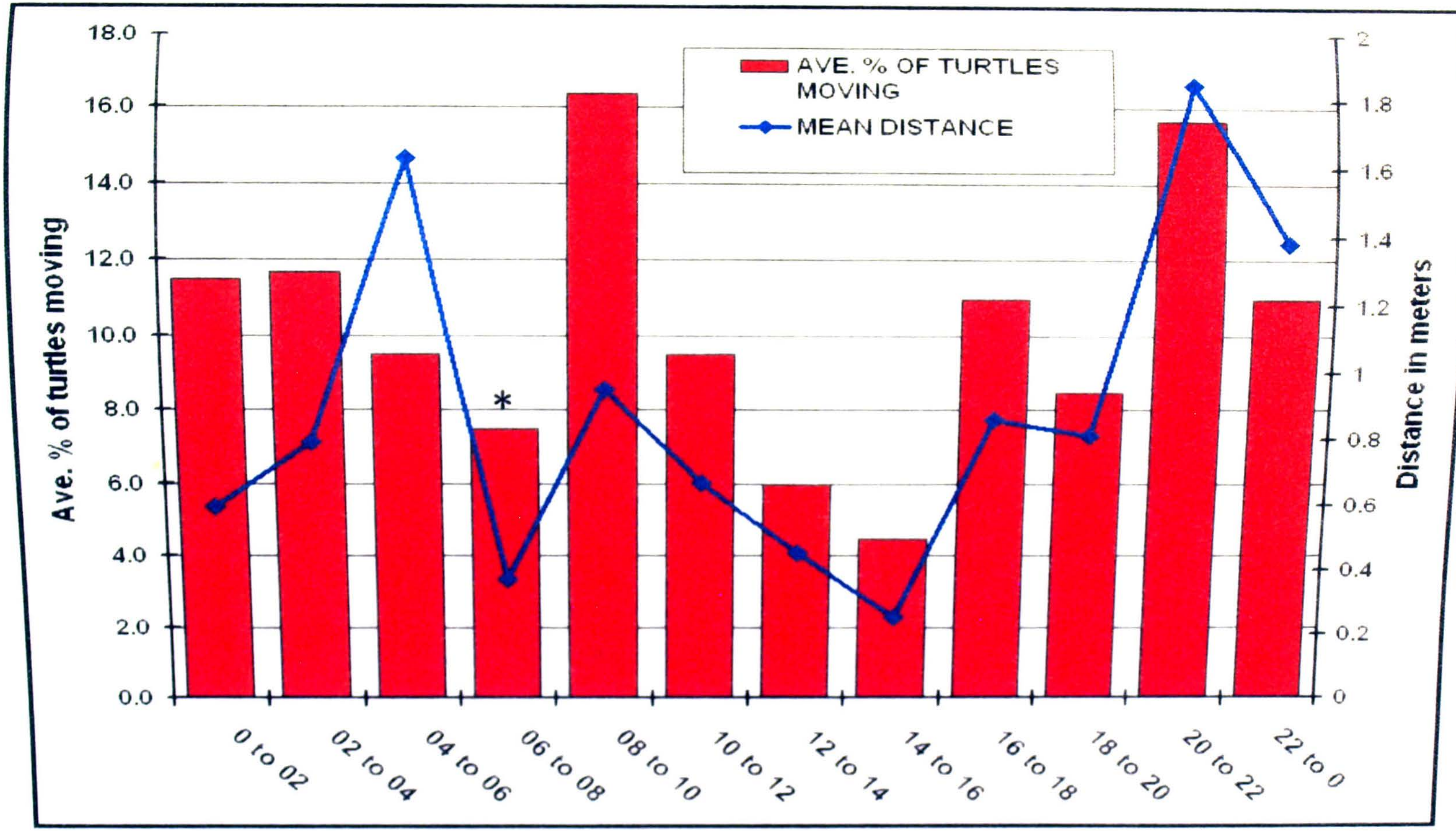

Figure 22. Average percent of turtles moving and mean distance traveled during five 24-hour surveys (16 August, 2 September, 23 September, 22 October, and 4 November 2004) involving 12 sampling episodes beginning every even hour. An asterisk identifies intervals lacking data.

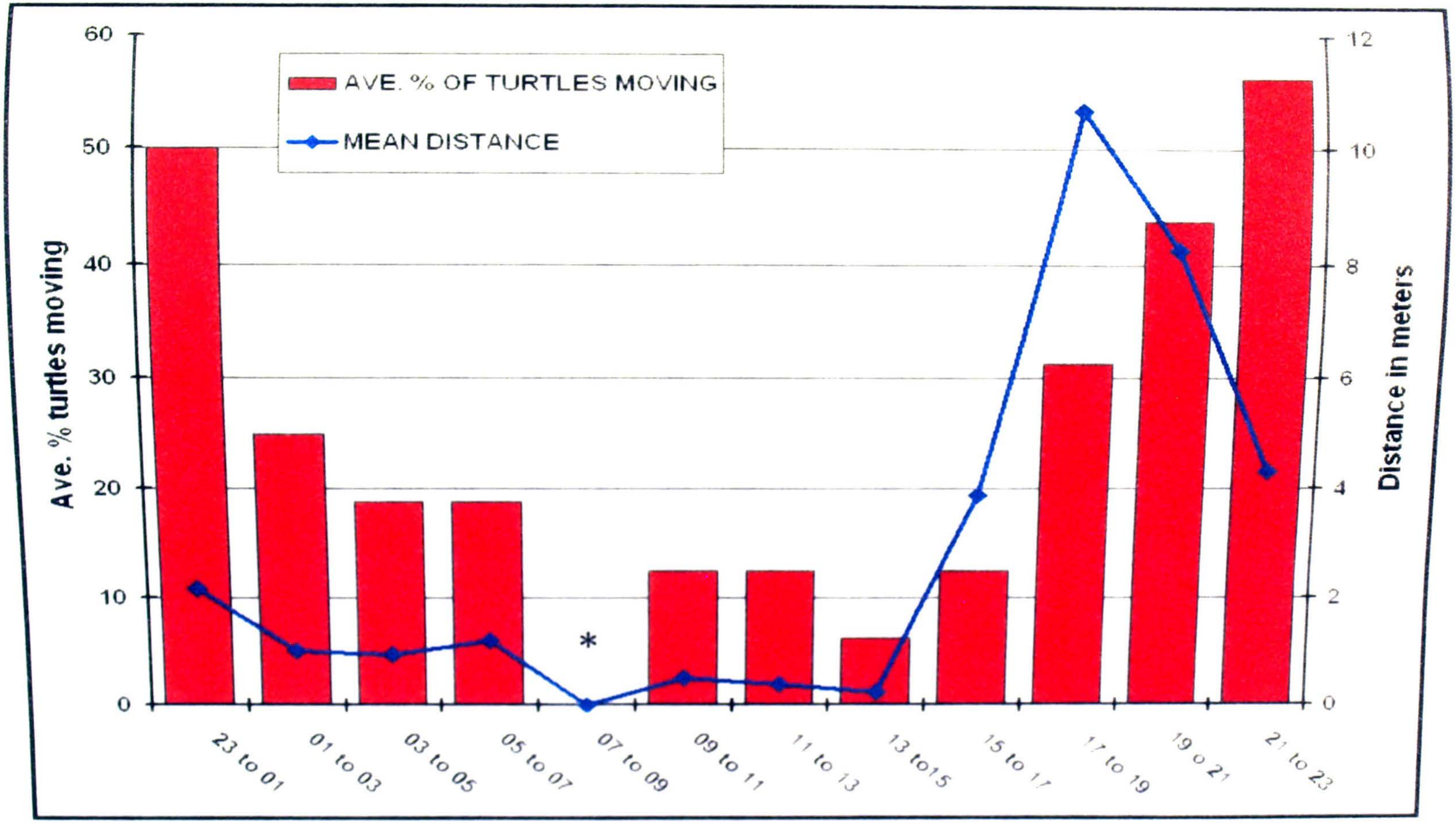

Figure 23. Average percent of turtles moving and mean distance traveled during two 24-hour surveys (27 July and 12 August 2004) involving 12 sampling episodes beginning every odd hour. An asterisk identifies intervals lacking data.

CHAPTER V

DISCUSSION

Movement and Overwintering Behavior

Most direct observations of *S. m. peltifer* moving in Whiteoak Creek were of individuals crawling on the stream bottom. This habit of bottom crawling as opposed to swimming, probable enabled radio-tagged individuals in this study to carry transmitter packages of up to 7.6% of their body mass without affecting their movement. Schubauer et al. (1990) used transmitters that reached 12% of the body weight of *Trachemys scripta* they tracked without any apparent adverse affects on their movement, buoyancy, and survivability.

Many movement studies have shown that turtles, along with many other reptile species, transverse a limited area throughout their lifespan (Mahmoud, 1969). *Sternotherus minor peltifer* is no exception to this rule. Its home range as documented in this study is generally smaller than that of other riverine species that occur in Whiteoak Creek. Plummer et al. (1997) found that male and female *Trionyx spiniferus*, known today as *Apalone spiniferus*, in Central Arkansas have home ranges with average lengths of 1756 ± 522 m and 1420 ± 590 m, respectfully, which are four to five times longer than what I found for *S. m. peltifer*. Likewise, the linear home range of *Graptemys geographica* was larger as determined by Pluto and Bellis (1988) at 2.1 km for male and for 1.2 km female. The difference in home range sizes among species is related to size differences of the individuals within the various species. Larger turtle species inhabit larger areas and have larger home ranges when compared to smaller species (Gibbons et al., 1990), suggesting size and therefore the metabolic demand of an organism directly affects the home range size of the organism. Thus it follows that larger turtle species must inhabit and transverse larger areas to meet their metabolic requirements. Turner et al. (1969) found in some lizard species that home range size positively correlates to the body weight of the individual. The data obtained on home range size of *S. m. peltifer* in this study is at odds with Dodd's et al. (1988) findings for the closely related species, *Sternotherus depressus*. This is probably due to the differences in sample sizes and methods of analysis. Dodd et al. (1988) only had sufficient data to calculate the 95 % minimum convex polygon for one male turtle's home range, while I used ArcGIS 9 to calculate the 100 % minimum convex polygon to include all aquatic habitats and exclude all terrestrial habitats of 14 turtles' home ranges. Only one *S. m. peltifer* (11-3 female) in Whiteoak Creek had a home range size (89 m^2) that was comparable to the 88 m^2 home range calculated by Dodd et al. (1988) for a male *S. depressus*. In Whiteoak Creek, *S. m. peltifer* displayed no apparent evidence of being territorial due to overlapping home ranges and sharing of microhabitats. Schubauer et al. (1990) and Harrel et al. (1996) found in *T. scripta* and *M. temminckii*, respectfully, overlapping home ranges occurred among and between males and females.

