Home Range, Hibernacula Fidelity, and Best Management Practices for Wood Turtles (*Glyptemys insculpta*) in Virginia.

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Abstract

Guidelines for timber harvesting, road construction, road maintenance, and other land use practices are needed for wood turtle (*Glyptemys insculpta)* management in the extreme southern part of their range. The development and implementation of best management practices can be an important tool in the conservation of the wood turtle. Currently specific guidelines do not exist for the southern range of the wood turtle and it is not known if behaviors are similar to northern populations.

We radio tracked 36 individual wood turtles from two populations in western Virginia to determine their home range, seasonal occupancy of buffer zones, and the annual fidelity to hibernacula.

There were no differences in the home ranges between Site 1 (14.99 ha) and the Site 2 populations (16.07 ha). Both populations have greater home ranges than reported for most northern populations. No significant differences were found between the home ranges of male and female wood turtles in the Site 2 population while Site 1 females (10.35 ha) had a smaller home range then males (24.27 ha).

Wood turtle movements within seasonal buffer zones (instream; 10 m, 30 m; 60 m; >90 m) were examined to help create land use guidelines. No wood turtles from either population were found greater than 10 m away from the stream during the winter season. During the spring and fall seasons 95 % of the wood turtle locations were found within 30 m of the stream. Wood turtles moved farthest from stream during the summer; however, 93 % of recorded locations were within 90 m of the stream.

There was no fidelity to winter hibernacula between 2006 and 2007 for males from either the Site 1 (0/4) or the Site 2 populations (0/4). Fidelity to hibernacula for females was 50% for both the Site 1 (2/4) and Site 2 (2/4) populations.

Four male wood turtles moved great distances (6.6 to 19.8 km). One wood turtle moved into a different watershed, extending the southern range of the species by 10 km.

Wood turtle populations in the extreme southern range need specific guidelines and best management practices to account for their differences with more northern populations.

Introduction

The wood turtle (*Glyptemys insculpta*) is a long-lived, medium-sized turtle. Wood turtles range from northern Virginia to southeastern Ontario, through Maine and Nova Scotia, west to eastern Minnesota and northern Iowa (Harding and Bloomer, 1979). They are seasonally aquatic and terrestrial with a home range that centers around streams or rivers (Fowle, 2001). Wood turtles require clear, clean water and can be sensitive to pesticide and sediment pollution (Harding and Bloomer, 1979; Burger and Garber, 1995). Urbanization, logging, stream channelization, and damming can have major impacts on wood turtle populations (Harding and Bloomer, 1979; Buech and Nelson, 1997). Wood turtles are considered threatened in much of their range because of pollution, loss of habitat and life history characteristics (Bowen and Gillingham, 2004). While some management practices have been implemented (Bowen and Gillingham, 2004), many states do not yet have wood turtle management plans.

While much is known about wood turtles, many questions have yet to be answered largely because of variability among wood turtle individuals and populations, it may be necessary to manage each population individually (Bowen and Gillingham, 2004). It is critical that more management plans are created and implemented to protect the wood turtle.

The goal of our study is to examine wood turtle movement of two populations in the southernmost part of their range and recommend best management practices that will protect these populations. Specifically, we examined home range, difference in movements between sexes and populations, and hibernacula fidelity.

Literature Review

The wood turtle is a medium-sized turtle with carapace lengths generally ranging from 14 to 20 cm (Conant and Collins 1998). The scientific name means "sculptured carved turtle" due to the raised growth annuli on the scutes of the carapace. Wood turtle is a common name thought to have originated from the annuli on the carapace which resemble a wood carving (Carr 1952). They are also referred to the "redleg" turtle due to the reddish-orange color on underside of the legs, neck, and tail (Harding 1997) (Figure1). The unhinged plastron is yellow in the middle with dark on the outer edge (Ernst et al. 1994) and a V-notch at the tail (Harding 1997). Wood turtle posterior marginal scutes are serrated and the snout is blunt with a notch on the upper jaw (Ernst et al. 1994).

Figure 1: Female wood turtle at Site 1

Wood turtles display sexual dimorphism with mature males generally being larger than females. The males also have a longer tail, broader head and limbs, thicker claws, a concave plastron, and larger scales on their legs. The shell of males is also generally more domed but narrower than females (Harding 1997). The male cloaca is located past the carapace where as the females cloaca is further in toward the body (Carr 1952; Ernst et al. 1994; Harding 1997). Wood turtles are most often confused with Blanding's turtle (*Emydoidea blandingii*), eastern box turtle (*Terrapene carolina*) and bog turtle (*Glyptemys muhlenbergi*) (Bowen and Gillingham 2004).

The carapace of hatchlings are brown, tan or gray and 2.8 to 3.8 cm long. Hatchlings lack a sculptured carapace and reddish-orange legs as seen in adults. Their tails are extremely long and have been documented to be as long as their carapace (Carr 1952; Harding 1997).

Wood turtles have been known to utilize a variety of habitats. They do not seem to use habitats randomly suggesting they actively select their habitat (Arvisais et al. 2004; Asmus et al. 1999). Activity usually centers around a stream or creek along the riparian area (Kaufmann 1992a). Quinn and Tate (1991) report wood turtle movement was highly variable, but individuals tend to show fidelity throughout the seasons. Wood turtles commonly utilize wooded areas containing enough openings in the canopy to allow for foraging habitat of herbaceous undergrowth (Ewert et al. 1998). Kaufmann (1992a) also reports wood turtles prefer a variety of habitats, and they can be considered an edge species.

Several studies have quantified habitat selectivity of wood turtles. In a Pennsylvania population, Kaufmann (1992a) found wood turtles preferred stream (34 %),

alder stands (25 %), grassy areas (20 %), cornfields (12 %), Hemlock stands (6 %), and deciduous forest (2 %). In Connecticut, wood turtles selected for wetlands (54 %) (Tuttle and Carroll 1997).

Wood turtle behavior is highly dependant on seasonal influences. They are mostly terrestrial during the summer months and aquatic during the winter, spring, and fall. Wood turtles are more active in the early summer months during nesting. While wood turtles are not thought to truly aestivate during extremely hot periods, they will move to the stream or bury themselves in mud to help stay cool (Kaufmann 1992a, 1992b). In the fall and spring, while daytime temperatures are less than 20° C and nighttime less than 10° C, the turtles spend most of their time in the water (Kaufmann 1992a).

Wood turtles are diurnal, and daily behavior patterns are very hard to determine as a result of individual and geographical variability. For example, Harding and Bloomer (1979) found wood turtles were active in the morning and late afternoon, Ernst and McBreen (1991) reported wood turtles most active in the morning during the summer, late morning and afternoon in the fall and spring, and Farrell and Graham (1991) observed most of the activity was in the middle of the day. Males are more likely to spend more time in or near the creek as compared to females who utilize open areas more (Kaufmann 1992a).

Mating occurs in the fall while the wood turtles are very active and just before they return to their hibernacula, where they are relatively dormant during the winter season (Bowen and Gillingham 2004). Preferred hibernacula tend to be deep pools in the stream with woody debris for cover (Harding and Bloomer 1979). Wood turtles have

been known to over winter in muskrat burrows, beaver ponds (Harding and Bloomer 1979), under overhanging banks with root wads (Farrell and Graham 1991; Kaufmann 1992a; Neiderberger and Seidel 1999), and on the bottom of streams (Bishop and Schoonmacher 1921; Garber 1989; Quinn and Tate 1991; Kaufmann 1992a; Neiderberger and Seidel 1999). Many wood turtles (between 2 and 70) can be found in the same hibernacula (Harding and Bloomer 1979; Farrell and Graham 1991). Harding and Bloomer (1979) suggests this congregation is not due to lack of suitable hibernacula but rather it is because they are "social hibernators" and prefer to hibernate with other wood turtles.