Many studies (Harrel et al., 1996; Plummer et al., 1997; Pluto and Bellis, 1988; Mahmoud, 1969; Schubauer et al., 1990) have shown males moving larger distances and utilizing larger home ranges than females. The sexual size dimorphism found in most turtle species has been thought to be advantageous for increasing males' mobility to aid in mate searching (Berry and Shine, 1980). Conversely, male *S. m. peltifer* in Whiteoak Creek have very similar mean home range lengths when compared to females. This al., 1990), suggesting size and therefore the metabolic demand of an organism directly affects the home range size of the organism. Thus it follows that larger turtle species must inhabit and transverse larger areas to meet their metabolic requirements. Turner et al. (1969) found in some lizard species that home range size positively correlates to the body weight of the individual. The data obtained on home range size of *S. m. peltifer* in this study is at odds with Dodd's et al. (1988) findings for the closely related species, *Sternotherus depressus*. This is probably due to the differences in sample sizes and methods of analysis. Dodd et al. (1988) only had sufficient data to calculate the 95 % minimum convex polygon for one male turtle's home range, while I used ArcGIS 9 to calculate the 100 % minimum convex polygon to include all aquatic habitats and exclude all terrestrial habitats of 14 turtles' home ranges. Only one *S. m. peltifer* (11-3 female) in Whiteoak Creek had a home range size (89 m^2) that was comparable to the 88 m^2 home range calculated by Dodd et al. (1988) for a male *S. depressus*. In Whiteoak Creek, *S. m. peltifer* displayed no apparent evidence of being territorial due to overlapping home ranges and sharing of microhabitats. Schubauer et al. (1990) and Harrel et al. (1996) found in *T. scripta* and *M. temminckii*, respectfully, overlapping home ranges occurred among and between males and females.

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Home range size can also be an indicator of the condition of the habitat. In general, as food resources increase home range size tends to decrease (Zug et al., 2001). If a small area meets the resource requirements such as habitat types and condition, then turtles can be more stationary (Pearse, 1923), and home ranges can probably be smaller. Galois et al. (2002) explained the increase in movements by *Apalone spinifera* as turtles searching for habitat with appropriate resources. Also home ranges sizes are limited by the particular habitat types available and the conditions of these habitats (Mahmoud, 1969). If a habitat resource is poor, then more area is needed to support an individual turtle thus a larger home range.

Since aquatic habitats are dynamic and could change with each significant rain event, the size of an individual turtle's home range should be expected to fluctuate within a given year or more likely between years. Plummer and Shirer (1975) found *Trionyx muticus* home range to be dynamic due to the ephemeral nature of its preferred habitat (sandbars) caused by periodical flooding, but some individuals' home ranges shifted to utilized different sections of the river without habitat alterations. For *S. m. peltifer* in Whiteoak Creek, the key habitat types were two stationary microhabitats (limestone bluffs and vegetated rock outcrops) and one ephemeral microhabitat (fallen trees). The distance between a stationary microhabitat and a fallen tree may change drastically over night, and the same is true with distance between individual fallen trees. This in return could cause greater separation between crucial resources, thus increasing the turtle's home range length. Home range size should be expected to differ between sites within a river system and definitely throughout the geographical distribution of the species due to differences in resource availability and distances between preferred habitats. Some individual *S. m. peltifer* home ranges only incorporated limestone bluffs. These home ranges would not be expected to fluctuate as much as home ranges where ephemeral microhabitats are being used. Home ranges mostly consisting of woody debris such as snags and fallen trees would be expected to change with time.

Sternotherus minor peltifer in this study displayed movement patterns similar to those described by Dodd et al. (1988) for *Sternotherus depressus*. As sister taxa, these two species are consider more closely related to each other than to the other two species of *Sternotherus* (Tinkle, 1958; Iverson, 1998), so behavior similarities should be expected. Individuals had preferences for certain sites within their home ranges that they frequented throughout the study. Most individuals would make long-distance movements up and down stream from a preferred area to stay days or weeks at a time before returning. Like *S. depressus*, multiple individuals utilized these preferred sites concurrently throughout the study. Harrell et al. (1996) found site fidelity as well in *Macroclemys temminckii* were many of there relocation fixes were 1.5 m from a previous know occupied microhabitat. Nearly half of the *Sternotherus depressus* relocations involved large flat rocks on the stream bottom (Dodd et al., 1988), while relocations for *S. m. peltifer* involved predominantly crevices in submerged limestone bluffs. Substrates below limestone bluffs and limestone outcrops occasionally consisted of large rocks, but mostly were dominated by cobble and gravel-sized rock. One difference between the two species is that mud habitats were selected more often by *S. depressus* than *S. m. peltifer*, a difference that may have been more a function of availability that choice. Both species exhibited a penchant for woody debris, such as fallen trees, logs, and root-debris. The similarities among the two species diets could account for the similarities in habitats being occupied. The diet of *S. depressus* consists largely of gastropods (Marion et al., 1991) much like that of *S. m. peltifer* (Folkerts, 1968).

Habitat preferences displayed by *S. m. peltifer* in this study were generally similar to those of other *Sternotherus* species, but differed in some respects. Ernst et al. (1994) mentioned commonly exploited habitats for *S. minor* included snags and fallen trees over a soft bottom. Most of *S. m. peltifer* in Whiteoak Creek were relocated on rocky substrates and were rarely documented traversing soft bottoms. The Whiteoak Creek population appeared to favor limestone bluffs and outcrops more than snags and fallen trees. Mahmoud (1969) found that habitats (rocks, logs, and overhanging banks) selected by *S. odoratus* and *S. carinatus* in Oklahoma to be similar to those Dodd et al. (1988) observed for *S. depressus*. I also found *S. m. peltifer* in these habitats, but to a lesser degree. The mean depth at which *S. m. peltifer* were found in this study was very similar to that reported for the species by Ernst et al. (1994). In Whiteoak Creek the mean depth was 0.89 m, which falls near center the 0.5-1.5 range given by Ernst et al. (1994). The dissimilarities in habitat selection mentioned above are probably the result of different geographical features dominating in where each species occurs and availability differences of each habitat within a given stream. Populations in the Tennessee River drainage are likely to occur in streams where limestone bluffs and vegetated rock outcrops are far more abundant than in streams on the Coastal Plain of the southeastern United States.

Sternotherus minor peltifer in Whiteoak Creek showed activity in every month of the annual cycle. However, there was a four-month period from December to March when activity decreased noticeably. Ernst et al. (1994) reported that *S. minor* in more northern latitudes hibernates from December through February. Much like *S. minor*, *Sternotherus odoratus* and *S. carinatus* in Oklahoma exhibited a three-month period with some inactivity lasting December through February (Mahmoud, 1969). *Sternotherus odoratus* was estimated to remain active for 330 days and *S. carinatus* 310 days (Mahmoud, 1969). In Pennsylvania, *S. odoratus* was inactive for a five-month period extending from November through March, with only 220 days of activity (Ernst, 1986). Plummer and Burnley (1997) found individual *Apalone spinifera* in Arkansas, much like *S. m. peltifer* in Whiteoak Creek, were not exclusively sedentary in winter but shifted hibernacula an average of 1.8 times over the course of winter.

The mean distance moved by *S. m. peltifer* in Whiteoak Creek decreased during the winter months while the depth of relocation points increased. These minimal distances moved during winter may have a vital physiological role moving into areas of high oxygen concentrations from low ones (Ultsch, 1989). Decrease in mean distance moved and increase in mean depth in Whiteoak Creek was probably directly related to changes in temperature. Gregory (1982) claims the most important aspect in impeding metabolic rates and inducing hibernation, thus reducing distance traveled, is the ambient temperature. Plummer and Burnley (1997) found body temperature of *Trionyx spiniferus* to be comparable to the ambient creek temperature. Turtle 8-9 also displayed this relationship. Water temperature was found to affect *Macroclemys temminckii* movement, but photoperiod was also suggested as another factor effecting the movement in winter months (Harrell et al., 1996). In the case of *Apalone spinifera*, mean distance moved decreased while the mean depth increased with the approach of winter (Galois et al., 2002). Deeper waters could provide some temperature stability throughout the winter. Fluctuation in ambient surface temperature would affect a reptile overwintering in shallow waters more so than one in deeper waters (Gregory, 1982). An unusually warm mid-winter day or warm rain might stimulate turtles overwintering in shallow water to reemergence prematurely subjecting them to harsh environmental conditions that might quickly return.

In Whiteoak Creek, it took the radio-tagged population of *S. m. peltifer* several weeks to enter the winter inactivity period and only about 2 weeks to emerge from it. This is not uncommon in reptile species. The time from when the first individual of a population enters winter dormancy to when all have done such could be several months (Gregory, 1982). The reemergence of the Whiteoak Creek population was preceded by a significant rain event that caused the creek to leave its banks. This might have been the main stimulus triggering resumption of activity.

Diel Behavior

Although my data show a proclivity for nocturnal movements by *S. m. peltifer*, diurnal movements were not uncommon. Most of the hand captures were during daylight hours (0700-1800), suggesting that the species is not limited to nocturnal movements only. The apparent preference for darkness I observed may have been affected by the absence of data from intervals missed when sampling. However, this is highly unlikely since the P-value was so significant at $P = 0.002$. Ernst et al. (1994) reported *S. minor* to be active during both day and night with a tendency to be most active in the morning. *Sternotherus depressus* displayed a variety of diel behaviors (nocturnal, crepuscular, and diurnal) during the annual cycle by being diurnal when water was cool and nocturnal when it was warm (Dodd et al., 1988). It appears that *S. m. peltifer's* diel behavior undergoes the same shifts with the seasons as *S. depressus*. This temporal activity shift has also been documented for *Sternotherus odoratus* in Oklahoma where a population exhibited a summer crepuscular behavior and a winter diurnal behavior (Mahmoud, 1969). In Whiteoak Creek, the diel behavior of *S. m. peltifer* appears to shift from nocturnal during warmer parts of the year to not having an affinity for either daylight or darkness in fall and winter. Before this can be confirmed, diel sampling including all seasons will have to be conducted. If real, the shift may not be photo-related but driven by a physiological restraint due to decrease in water temperature in the fall and winter months. Graham and Hutchison (1979) found similar results suggesting temperature and not the variation in photoperiod was affecting diel movements in *Chrysemys picta*, *Clemmys guttata*, and *Sternotherus odoratus*.

Competition for food resources can influence habitat partitioning and community structure. Interspecific competition, in particular, has direct effects on the evolutionary process within a community. When one species out-competes another species for a food resource, the two species can become spatially separated and unable to coexist in the same habitat. Conversely, the separation does not necessarily have to be spatial but maybe temporal. Temporal separation between two species with comparable diets may reduce competition, thus causing species adaptation to different rhythmic regimes (Gourley, 1979).

The nocturnal nature of *S. m. peltifer* in Whiteoak Creek may be evolutionary adaptive minimizing resource competition with a coinhabitant, the larger turtle species, *Graptemys geographica*. Both species have analogous gastropod-based diets, but conversely dissimilar diel behaviors. *Graptemys geographica* is diurnal and is well known as a basking turtle (Ernst et al., 1994), while *S. m. peltifer* in Whiteoak show a nocturnal behavior. *Sternotherus minor peltifer* and *S. m. minor* adults have a molluskivorous diet while smaller individuals feed on insects (Folkerts, 1968; Tinkle, 1958). The diet of the population studied by Folkerts (1968) consisted of 69.5 % snails, and only 0.1 % bivalues. With an increase in body size, *S. m. minor* appear to shift from insectivorous to molluskivorous (Ernst et al., 1994; Tinkle, 1958). Much like *S. m. minor*, *G. geographic* has demonstrated both molluskivorous and insectivorous diets. Vogt (1981) found this to be true in a population in Wisconsin, and characterized the diets as molluskivorous for females and insectivorous for males. In studies conducted in Arkansas (Ernst et al., 1994) and Missouri (White and Moll, 1992) the diet of *G. geographica* consisted mostly of freshwater gastropods. In Whiteoak Creek, interspecific competition for aquatic gastropods between *S. m. peltifer* and *G. geographica* over time, may have forced *S. m. peltifer* to adapt to a nocturnal behavior.

Conclusion

In Whiteoak Creek, *Sternotherus minor peltifer* exhibits home ranges that vary widely in size overall and between the sexes. Since Whiteoak Creek has a dynamic nature both seasonally and annually, this variability is not unexpected. The animals studied were very active in every month of the annual cycle except for a four-month period from December to March when activity decreased markedly. During this four-month period, the tracked animals occupied less microhabitats, preferred deeper water, and traveled less distances than any other time during the course of the study. The Whiteoak Creek population favored submerged limestone bluffs, vegetated rocky outcrops, and woody debris. On a daily basis, they were active throughout the 24-hour cycle, but tended to show a preference for nocturnal movements. Although both males and females preferred the cover of darkness when moving, males were more likely to move during daylight hours than females. The nocturnal behavior could be the result of an evolutionary process to minimize competition for food (gastropods and mollusks) with *G. geographica*, but only future diet assessment will verify this hypothesis.

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APPENDIX

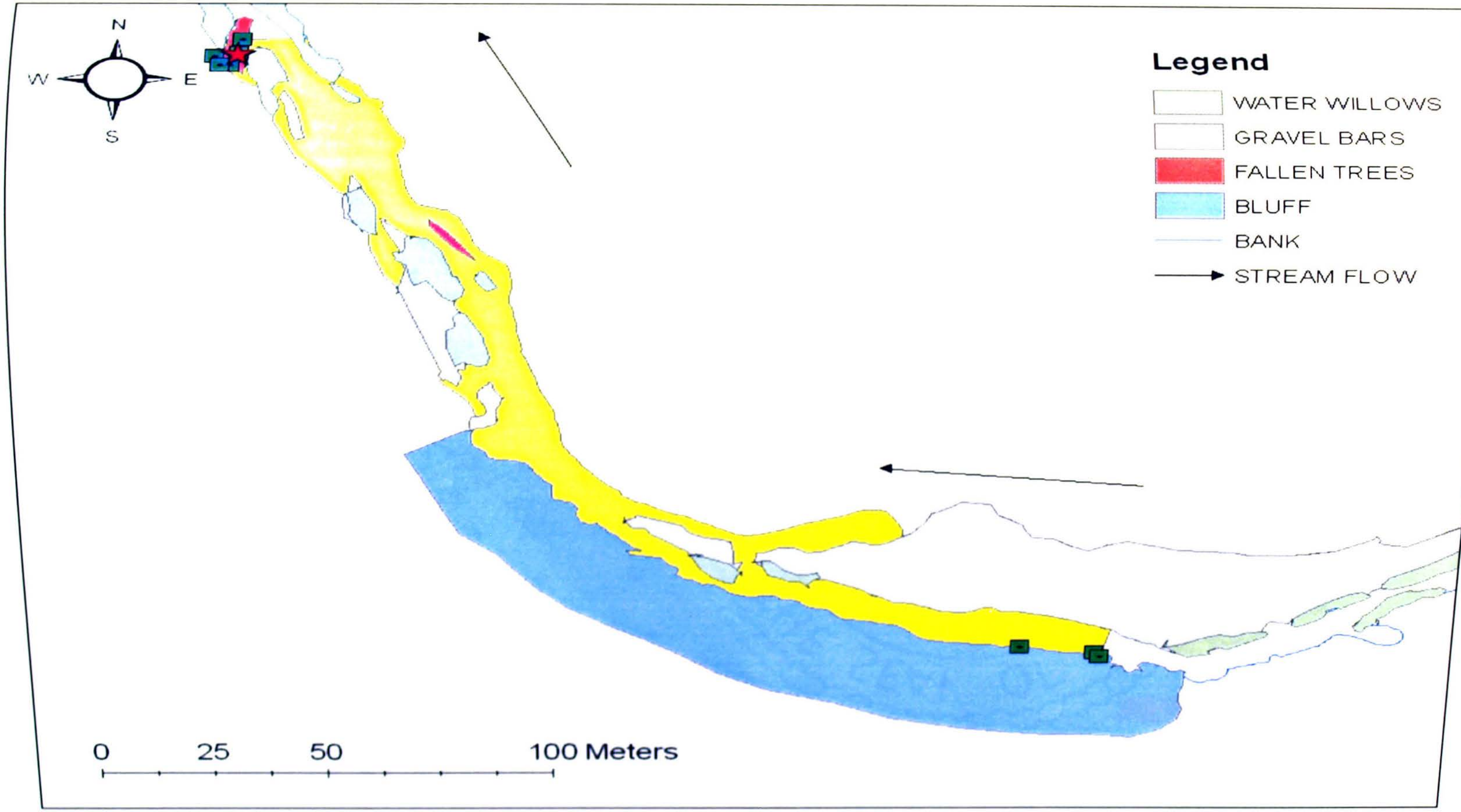

Figure A-1. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 2-8 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