Wood turtles are opportunistic omnivores. They have been known to eat a wide variety of foods including berries, green leaves, algae, mosses, mushrooms, mollusks and other invertebrates. They have also been observed eating dead fish, baby mice, and almost anything else that is edible that are capable of catching and swallowing (Harding and Bloomer 1979). Juvenile wood turtles are more carnivorous than adults (Harding 1991). In captive wood turtles, aggressive attempts by both males and females to gain dominance over food have been observed. In Pennsylvania wood turtles stopped eating when water temperatures were below 17.2° C and air temperatures below 23° C (Ernst 1986).

Wood turtles exhibit a unique behavioral feeding technique called "worm stomping." Kaufmann (1986) observed the turtles stomping their feet and slamming their plastron on the ground in an effort to mimic the sound of rain and cause earthworms to rise to the surface where the wood turtles can capture them. These "stomps" can be heard several meters away and may last anywhere from 15 minutes to over 4 and a half hours.

On average turtles caught 2.4 worms per hour by stomping. Only 2 worms were eaten in 6 months without "worm stomping" (Kaufmann 1986). Worm stomping has been observed in the wild and captivity in both young and old turtles (Kaufmann 1986; Tuttle and Carroll 1997).

Home range of wood turtles tends to be small ranging from several hundred meters to 25 hectares (ha) (Quinn and Tate 1991; Bowen and Gillingham 2004) and can vary greatly, along with habitat selectivity, depending on the season and geographic location of the turtles (Harding and Bloomer 1979). Northern populations generally have larger home ranges than southern populations (Arvisias et al. 2002). Ranges are elongated around a stream or river corridor (Daigle 1997). While movement and range has been documented to be highly variable among individuals, wood turtles rarely move very far from the stream. In West Virginia, 200 meters was the maximum distance any wood turtle was found away from a stream (Neiderberger and Seidel 1999). Some turtles exhibited yearly or seasonal variation in movement, while others showed very little variation (Kaufmann 1995).

It is unclear whether wood turtles exhibit territorial behavior. Kaufmann (1992b) found a linear dominance hierarchy in a Pennsylvania population. This hierarchy was thought to be based on age and size of the male turtle and enforced with combat. However home ranges of multiple wood turtles can substantially overlap suggesting the territorial dominance does not limit the utilization of the same resources.

Sex may (Daigle 1997) or may not (Ross et al. 1991; Kaufmann 1995; Tuttle and Carroll 1997; Arvisais et al. 2002) have an impact on home range size. It does not appear that the size or dominance rank affect home range size either (Kaufmann 1995;

Tuttle and Carroll 1997). While home ranges of wood turtles are generally small (Pennsylvania 213m – 680 m), they are capable of making long distance movements between 1 and 3 km (Ernst and McBreen 1991; Daigle 1997). Females have been known to move several kilometers to find a suitable nesting site (Walde 1998; Ernst 2001a, 2001b), and juveniles have been documented to move up to 500 m (Brewster and Brewster 1991). Wood turtle ranges are highly variable across populations. Arvisias et al. (2004) found that in the Mauricie Region of Quebec the home range was 27.6 ha for females and 30.3 ha for males. However in New Hampshire, Tuttle and Carroll (1997) report home ranges of 3.9 ha for females and 5.8 ha for males. Wood turtles have been shown to exhibit homing abilities up to 2 km. This ability appears to be independent of age and sex (Carroll and Ehrenfeld 1978).

Wood turtles have high variability among populations for age at sexual maturity, with most between 9 and 20 years old (Bowen and Gillingham 2004). Secondary sexual characteristics can be an indicator of sexual maturity, but there are exceptions as well. For instance, females may have secondary sexual characteristics but may not be mature enough to nest and males displaying these characteristics may not be large or strong enough to reproduce successfully (Bowen and Gillingham 2004). Generally, minimum carapace length of 160 mm for females is most reliable for determining sexual maturity (Harding and Bloomer 1979). Mating can occur throughout the year but is most common in the fall and spring when the turtles are concentrated near the hibernacula (Ernst and McBreen 1991). Wood turtles have only have one clutch per year (Harding and Bloomer 1979; Ernst et al. 1994), with an average clutch size of 8 to 10 eggs per nest (Powell 1967; Farrell and Graham 1991; Harding 1991). In Virginia, (Ernst and McBreen 1991)

found the maximum clutch size is 12 eggs. Nesting season depends on location any ranges between May and July. In Virginia nesting generally occurs in June (Ernst and McBreen 1991). Nesting habitat is critical to egg survival and females make long migrations to get to suitable nesting sites (Ernst and McBreen 1991). Incubation is temperature dependant (Harding 1991; Walde 1998), with time to hatch ranging from 46 to 116 days (Ernst and McBreen 1991; Harding 1991; Walde 1998). Incubation time for eggs from captive wood turtles in Virginia suggests an average of 52 days (Ernst and McBreen 1991). Sex of the offspring is genetically determined (Ewert and Nelson 1991).

In the late spring female wood turtles begin looking for suitable nesting habitat. Females will travel several kilometers in order to nest (Ernst 2001a, 2001b). Nesting habitat may be the most important factor to wood turtle survival (Bowen and Gillingham 2004). Preferred nesting sites are areas with full sun generally on a southern slope with little or no vegetation and on well-drained washed sand or gravel (Harding 1994; Buech and Nelson 1997). Wood turtles also seem to choose nest sites that are exposed to full afternoon sun (Harding 1994) to allow the nesting site to receive the most heat to speed egg development (Buech and Nelson 1997). Nesting sites are usually located close to the stream, but a meter or more above flood levels (Harding 1994; Buech et al. 1997). Some nesting areas have been observed in gravel/sand pits, eroding road/riverbanks, sand bars, dirt roads, and along railroad tracks (Brooks et al. 1992; Buech et al. 1997; Walde 1998; Wusterbarth 2000).

Low fecundity, older ages at sexual maturity, low juvenile survival rates, and high nesting/hatchling predation can result in low recruitment of wood turtles. The

establishment of stable adult populations is crucial to wood turtle populations (Bowen and Gillingham 2004). Small decreases in adult numbers may potentially lead to extirpation of the population (Congdon et al. 1993; Congdon et al. 1994; Compton 1999). However, wood turtle populations may be at risk even if numerous adults are present. In some areas there may be "ghost populations" with many unsuccessfully reproducing adult wood turtles (Compton 1999). It is very important to verify recruitment (the presence of hatchlings and juveniles) before determining the health of the population (Compton 1999; Bowen and Gillingham 2004).

Many biologists believe the greatest threat to wood turtles is habitat alteration and destruction (Harding and Bloomer 1979; Ernst 2001b; Bowen and Gillingham 2004). Urbanization is responsible for much of this habitat destruction in the eastern United States (Harding and Bloomer 1979; Ernst and McBreen 1991) as well as road construction (Gibbs and Shriver 2002). Stream channelization and damming of rivers can destroy large areas of wood turtle habitat (Harding and Bloomer 1979; Harding 1991; Buech and Nelson 1997). Since wood turtles are thought to be pollution intolerant, pesticide and sediment runoff can potentially affect populations (Harding and Bloomer 1979; Burger and Garber 1995). Saumure and Bider (1998) investigated the impact of agricultural development on wood turtles and found 23 % fewer juveniles and relatively fewer adults in the agricultural area. Shell fractures were 2.7 times more common and growth rates were slower in these agricultural sites (Saumure and Bider 1998). While small-scale disturbances can be tolerated by the wood turtles, even helpful in some cases, the negative effects of timber and agricultural machinery may be more significant

(Harding 1991). All of these disturbances can result in direct mortality and destruction of nesting habitat (Buech et al. 1997; Saumure and Bider 1998).