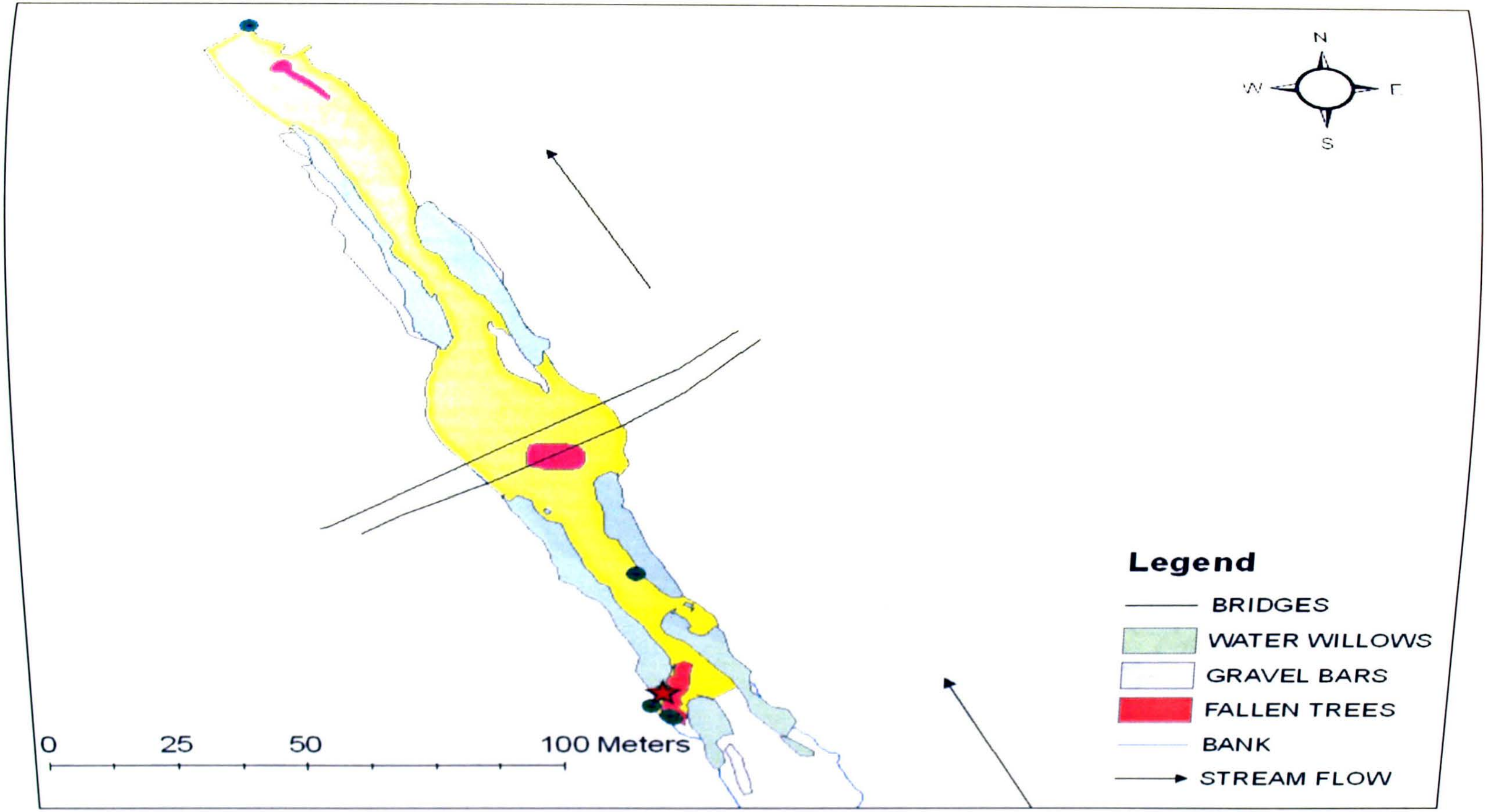

Figure A-2. Initial capture site (red star), subsequent relocation points (green circles), and home range (yellow) for male 2-1 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

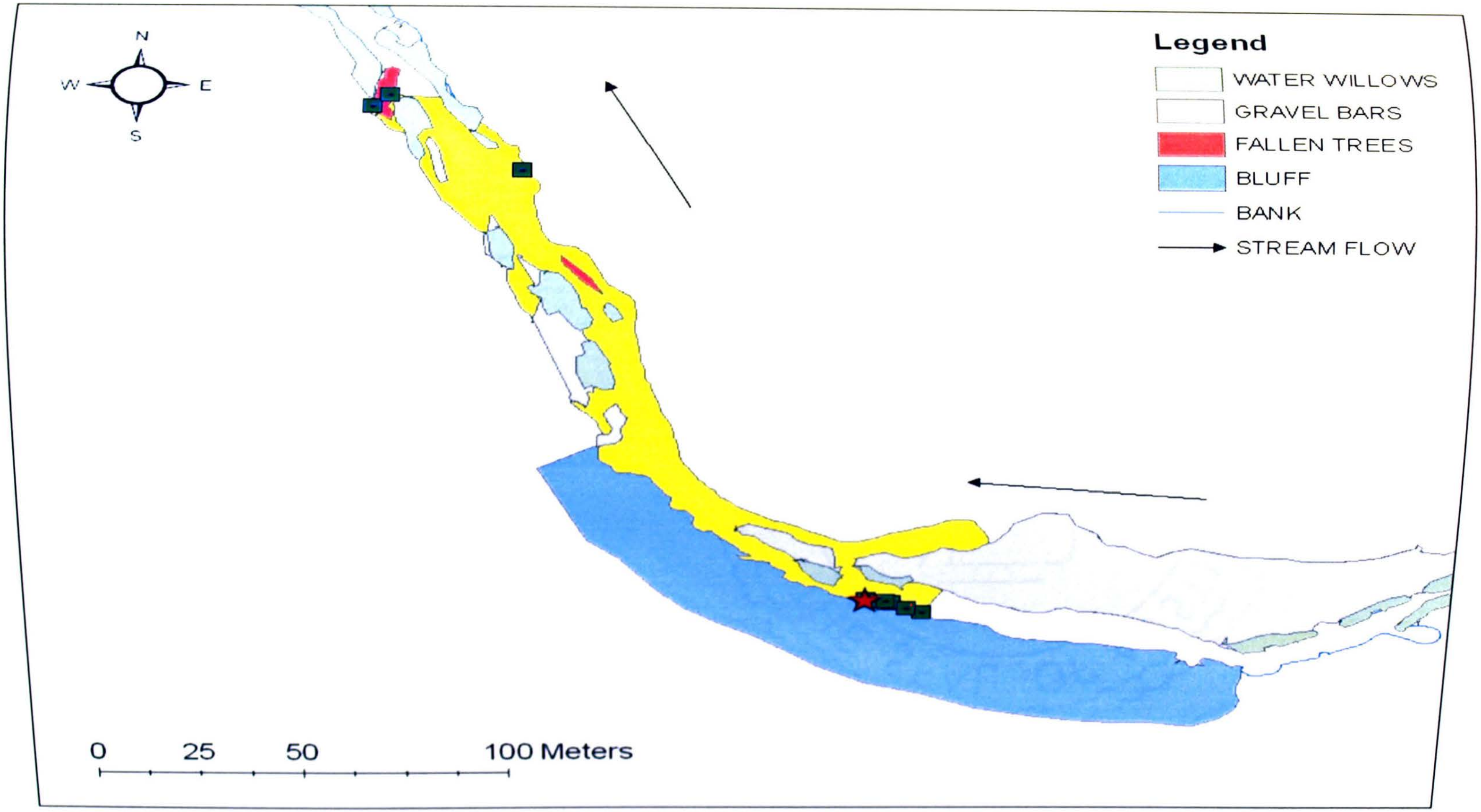

Figure A-3. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 6-0 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

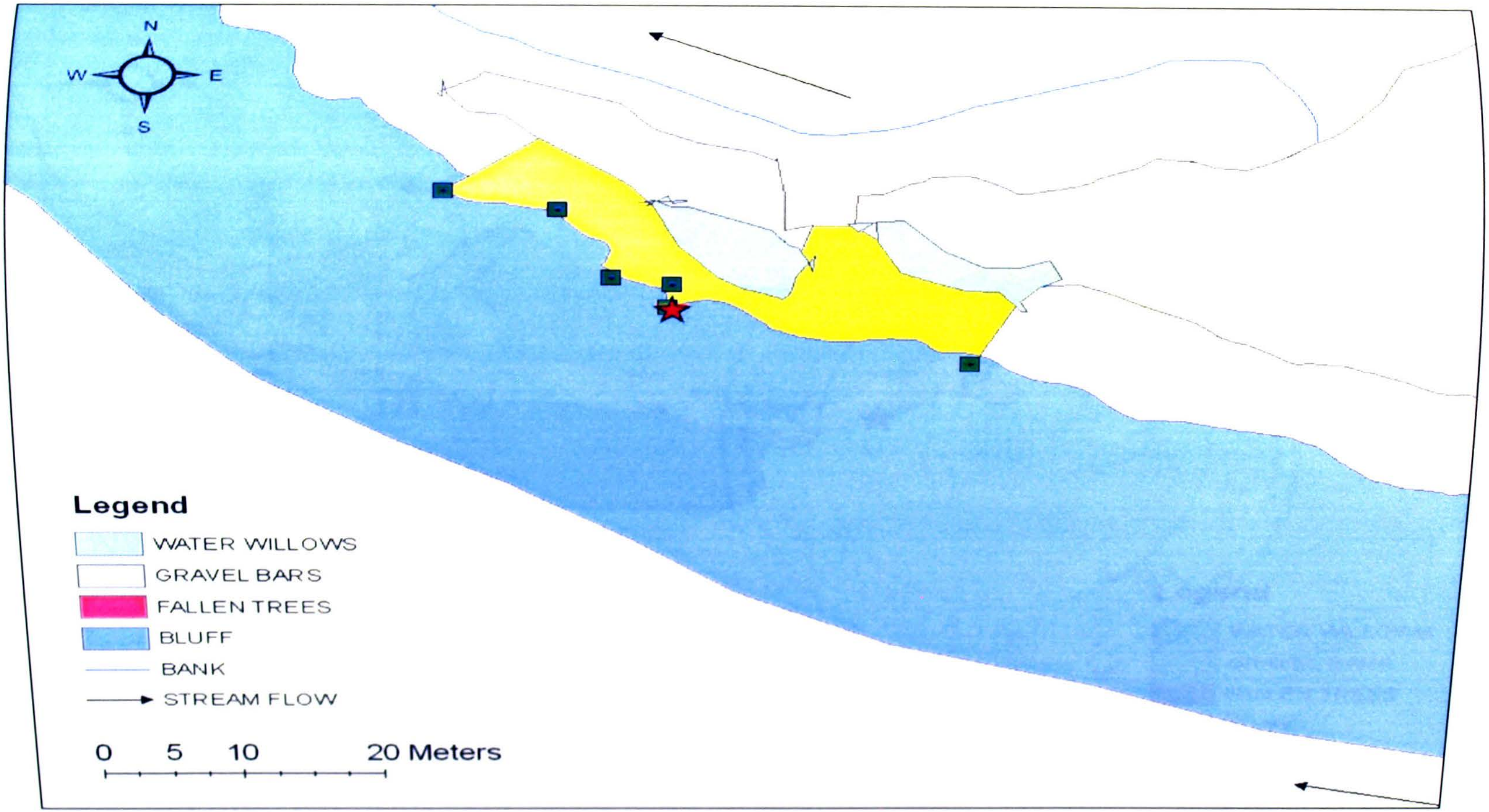

Figure A-4. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 11-3 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

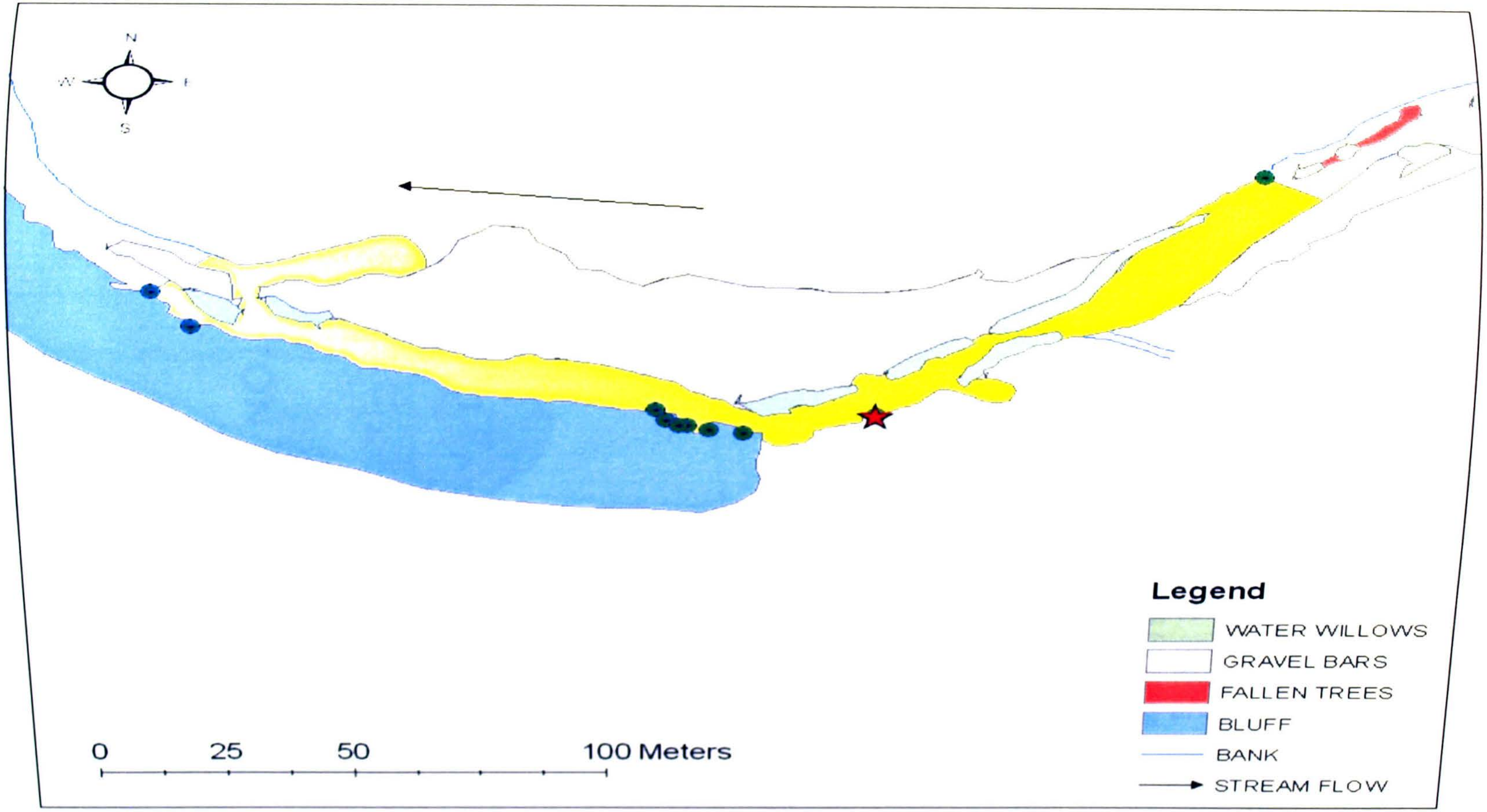

Figure A-5. Initial capture site (red star), subsequent relocation points (green circle), and home range (yellow) for male 8-1 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

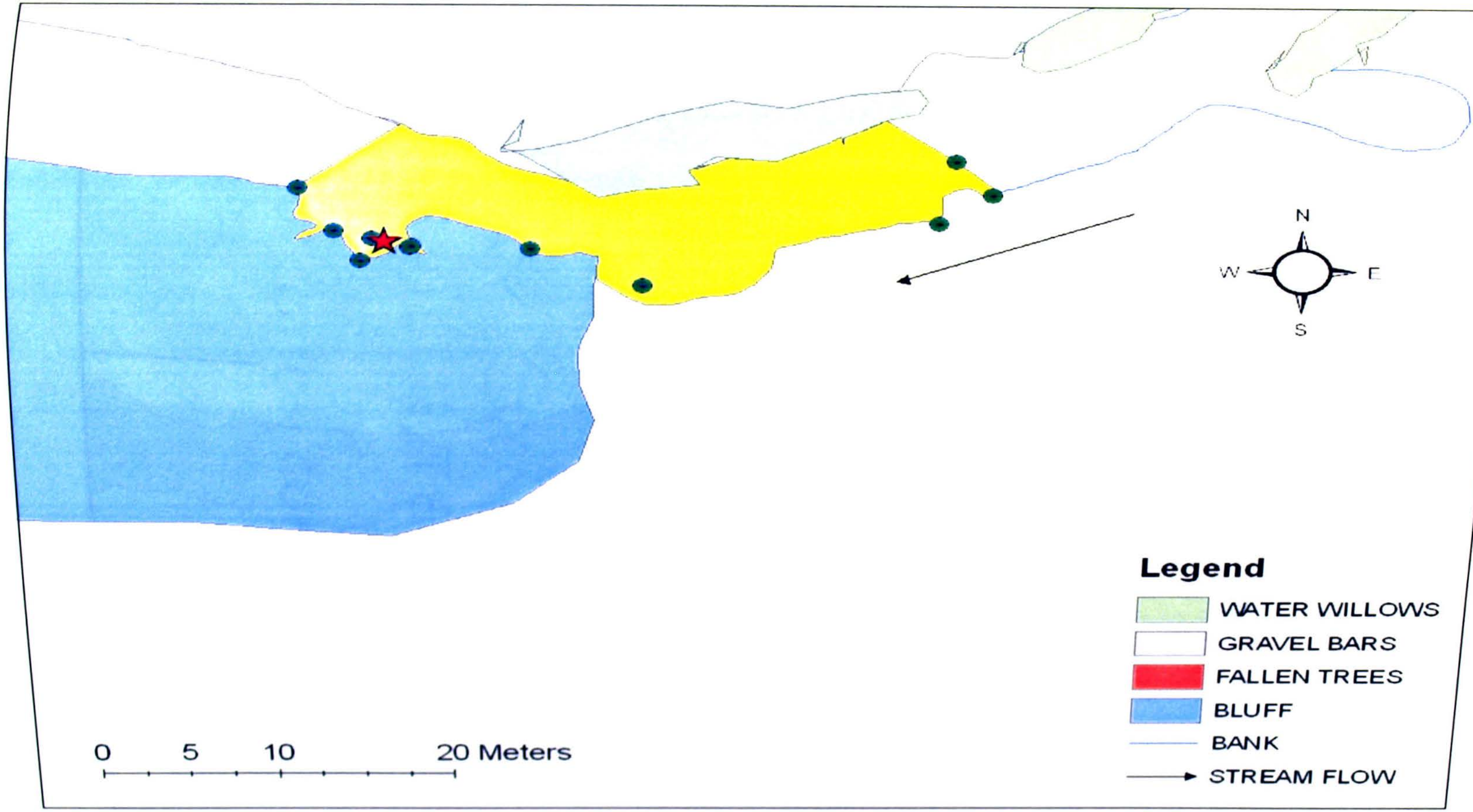

Figure A-6. Initial capture site (red star), subsequent relocation points (green circles), and home range (yellow) for male 11-10 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

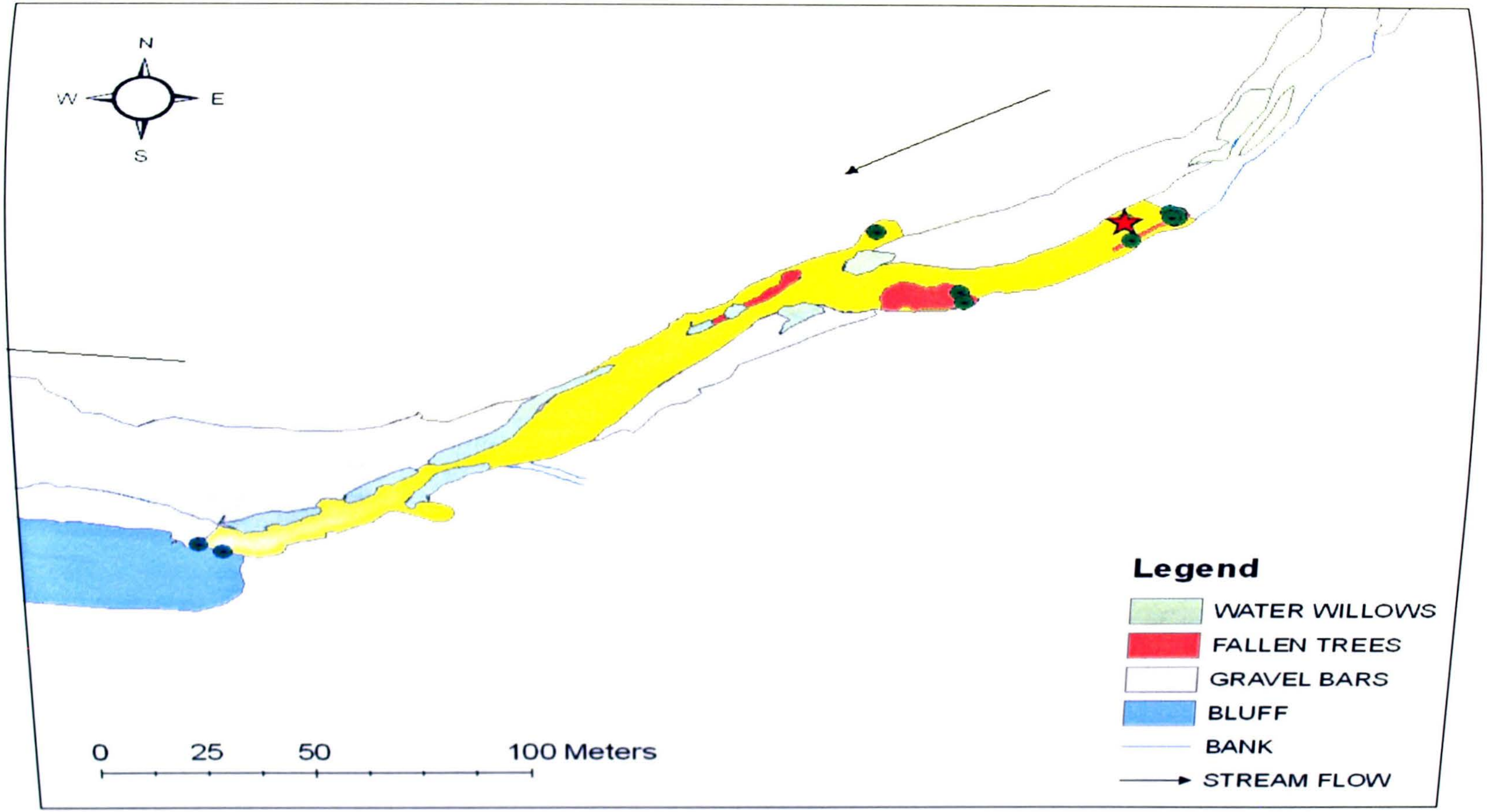

Figure A-7. Initial capture site (red star), subsequent relocation points (green circles), and home range (yellow) for male 2-2 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