Collections of wood turtles for food purposes, the pet trade and biological supply companies may be responsible for population declines and in some cases extirpation (Harding and Bloomer 1979; Harding 1991; Ernst et al. 1994). Illegal collection of wood turtle still occurs, but the extent unknown (Levell 2000).

Several studies have shown that opening an area to human recreation can cause wood turtle declines. Garber and Burger (1995) found that two stable wood turtle populations were extirpated when the area was opened to recreation. Increased recreational activities may increase the amount of trash and food litter, subsequently increasing the number of predators (raccoons, foxes, skunks) which prey on nests and adults (Engeman et al. 2003) Recreation also increased the probability of humans taking or relocating wood turtles as they find them "irresistible" (Garber and Burger 1995). Wood turtles may become entangled in plastic or fishing line (Garber and Burger 1995; Wusterbarth 2000; Ernst 2001a, 2001b). Wood turtles have also been shot by vandals (Harding 1991).

Heavy nest predation is another cause for wood turtle decline. Egg, hatchling and juvenile survival is often low due to predation from raccoons, foxes, coyotes, opossums, skunks, birds, and other turtles (Harding and Bloomer 1979). Adults also face predation usually resulting in shell damage and limb amputation from raccoons and rodents (Harding 1991; Walde et al. 2003).

Currently there are few management plans specifically for wood turtles; however some plans are being implemented. The Hiawatha National Forest has implemented

guidelines for wood turtle management that include not stabilizing or revegetating potential nesting habitats, maintaining safe turtle access to nesting habitats, and mitigation of nesting habitat destruction through creation of new nesting areas (Indian National Wild and Scenic River Decision Notice and Management Plan).

Timber harvest near wood turtle habitat is fairly common and very few specific regulations for wood turtle protection exist. Massachusetts requires maintaining riparian buffer zones, bridging stream crossing areas, and logging in the winter while the turtles are in the hibernacula (Kittredge 1996; Erb 2006). According to Compton (1999), the Maine Shoreland Zoning Ordinance in cooperation with Champion International Corporation, a large landholder, has a riparian plan that will protect 80-85 % of wood turtle habitat from timber harvest. Compton (1999) recommends that a 300 m riparian buffer zone would protect 99 % of wood turtle areas.

Methods

We studied two populations of wood turtles in the southern part of their range in Rockingham County, Virginia; Site 1, a 2nd order stream, and Site 2, a 3rd order stream, (Figure 2). Exact location of the sites is confidential due to the sensitive status of the wood turtle.

Wood turtles were tagged and tracked along a 2.5 km section of Site 1. Site 1 averages 3 m in width with pool depths averaging 0.6 m. The summer hydrograph is low with many intermittent sections. The habitat at Site 1 is characterized by a mosaic of autumn olive (*Eleaganus umbellata*) and new growth forest mainly consisting of oak (*Quercus spp.*), maple (*Acer spp.*), and brushy fields. Currently timber harvest occurs in the area with one plot within 100 m of the stream (Figure 3). A low traffic volume forest service road runs within 30 m of the stream for 2 km.

Site 2 averages 10 m in width with pool depths averaging two meters. The river maintains permanent flow during normal summer conditions. However, in severe dry periods sections of the river will become intermittent. A county owned road, runs along Site 2. About 10 km of the road is located within 30 m of the river.

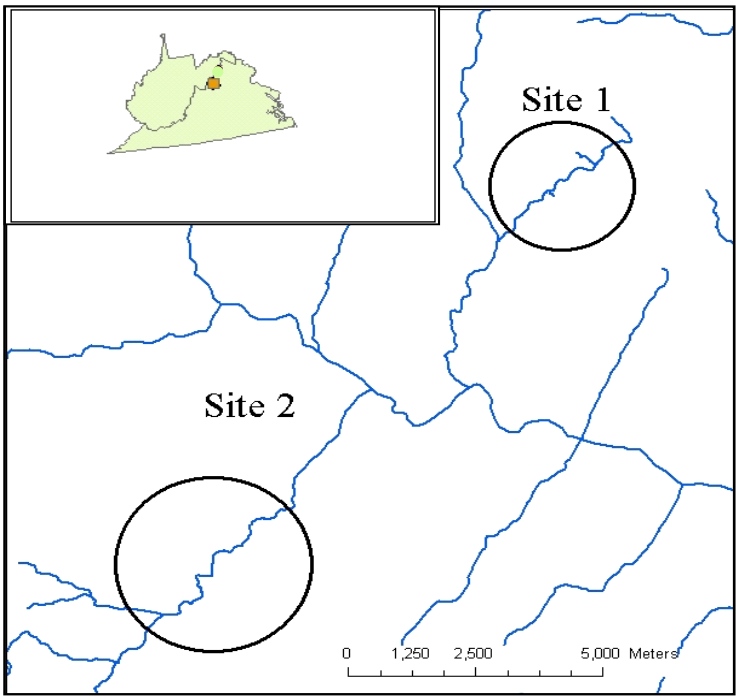

Figure 2: Location of study Site 1 and Site 2 in Rockingham County, Virginia

Tagging and Tracking Methods

Radio transmitters (model MBFT-3L from Lotek, New Market, Ontario) weighing 26 grams with a battery life of 1,226 days) were externally attached to the right rear marginal scutes. Transmitters did not exceed 3% of the total body weight. When juvenile wood turtles were captured, they were tagged with tags weighing 2.1 grams (Model NTC-4-2L from Loteck, New Market, Ontario).