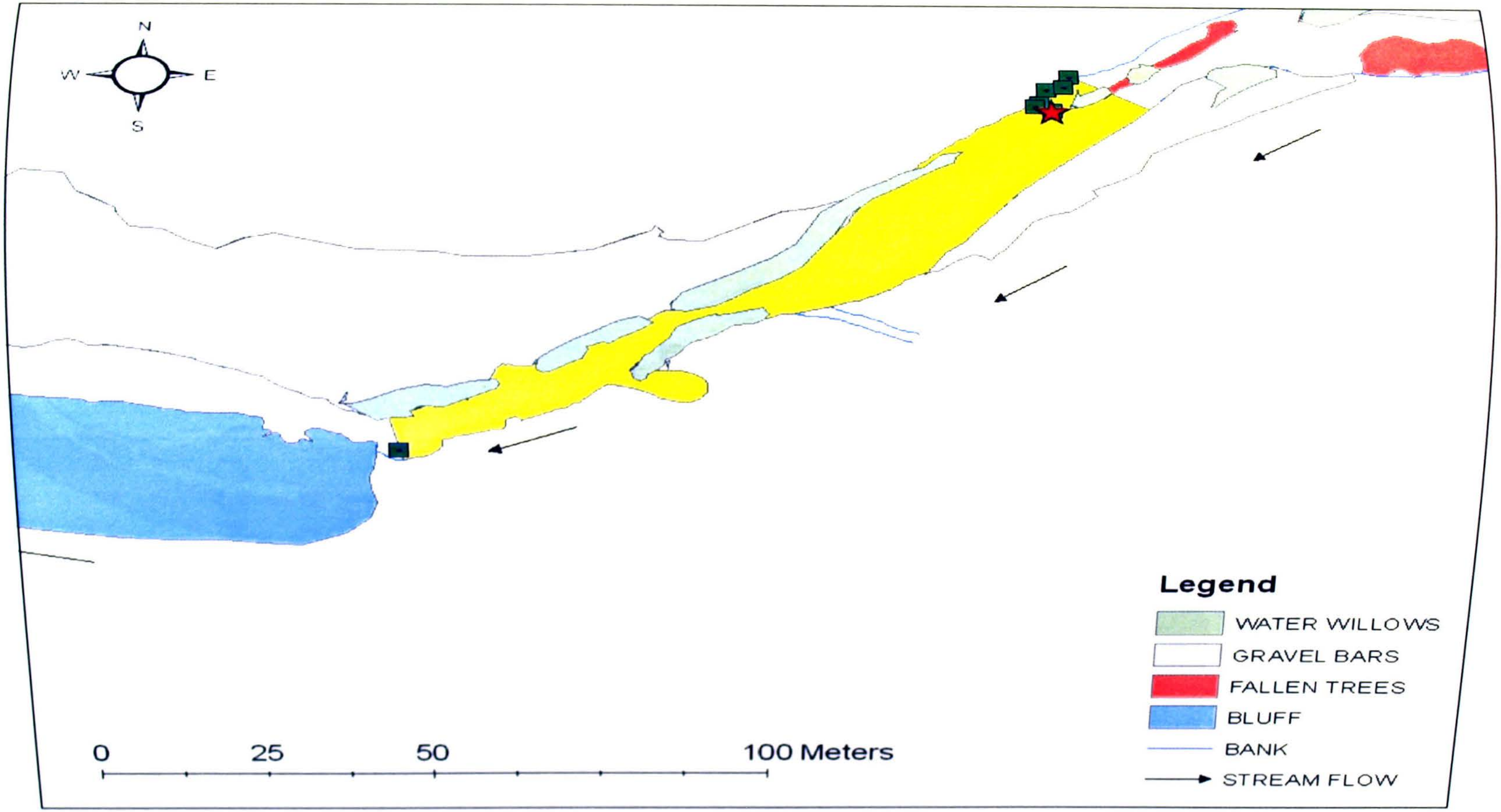

Figure A-8. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 9-0 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

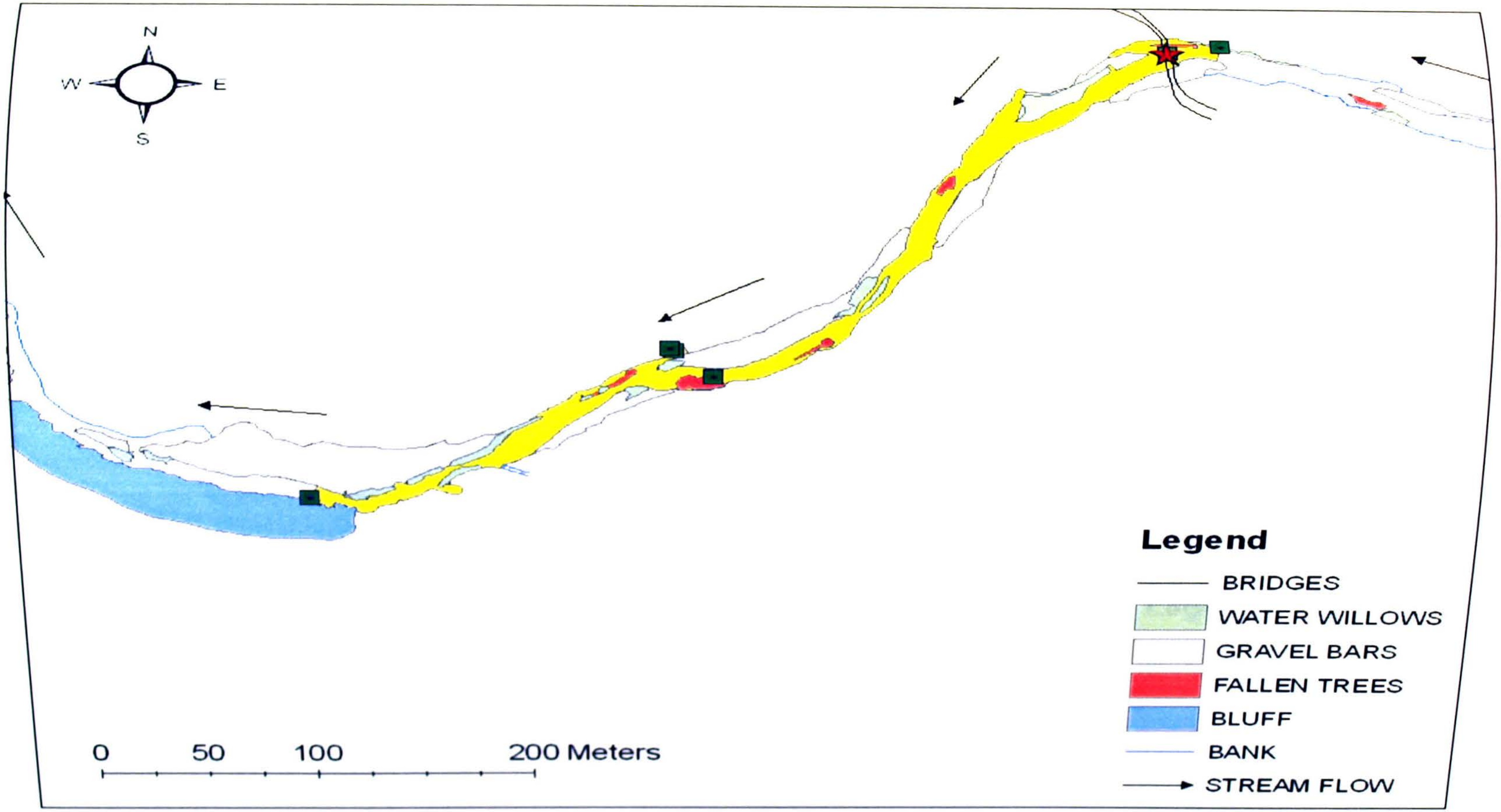

Figure A-9. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 10-8 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

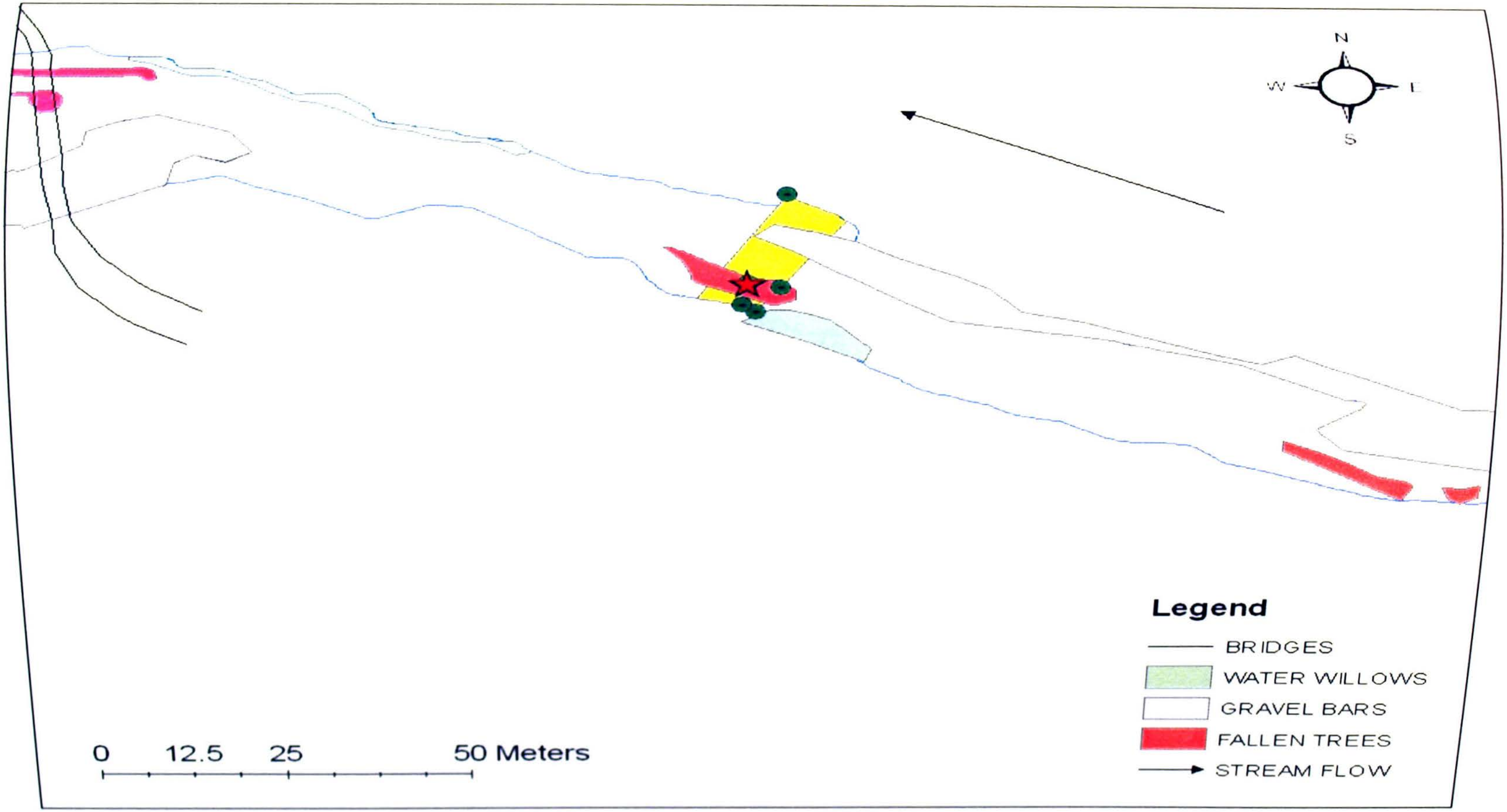

Figure A-10. Initial capture site (red star), subsequent relocation points (green circles), and home range (yellow) for male 8-8 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

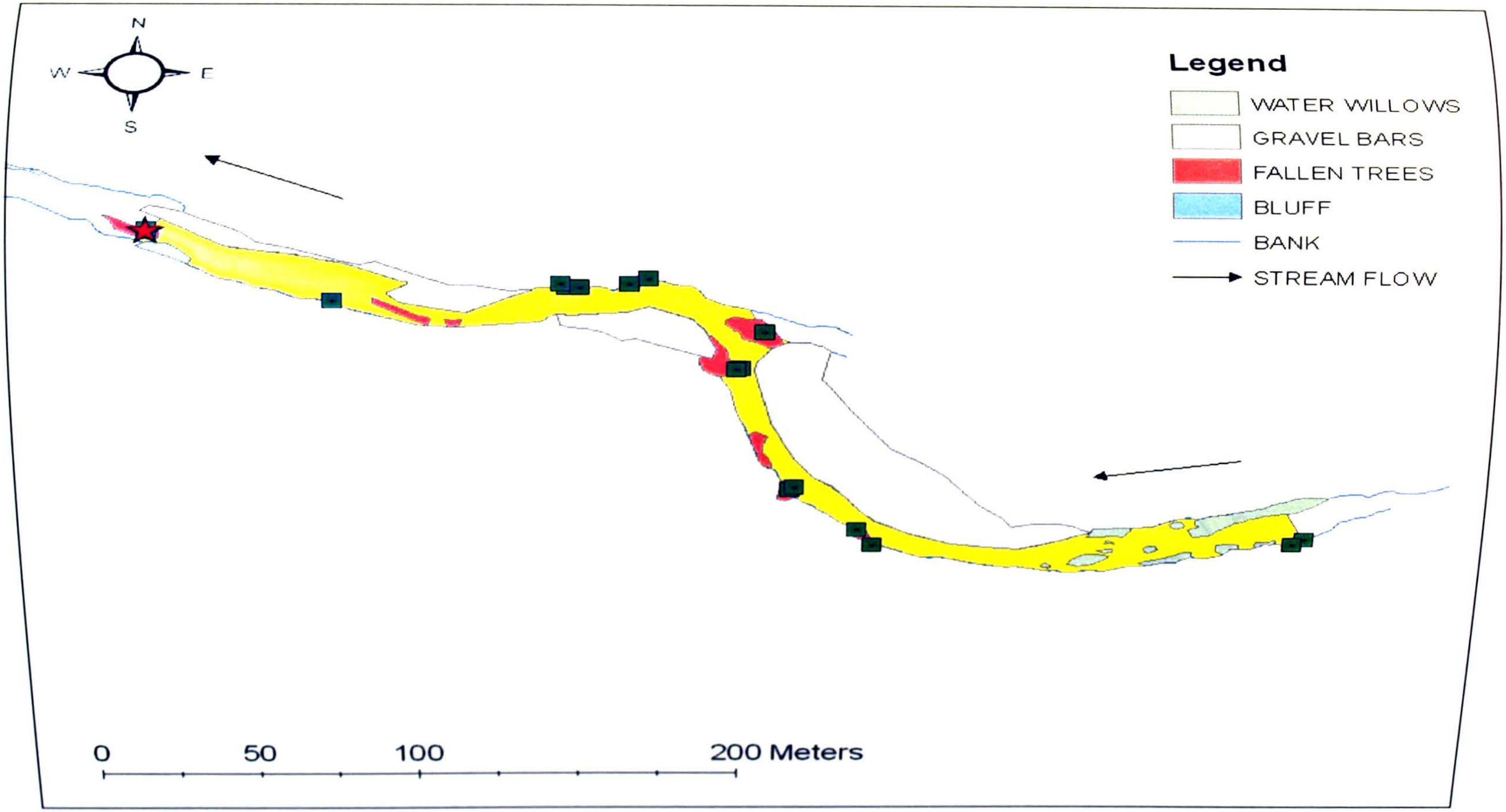

Figure A-11. Initial capture site (red star), subsequent relocation points (green squares), and home range (*yellow*) for female 1-11 at the Gander Branch site in Whiteoak Creek, Humphreys County, Tennessee.

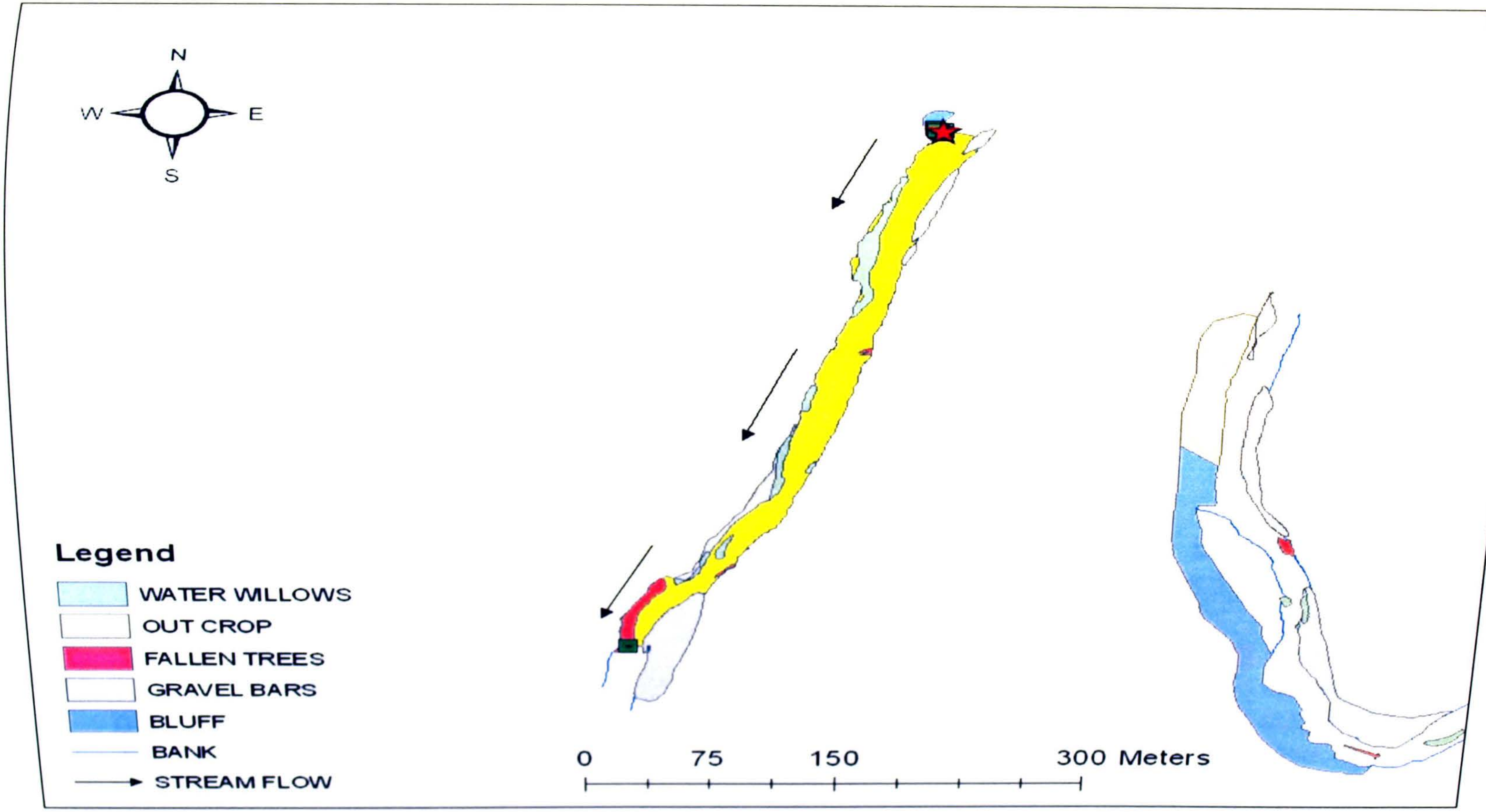

Figure A-12. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 0-8 at the Rushing Bluff site in Whiteoak Creek, Houston County, Tennessee.