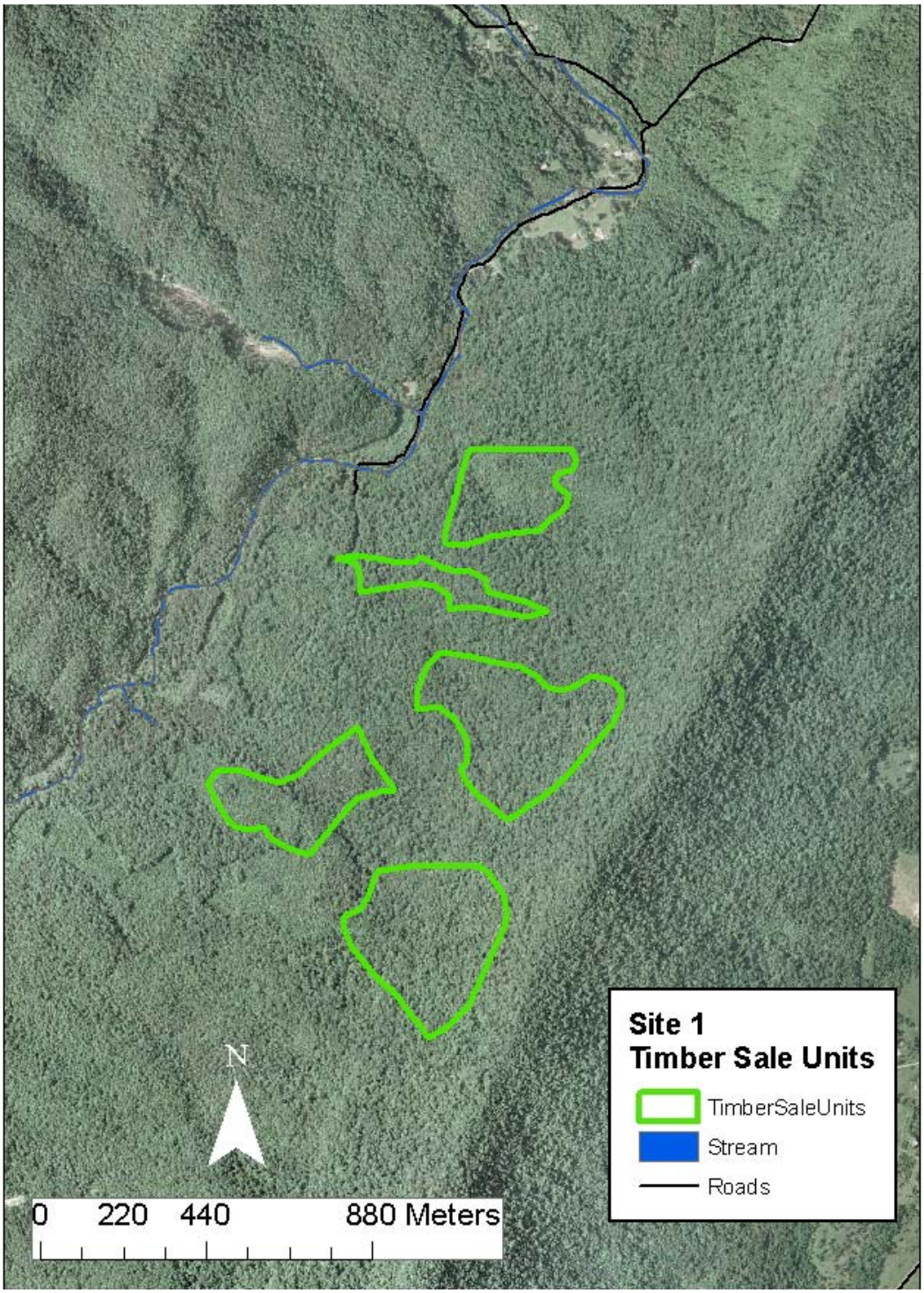

Figure 3: Locations of current and planned timber harvests at Site 1 study area.

Tags were attached by tie wire to holes drilled in the first and fourth marginal right rear scutes. Tags were then glued on with PC-11, a marine grade epoxy, to help avoid tag loss (Donaldson and Echternacht, 2005). In addition to the radio tag each captured turtle also received a passive transponder tag (PIT) (Boarman, et al. 1998) and holes were drilled on the marginal scutes to provide a permanent unique identification number to each turtle for long-term identification (Cagle, 1939).

Wood turtles were initially captured spring 2006, late fall of 2006, winter of 2007, and early spring of 2007 while they were in the streams and more easily observed by eye or by underwater cameras. When a new wood turtle was located a global positioning system (GPS) point of the location was recorded along with the time, air temperature, and water temperature. All GPS data was recorded using WGS 1984 coordinate system. Carapace length, plastron length, depth, and width of shell were measured to the nearest tenth of an inch using tree calipers. Turtles were aged by counting annuli (Harding and Bloomer, 1979; Garber, 1989) on at least three different scutes and weights were recorded using a spring scale. Wood turtles were examined for drilled holes in the scutes that indicate a previous capture as well as an identification number (Cagle, 1939). In general, the wood turtles were held in captivity no longer than one hour and were released at the same location as capture. Wood turtles were tracked weekly and locations recorded along with time, air/water temperature, a brief description of the habitat, and behavioral notes were made.

Home Range, Site Fidelity, and Buffer Zones

Home range was determined by the minimum convex polygon method (MCP)(White and Garrott, 1990) using Hawth Tools, an ArcMap extension (Beyer,

2004). For both home range estimate and calculation of buffer zones, turtle movement was divided into spring (March 30-May15), summer (May15-September 30), fall (September 30-November 15), and winter (November 15-March 30) (Neiderberger and Seidel, 1999). Turtles with less than 15 recaptures or less than three seasons of data were not included in the averages and comparisons of home range. We calculated home range both with and without outliers.

We tested differences between two home ranges for both populations and sexes. We used the Mann Whitney U test because home range was not normally distributed (Shapiro-Wilk) (Dowdy and Wearden, 1991). Home ranges were considered significantly different if the p-value was less than or equal to 0.05.

Hibernacula fidelity was determined by mapping hibernacula in 2006 and 2007 and percentage of wood turtles returning to the same hibernacula was calculated.

A 5 m buffer (Site 2) and a 3 m buffer (Site 1) was made in order to accurately show the width of the two rivers. Four buffer zones (10, 30, 60, 90 m) were created to determine seasonal preferences. Different proportions of wood turtle occurrences in each buffer zone were tested using Pearson's Chi-square. Statistical significance was determine if the p-value was ≤ 0.05.

Results

From 2006-2007 we captured and tagged a total of 47 individual turtles (1,283 recaptures). However because of late capture dates, tag loss, and tag failure we only analyzed data from 36 of these turtles. We tagged or observed 6 males, 8 females, and 1 juvenile at Site 1. We tagged 16 males, 15 females, and 2 juveniles at Site 2. The capture date, number of recapture events, and fate of the tags is summarized in Tables 1 and 2.

Home Range

We found some large movement from 2 males (13.6 km and 19.8 km) at Site 1 and 2 males (6.6 km and 19.5 km) at Site 2 that skewed some of our data. We determined outliers by using graphical (box plots and histograms) techniques to examine the effect on mean and standard deviation. These turtles were considered outliers in some of our statistical tests.

Table 1: Home range estimate (ha) using minimum convex polygon method (MCP) and summary of wood turtles at Site 1 including sex, age, date tagged, fate of tags (TR = Tag removed from turtle; O = Operational throughout study; TL = Tag loss), and number of recaptures per turtle. Wood turtles with less than 15 recaptures were not used for data analysis.
*Denotes outlier in home range

Turtle Number	Sex	Age	Date Tagged	Fate	# of Recaptures	MCP Area
550	Female	15	11/10/2006	TR	14	0.5
660	Female	15	10/9/2007	O	9	0.4
219	Female	13	6/16/2006	O	62	10.4
240	Female	11	6/16/2006	O	62	5.6
258	Female	13	6/16/2006	O	59	18.6
560	Female	14	6/25/2007	O	18	3.3
640	Female	15	11/10/2006	O	36	13.8
730	Female	13	6/4/2007	O	22	10.4
278*	Male	15	6/16/2006	O	44	3,062.6
180*	Male	15	6/16/2006	O	31	92.08
520	Male	13	12/19/2006	O	35	19.38
590	Male	13	4/18/2007	O	25	25.78
610	Male	16	11/10/2006	O	35	27.8
690	Male	12	11/10/2006	TL	12	0.02

Home range sizes were compared between the Site 1 and Site 2 populations. No statistical difference in home range size was found including outliers (Mann Whitney U, U = 89.00, p = 0.198) or excluding outliers (Mann Whitney U, U = 68.00, p = 0.145). Wood turtles tagged at Site 1 had a mean home range of 22.70 ha. (SD = 25.65)(excluding outliers; 14.99 ha.; SD = 8.51)(Table 1).The home range at Site 2 averaged 61.25 hectares (Ha.)(SD = 203.20) (excluding outliers; 16.07 ha.; SD = 22.96) (Table 2).

There was a significant difference including outliers (Mann Whitney U, U = 0.00, p = 0.01) and excluding outliers (Mann Whitney U, U = 0.00, p = 0.024) between male and female home range at Site 1. Mean home range for females at Site 1 was 10.35 ha. (SD = 5.52). Home range for males at Site 1 including outliers was 24.27 ha. (SD = 4.39) and excluding outliers 645.49 ha. (SD = 1,351.53).