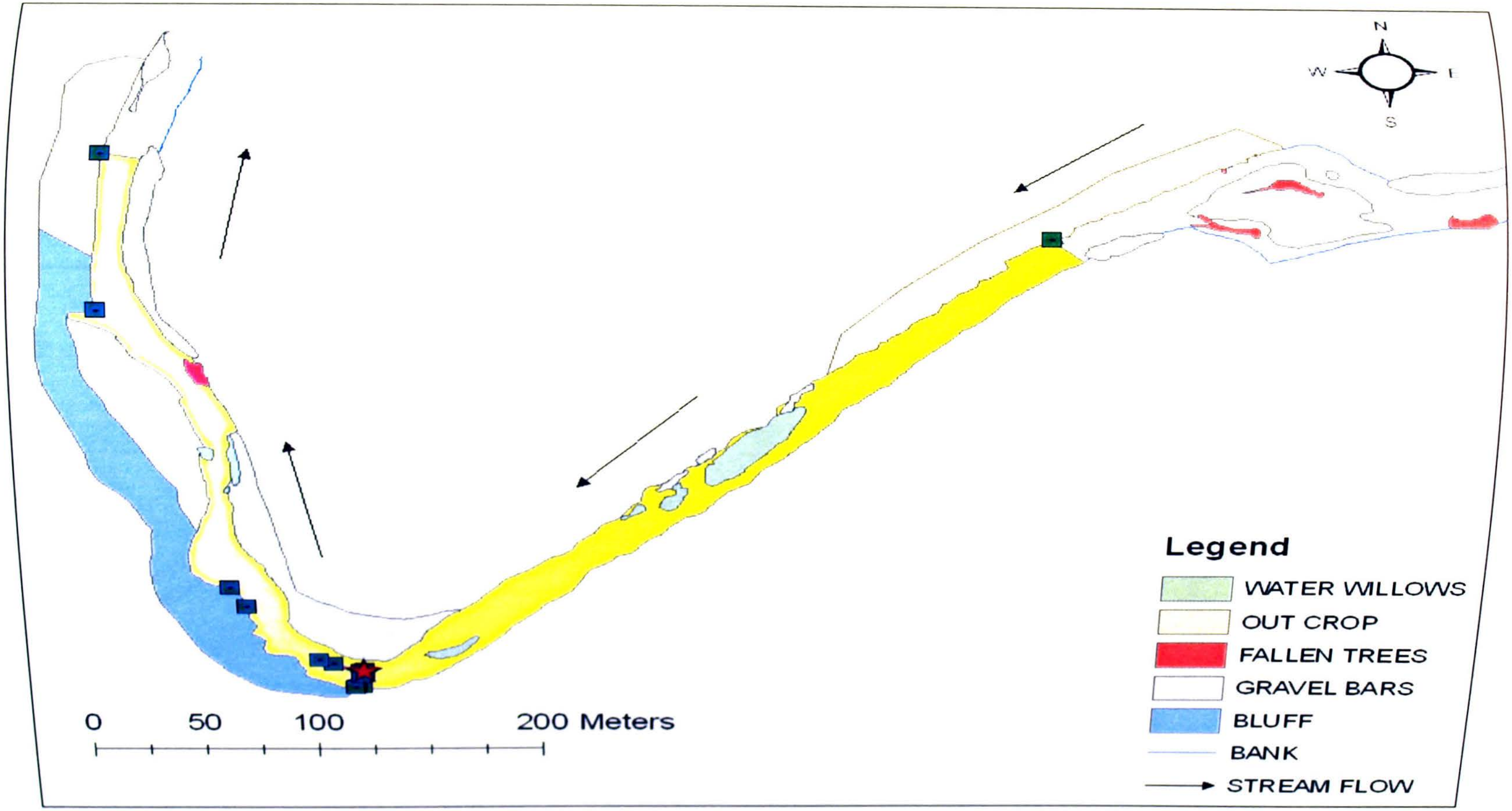

Figure A-13. Initial capture site (red star), subsequent relocation points (green squares), and home range (yellow) for female 2-9 at the Rushing Bluff site in Whiteoak Creek, Houston County, Tennessee.

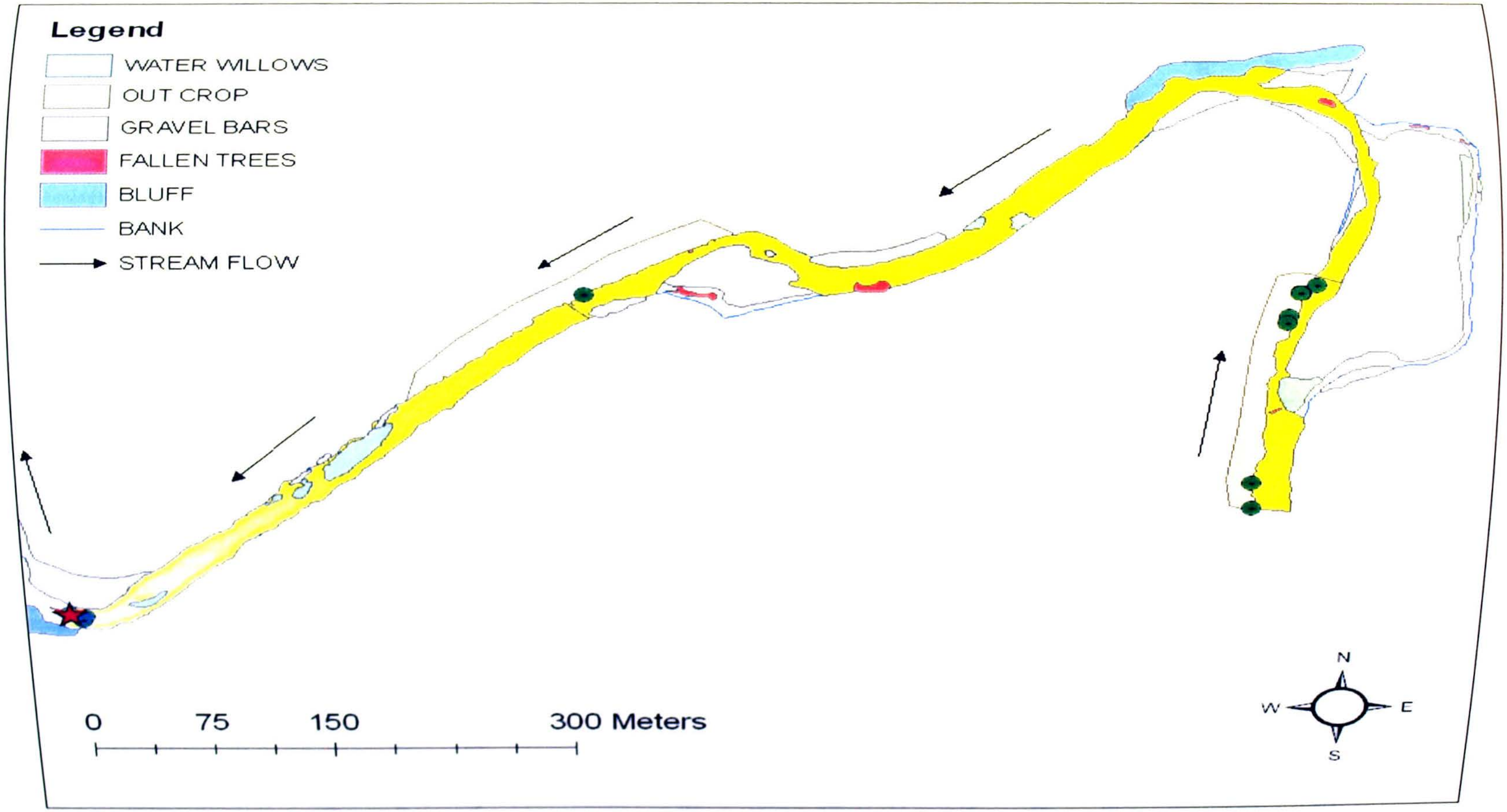

Figure A-14. Initial capture site (red star), subsequent relocation points (green circles), and home range (yellow) for male 10-11 at the Rushing Bluff site in Whiteoak Creek, Houston County, Tennessee.

VITA

Joshua Robert Ennen was born in Watseka, Illinois on 2 March 1981 to Scott Ennen and Glenda Ennen of Milford, Illinois. He has three siblings: two older brothers, Matthew Ennen and Damon King, and a younger sister Susan Ennen. He graduated from Maryville High School in Maryville, Tennessee in May 1999. After graduation, he enrolled in Maryville College, a local 4-year liberal arts institution. While at Maryville College, he worked as a field assistant for Dr. W. B. Cash on the reptile portion of the All Taxa Biodiversity Inventory of the Great Smoky Mountain National Park. Also at Maryville College, he completed an undergraduate thesis on the temporal calling dynamics of *Rana sylvatica*, Wood Frog. He graduated in May 2003 and received a research assistantship in the Center for Field Biology at Austin Peay State University. There he entered the Master of Science program and received a degree in biology under the tutelage of Dr. A. Floyd Scott in August 2005.

He plans to continue research in the area of herpetology and ecology while pursuing a Doctorate of Philsophy from the University of Southern Mississippi. He hopes to work on the population structure and ecology of the endangered *Graptemys flavimaculata*, Yellow-blotched Map Turtle.