No significant differences in home range between sexes were found including outliers (Mann Whitney U, U = 67.00, p = 0.403) or excluding outliers (Mann Whitney U, U = 67.00, p = 0.574). A mean of 20.97 ha. (SD = 30.20) was found for females at Site 2. Three potential male outliers were present at Site 2. Including outliers included we found male home range was 290.89 Ha. (SD = 809.81). Excluding the outliers male home range was 11.59 Ha. (SD = 13.40).

We found no significant differences in home range of female wood turtles (Mann Whitney U, U = 18.00, p = 0.069) between the two sites. No statistical difference in home range was found including outliers (Mann Whitney U, U = 14.00, p = 0.158) or excluding outliers (Mann Whitney U, U = 9.00, p = 0.189) for male home ranges.

Table 2: Home range estimate (ha) using minimum convex polygon method (MCP) and summary of wood turtles at Site 2 including sex, age, date tagged, fate of tags (O = Operational throughout study; TL = Tag loss; B= Battery Failure; U = Unknown fate), and number of recaptures per turtle. Wood turtles with less than 15 recaptures were not used for data analysis.
*Denotes outlier in home range

Turtle Number	Sex	Age	Date Tagged	Fate	# of Recaptures	MCP Area
480	Female	15	11/3/2006	TL	3	n/a
540	Female	14	9/22/2007	O	10	0.9
600	Female	15	11/29/2006	TL	11	3.0
360	Female	12	5/4/2007	B	8	0.1
570	Female	13	4/9/2007	O	27	42.3
580	Female	15	6/5/2007	O	21	57.6
720	Female	12	11/29/2006	O	37	11.3
620	Female	15	4/9/2007	O	28	3.0
630	Female	15	4/9/2007	O	24	1.7
530	Female	17	3/30/2007	O	29	0.8
230	Female	15	5/24/2007	O	23	2.1
240	Female	14	4/2/2007	O	27	92.5
1000	Female	15	11/3/2007	O	37	7.9
300	Female	16	11/3/2007	O	38	9.5
4802	Female	15	11/3/2006	O	40	2.1
260	Male	15	11/3/2006	U	12	6.6
278*	Male	15	6/16/2006	O	44	3,062.6
420*	Male	12	11/29/2006	O	31	1,023.8
700*	Male	15	11/29/2006	O	37	137.9
280	Male	17	5/4/2007	O	27	1.5
340	Male	14	11/3/2006	O	42	32.5
320	Male	16	4/9/2007	O	27	17.9
210	Male	15	11/3/2006	O	41	16.3
6002	Male	14	6/5/2007	O	20	3.6
380	Male	13	11/3/2006	O	39	4.1
400	Male	20	4/9/2007	O	28	2.4
440	Male	14	4/9/2007	O	25	42.4
500	Male	16	5/4/2007	O	25	5.4
510	Male	13	6/5/2007	O	23	2.9
670	Male	19	11/3/2006	O	45	2.2
680	Male	13	5/4/2007	O	25	7.8
3202	Juvenile	7	7/18/2007	O	16	6.4
150.540	Juvenile	8	9/22/2007	O	3	n/a

Outliers

A flood occurred in mid-November 2006 with a flow of 6,000 cfs recorded at a USGS Gauge Station approximately 6 km downstream of Site 1. This flood washed two male turtles (#278 and #180) from Site 1 downstream approximately 9 km into the main stem. In the summer of 2006, wood turtle 180 began traveling back up the tributary toward Site 1. However he never came within 3.0 km of Site 1. Wood turtle 180 traveled 13.6 km in total. Wood turtle 278 moved upriver in the main stem, and went up the tributary leading to Site 2. By August 2007, wood turtle 278 reached the Site 2 study site. In total 278 traveled 19.75 km from Site 1 to a tributary above Site 2 (Figure 4). These two males were considered outliers for Site 1.

Site 2 has two potential male outliers as well. Wood turtle 700 traveled 4.4 km upstream from the middle of Site 2 in May/June 2007. For the winter he moved 2.2 km downstream to a hibernacula. From May to November 2007 wood turtle 700 moved 6.6 km. Wood turtle 420 moved 8.5 km upstream and then crossed overland into a different watershed. In total, wood turtle 420 traveled 19.5 km (Figure 5).

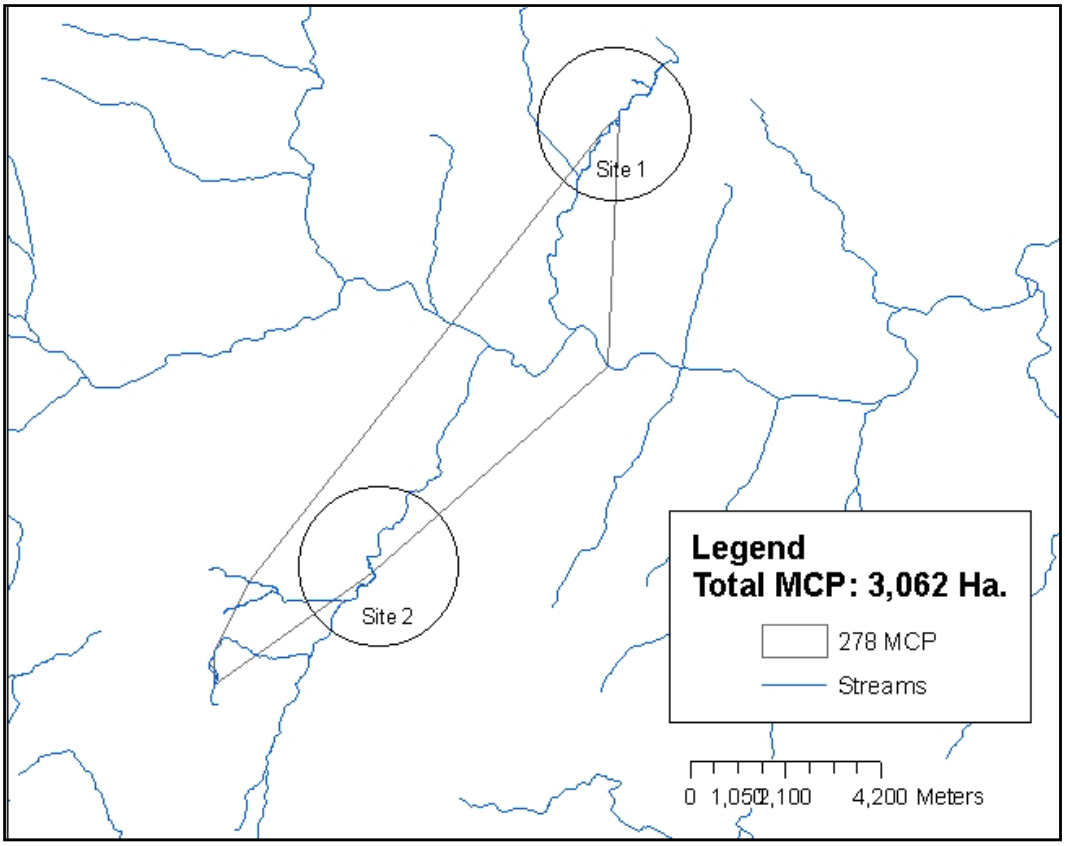

Figure 4: Home range (ha) using minimum convex polygon (MCP) for wood turtle identification number 278.Total movement was 19.75 km.

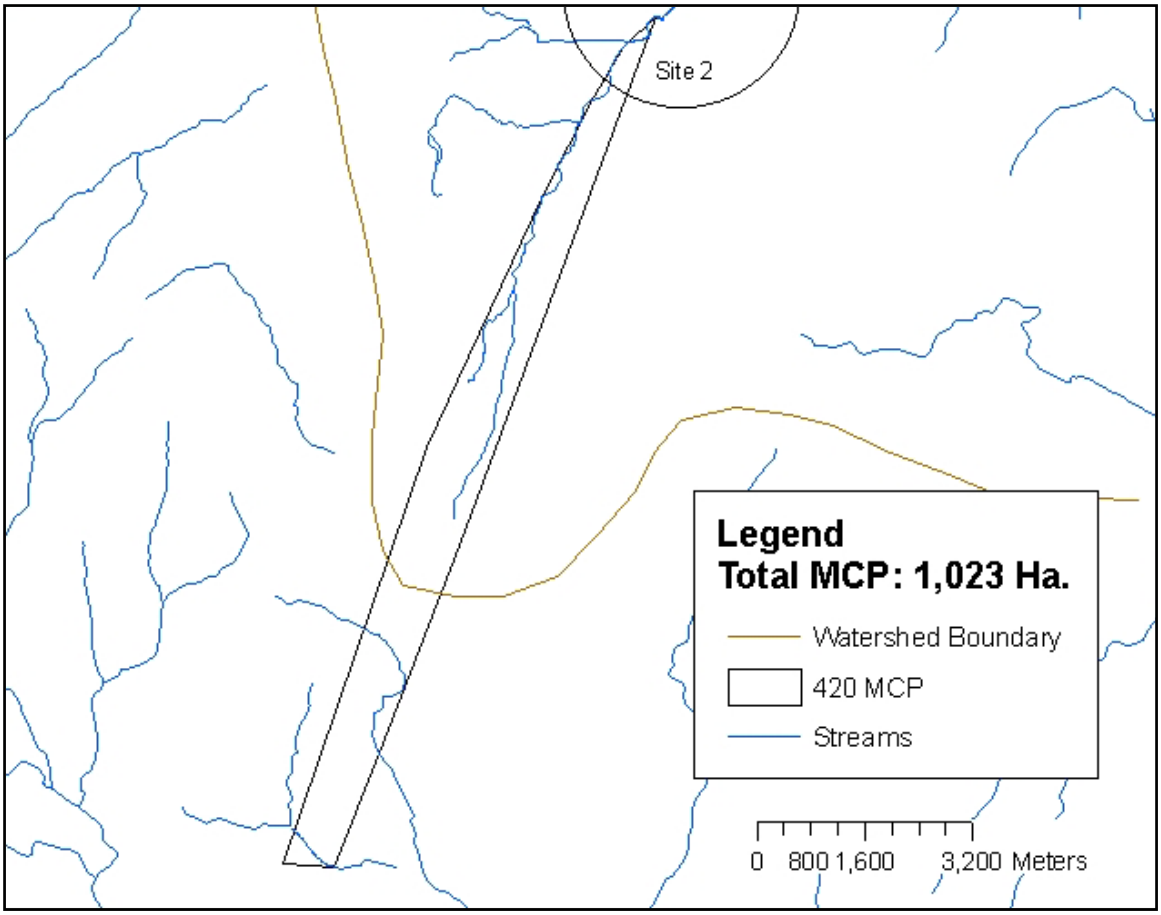

Figure 5: Home range (ha) using minimum convex polygon (MCP) for wood turtle identification number 420.Total movement was 19.50 km.

Hibernacula Fidelity

At Site 1, eight turtles (4 males, 4 females) were recaptured for both winters. Only 25 % of the wood turtles returned to the same hibernacula in 2007. Female wood turtles showed more fidelity than males with 50 % of females returning while none of the male wood turtles used the same hibernacula both winters. At Site 2 ten turtles (6 males, 4 females) were recaptured both winters. Only 20 % of the wood turtles returned to the same hibernacula in 2007. Female wood turtles showed 50 % fidelity to a hibernacula while none of the males returned to the same hibernacula. When Site 1 and Site 2 were combined 4 (all female) of 18 wood turtles (22 %) returned to the same hibernacula.

Overall 50 % of female wood turtles returned to the same hibernacula. None of the males at either site exhibited hibernacula fidelity. We found many of the hibernacula were occupied by multiple wood turtles (66 % at Site 1; 64 % Site 2). We located 6 hibernacula in 2006 and 2007 at Site 1. Four of those hibernacula contained at least two tagged turtles. Eleven hibernacula were found at Site 2. More than one tagged turtle occupy 7 of the hibernacula.

Buffer Zones

Site 1

We found a statistical difference in buffer zone usage among seasons (Pearson's Chi-square = 278.79, df = 15, $p < 0.001$). During the winter season no wood turtles were found outside the 10 m buffer zone at Site 1 (Table 3). During the winter 100 % of the males and 98.3 % of the females were found in the stream. In the spring, we found no wood turtles outside of the 60 m buffer, and at least 50 % of the time both males and females were within 10 m of the stream. The fall buffer zones were similar to the spring with no wood turtle traveling outside the 60 m buffer with at least 75% of the wood turtles locations were within 10 m of the stream. When fall and spring buffer zone usage was compared, we found there was a statistical difference in proportion of the time spent in the various buffer zones (Pearson's Chi-square = 11.72, df = 3, $p = 0.01$). In the summer, the wood turtles moved the farthest from the stream. Both males and females had individuals outside the 90 m buffer (1.8 % and 8.5 % outside 90 m respectively).

Site 2

During the winter season no wood turtles were found outside the 10 m buffer at Site 2 (Table 4), and 97.2 % of the males and 96.1 % of the females were found in the

stream. In the spring, we found no wood turtles outside of the 60 m buffer with about 50 % of the time both males and females were within 10 m of the stream. The fall buffer zones were similar to the spring with 98.7 % within the 60 m buffer and 97.3 % within the 30 m buffer zone. At least 85.2 % of the time the wood turtles were within 10 m of the stream. When fall and spring buffer zone usage was compared, we found there was a statistical difference in proportion of the time spent in the various buffer zones (Pearson's Chi-square = 36.13, df = 4, $p < 0.001$). In the summer, the wood turtles moved the farthest from the stream. Both males and females had individuals outside the 90 m buffer (3.6 % and 5.9 % outside 90 m respectively).

We experienced no mortality of radio tagged turtles during our study period. A juvenile turtle was found dead on the county road along Site 2 in August 2007. This was the only observed mortality at either site.

Table 3: Percentage of all, male, and female wood turtle recaptures within each buffer zone during each season at Site 1. The instream area is considered to be 3 m wide.

	Summer	Male	Female	**Fall**	Male	Female	**Winter**	Male	Female	**Spring**	Male	Female
Instream	**7.0**	20.0	1.5	**42.7**	77.8	25.5	**98.9**	100.0	98.3	**19.4**	26.7	12.5
10 m	**28.6**	36.4	25.4	**79.3**	85.2	76.4	**100.0**	100.0	100.0	**51.6**	53.3	50.0
30 m	**54.1**	69.1	47.7	**95.1**	96.3	94.5	**100.0**	100.0	100.0	**96.8**	93.3	100.0
60 m	**83.8**	83.6	83.8	**100.0**	100.0	100.0	**100.0**	100.0	100.0	**100.0**	100.0	100.0
90 m	**93.5**	98.2	91.5	**100.0**	100.0	100.0	**100.0**	100.0	100.0	**100.0**	100.0	100.0

Table 4: Percentage of all, male, and female wood turtle recaptures within each buffer zone during each season at Site 2. The instream area is considered to be 5 m wide

	Summer	Male	Female	**Fall**	Male	Female	**Winter**	Male	Female	**Spring**	Male	Female
Instream	**19.4**	21.8	15.4	**62.4**	65.5	58.1	**97.3**	98.2	96.1	**30.0**	32.5	26.7
10 m	**33.6**	38.7	26.5	**85.2**	92.0	75.8	**100.0**	100.0	100.0	**50.0**	52.5	46.7
30 m	**62.7**	64.9	59.6	**97.3**	98.9	95.2	**100.0**	100.0	100.0	**94.3**	92.5	96.7
60 m	**86.4**	86.1	86.8	**98.7**	100.0	96.8	**100.0**	100.0	100.0	**100.0**	100.0	100.0
90 m	**95.5**	96.4	94.1	**100.0**	100.0	100.0	**100.0**	100.0	100.0	**100.0**	100.0	100.0

Discussion

While the home ranges were similar between the two populations we studied, both populations had greater home ranges than reported for northern populations (Ross et al., 1991; Kaufmann, 1992a; Daigle, 1997). This could be because the Site 1 and Site 2 wood turtles are on the edge of their range. This habitat may be marginal, requiring the wood turtles have to travel farther to get the resources (food, nesting areas, mates) they require. Our data suggests similar wood turtle home ranges in the southernmost portion of the range.

We found differences in the home ranges of males and females between populations. In the Site 2 population we found no significant difference between male and female home range size. While in the Site 1 population we found males had a significantly larger home range than females. These mixed results were similar to the literature. A study by Daigle (1997) showed home range size differed between the sexes, while Ross et al. (1991), Kaufmann (1995), Tuttle and Carroll (1997) and Arvisais et al. (2002) found no difference between the sexes. We did not investigate home range differences by age because all the wood turtles we used for home range analysis were adults (approximately 12 – 16 years). Aging wood turtles over 15 years old can be difficult due to wornness of the shell and crowding of the annuli. Wilson et al. (2003) found that counting annuli are only accurate to age a turtle after calibrating the relationship between annuli counts and actual age. No studies have been done to calibrate this relationship for wood turtles.

Hibernacula fidelity could influence wood turtle management. Neither the Site 1 nor Site 2's populations exhibited hibernacula fidelity. If a hibernacula would be

destroyed (naturally or man caused) the wood turtles could utilize a different hibernacula. New hibernacula could also be created that the wood turtles can use. However females did show some hibernacula fidelity. This could be useful for relocating individual turtles.

Although we found little hibernacula fidelity, we found specific site fidelity throughout the year. In general we observed the females tended to show site fidelity. The three females at Site 1 that were tagged in June of 2006 showed high fidelity to specific sites throughout the seasons. Wood turtle 219 even traveled over 90 m away from the stream to the same area with many mushrooms, both summers. Unfortunately the males tagged in June 2006 were washed out of Site 1 and we was unable to determine any fidelity throughout the year. Harding and Bloomer (1979), Quinn and Tate (1991), and Arvisias et al. (2002) found that individual wood turtles display site fidelity year to year.

The long distant movements made by the two males (13.6 km and 19.8 km) at Site 1 were probably caused by the flood in November 2006. Before the flood the wood turtles had already moved into the stream but all of them were not embedded in the rootwads or under banks as they are later in the winter. The flood also washed a female 1 km downstream. The hibernacula she was in before the flood was the same hibernacula she used in 2007. It was too late in the year for her to move back upstream and she found a suitable hibernacula that allowed her to survive the winter. Flood events may be important for immigration and emigration of individuals among populations.

All the wood turtles moving over 5 km were males. These wood turtles moved between 6.6 km to 19.75 km. These large distances have never been reported in any other studies. Daigle (1997) reported a male that moved 2.8 km and Ernst and McBreen

(1991) found a male traveling 1 km. This could be due to the mark/recapture method most commonly used to examine turtle movement when radio tags are unavailable. This method marks wood turtles and then later biologists return the area to look for marked wood turtles. If the wood turtles have made large movements it would be difficult to find the marked wood turtle again. Most studies do not radio tag large numbers of turtles and may miss the small percentage of the population that move greater distances.

The long distant movers from the Site 1 and Site 2 populations never returned back to their original location. Females will move long distances (1.0 - 3.7 km) searching for nesting areas (Walde, 1998; Ernst, 2001b), however they will return to their home area. The long range male movement may be for genetic dispersal. The frequency of these large movements is unknown and DNA sampling could show the connectivity between the two populations.

Wood turtle # 420 traveled into a different watershed to the south of Site 2 (Figure 5). At his current location he is the southern most known wood turtle. This extends the wood turtle range about 10 km south.

Management Recommendations

Mowing can be detrimental to wood turtles, causing death and severe injuries (Saumure and Bider, 1998). The damage can come from directly being cut by the blades as well as being run over by the tractor. Several of the wood turtles spent the summer in the ditch next to the road. However, we rarely found them on the other side of the road. This roadside is mowed twice a year by the Virginia Department of Transportation. We recommend mowing before April 15 or after October 30 (Table 5). If this is not possible then injuries to the wood turtles can be limited by using a sickle bar set at least 8 inches off the ground.

An open field recreation area located approximately 800 m upstream of Site 2 and is mown once a year to control the encroachment of woody trees. It is not possible to use a sickle bar in this area. Mowing dates should be moved to between October 15 and May 1 (Figure 6). The other potential management practice is to have controlled prescribed burns in this area in the early spring. This would remove any woody growth and promote the growth of native herbaceous plants that may be a suitable food source for the wood turtles. There are four campsites along a stream on the edge of the recreation area that are heavily used in the summer. We recommend moving the campsites to the other side of the road to help avoid illegal collection and/or injury from vehicles.

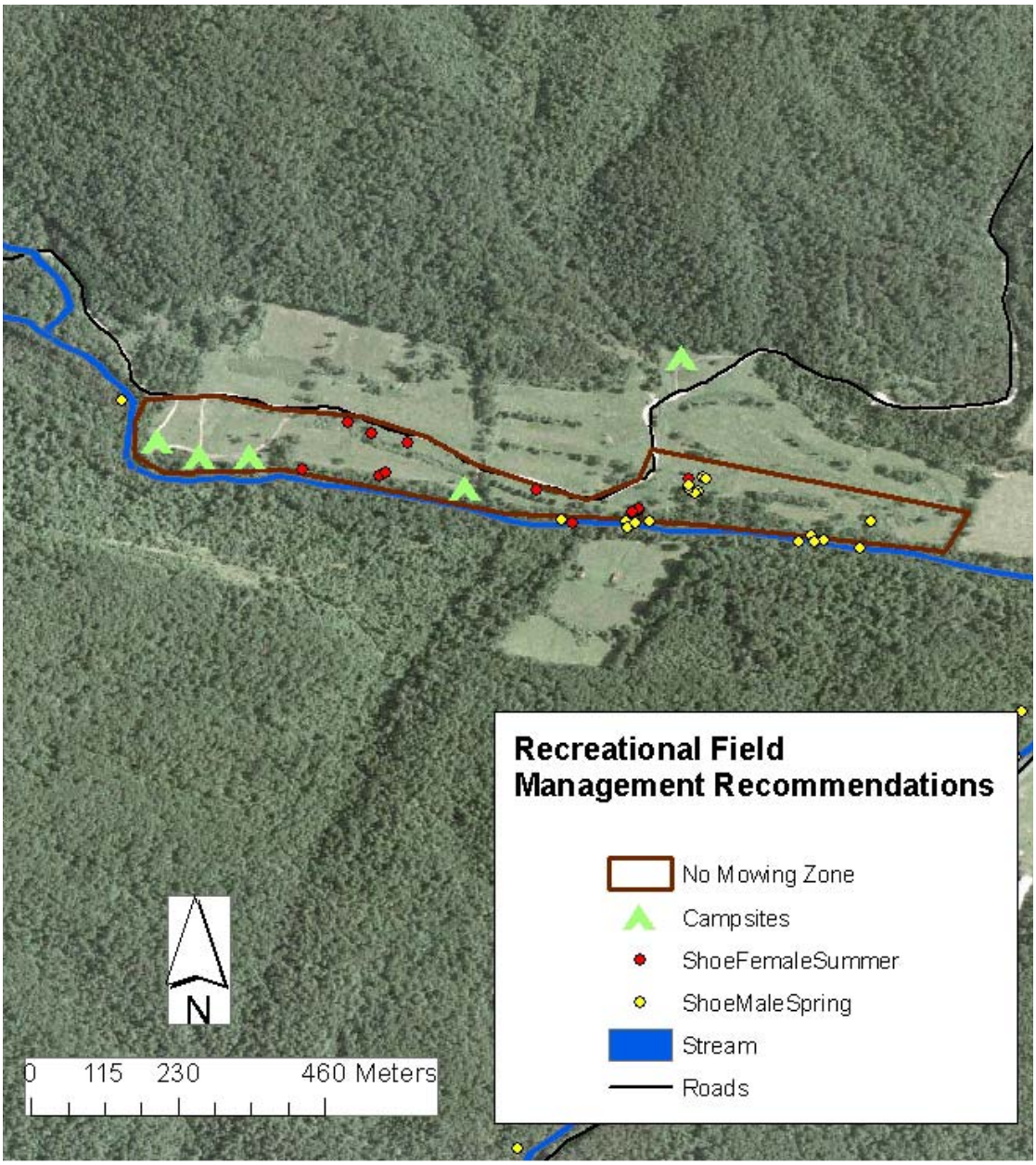

Figure 6: Recreational field showing male and female wood turtle locations along with campsite locations and the recommended no mowing zone between October 15 and May 1.

Small-scale openings have been shown to create feeding and nesting areas (Harding, 1991). However, if heavy machinery is used the side effects may be worse than the benefit by destroying nesting areas and direct mortality to the turtles (Buech et al., 1997). Site 1 is covered heavily in some areas with autumn olive, an invasive exotic species. While our study did not specifically examine the need for open mosaics, Ernst et

al. (1994) found wood turtles prefer openings in the streamside canopy over unbroken forest. This suggests the removal of some of the autumn olive bushes (by hand or by equipment in the winter) may promote native herbaceous plant growth and create additional nesting sites. Selective cutting of trees and may open new areas for the turtles. However it is important to leave the cut trees as the turtles will utilize the tree for cover. Additional studies are needed to examine to effect of this management practice.

Female turtles often move long distances to find suitable nesting sites. This often causes the females to cross roads, increasing road mortality. While our study did not determine if nesting sites are a limiting factor to wood turtle populations, Buech and Nelson (1991) found that the lack of predator resistant nesting areas limits the wood turtle populations in Minnesota. Nest creation may benefit the Site 1 and Site 2 population. However it is feasible to create nesting sites following the nest building protocols of Buech and Nelson (1991) detail nest building protocol. These sites can be built close to the wood turtle populations, possibly reducing the need for these dangerous long range nesting movements. If machinery is needed it is recommended to construct the sites between December 1 to March 1 while the turtles will be in the stream.

The long-term viability of the existing populations cannot be determined until recruitment is quantified. We found one juvenile turtle (~ 1 year old) at Site 1 and two juvenile turtles (~ 8 years old) at Site 2. The juveniles that were tagged were very hard to locate as they would bury themselves under leaves and multiflora rose bushes. Juvenile wood turtles may be present in adequate numbers and just not vulnerable to capture techniques or they may not be successfully recruiting. We recommend returning to the

study sites in 5 years in the fall or spring and searching for unmarked wood turtles. This could indicate how well new wood turtles are recruiting into the population.

Seasonal buffer zones are very critical for wood turtle management. Since wood turtles exhibit seasonal movements its possible to plan land use practices during certain seasons in order to protect the wood turtles. In order to protect the majority of the population, we recommend 90 m buffer zones in the summer (May 15 – September. 30), 30 m buffer zones in the spring and fall (April 1 – May 15 and October 1 – November 15), and 10 m buffer in the winter (November 15 – March 30). These buffer zones will allow for certain land use activities while protecting the wood turtle populations (Table 5). Compton (1999) recommends that 300 m buffer zones will protect 99 % of wood turtle locations. Massachusetts Natural Heritage and Endangered Species Program's (Erb, 2006) buffer zone guidelines are 0 – 15 m (November 15 – February 28), 15 – 90 m (November 1- March 31), and 90 – 180 m (May 15 – October 15). These buffer zones can be extended up to 300 m if the habitat is favorable to wood turtles. My data suggests wood turtle usage of buffer zones will vary by locations. It appears to be important to manage each wood turtle population uniquely. Without specific population data, buffer zones should be very conservatively drawn to ensure the protection of the wood turtles.

Timber harvesting is often an issue near wood turtle habitat. We recommend that timber harvesting methods such as clearcuts, group selection, modified shelterwood, and salvage harvests can be conducted 30 m or farther from the stream from November 15 – April 1 (Table 5).

Management Recommendation Conclusions

1. We recommend mowing roadsides between October 30 and April 15.
2. If mowing year round is necessary, we recommend using a sickle bar from the road with the mowing height set at least 8 inches high.
3. We recommend prescribed burning activities within 10 – 90 m of the stream take place between November 15 and April 1.
4. We recommend prescribed burning over 90 m from the stream take place from October 1 – May 15.
5. We recommend no mowing between May 1 and October 15 at the designated area at the recreational field.
6. We recommend moving the campsites at the recreational fields to other side of road.
7. We recommend clearcuts, group selections, modified shelterwood, and salvage timber harvests to be done between November 15 and April 1 outside of the 30 m riparian buffer zone.
8. If nesting sites are made, we recommend they should be placed no farther than 30 m away from the stream and should be constructed between November 30 through March 15.
9. We recommend returning to Site 1 and Site 2 in the spring or fall in about 5 years to look for new turtles in order to estimate recruitment.

Table 5: Management recommendations for various land use practices by season and by buffer zone.

	In-Stream	Stream - 10 m	10 m - 30 m	30 m - 60 m	60m - 90 m	> 90 m
Heavy Equipment	N	N	W[a]	W	W	W, Sp, F
Mowing	n/a	W[b]	W[b]	W[b]	W, Sp, F[b]	W, Sp, F[b]
Bridge Maintenance	W, Sm[c]	n/a	n/a	n/a	n/a	n//a
Create New Roads	n/a	N	N	N	N	W, Sp, Sm, F
Create Nests	n/a	W[d]	W[d]	N	N	N
Create Hibernacula	Sm[e]	n/a	n/a	n/a	n/a	n/a
Prescribed Burns	n/a	W	W	W	W	W, Sp, F
Clearcut	N	N	N	W	W	W, Sp, F
Group Selection	N	N	N	W	W	W, Sp, F
Modified Shelterwood	N	N	N	W	W	W, Sp, F
Salvage Harvest	N	N	N	W	W	W, Sp, F

[a] Use should be highly limited due to possibly destruction of nesting sites
[b] Mowing can be done year round if a sickle bar is used from road and set 8 inches high.
[c] If deep pool under bridge, maintenance in summer. If no deep pool maintenance in winter.
d Our data is unclear on if creation of nests is required.
e Our data is unclear on if creation of hibernacula is needed.

W = November 15 – April 1
Sp = April 1 - May 15
Sm = May 16 - September 30
F = October 1 – November 15
N = Never

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