Home Range and Habitat Preferences of *Terrapene carolina carolina* at Jug Bay Wetlands Sanctuary, Maryland

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ABSTRACT

Terrapene carolina carolina (Eastern Box Turtle) home range size and habitat preferences were studied over a 9 year period at the Jug Bay Wetlands Sanctuary in Maryland. Males were found to have a mean home range of 1.51 ± SD 1.33 Ha; while females have a significantly larger ($t(20)=2.589$, $p=0.018$) home range of 5.92 ± SD 7.49 Ha. The home range estimates based on two commonly used data-collection methods, mark-recapture and telemetry, were also compared to determine which was more accurate when compared to the overall home range (based on compiled data from the 2 methods). Telemetry females and males were found to have significantly different home ranges ($t(16)=2.234$, $p=0.040$), and the difference between female random and compiled data was also found to be significant ($t(21)=-2.465$, $p=0.022$). To increase confidence levels in the home range size study turtles were chosen from the database based on 10+ sightings (29 on average). Females were found to use all 7 habitat types with no significant preference, and males were found to use most of the habitats with similar frequency to the females although they did use the meadow appreciably less and were never found in the Phragmites. The significant size and diversity of female home ranges has important implications, because without their recognition critical nesting habitats are likely to be left overlooked by conservation plans putting *T. c. carolina* populations at risk.

KEY WORDS: Eastern Box turtle; home range; habitat; Maryland; tidal wetland; marsh

INTRODUCTION

There is currently an accelerating rate of decline in global biodiversity resulting in impoverished and dysfunctional ecosystems (Ehrlich and Ehrlich, 1981); among the principal causes for this decline are habitat loss, degradation, and fragmentation (Mitchell and Klemens, 2000). It is therefore no surprise that the primary cause of turtle population decline is the ever increasing rates of habitat loss (Mitchell and Klemens, 2000); therefore understanding the home range and habitat preferences of *T. c. carolina* is crucial for their conservation. Currently box turtles are viewed as predominantly terrestrial; however, at the Jug Bay Wetlands Sanctuary (Swarth, unpublished data) in Eastern Maryland female (and more rarely male) *T. c. carolina* include the tidal wetlands in their home ranges. Since this appears to be the only reported case of *T. c. carolina* using a tidal environment, it is important to determine the significance of this habitat to box turtles.

Terrapene carolina carolina

Terrapene carolina carolina (Eastern box turtle) is one of the most common terrestrial reptiles in the eastern United States (Claussen et al., 1991), ranging from the mid-west to the East Coast, (Figure1). Box turtles have relatively long life spans, generally ranging from 30-40 years in the wild (Stickel, 1978; Ernst et al., 1994) with a few reported cases of *T. carolina* ranging from 80 to even 138 years old (Oliver, 1955; Stickel, 1978). Of the many studies of *Terrapene* genera, the handfull of long term studies all suggest a declining population trend in *T. carolina* (Stickel, 1978; Williams and Parker, 1987; Doroff and Keith, 1990; Dodd, 2001).

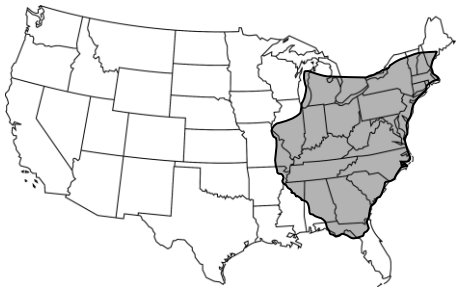

Figure 1. Distribution of *Terrapene carolina carolina.* Adapted from Dodd, 2001.

Home range

Milam and Melvin (2001) defined home range as "the area occupied by an animal for feeding, reproduction, and other activities essential to its survival, including sallies and extended trips outside core habitat-use area. Past studies have excluded sallies from their home range estimates, looking only at the "utilized home range," which is the area which is used in daily activity (Stickel, 1950; Madden, 1975; Stickel, 1989; Dodd, 2001); this study has sided with Milam and Melvin (2001) on the basis that a great deal of female *T. c. carolina* excursions are for nesting purposes. If these habitats are excluded from their home range they stand a higher chance of not being protected which could put the populations at great risk of surviving. While the definitions of home range vary greatly, the methods researchers' use to calculate home range size vary even more, making comparisons of home range area quite difficult. One of the oldest methods of home range estimation is the Minimum Convex Polygon (MCP) method first proposed by CO Mohr in 1947. By its nature MCP is one of the simplest home range

measurement methods because it is simply the area of a polygon formed by connecting the outermost data points of an organism (Plummer, 2003). The main drawback to this method is that it often includes areas in which the subject was never seen in, thus the accuracy of the method is dependant on sample size. The second oldest method, and perhaps the most popular is the Bivariate Normal Home Range method (Jennrich and Turner, 1969). The bivariate normal method is based on the statistical distribution of sightings along an x-y axis, forming an ellipse. This method stipulates that the data be normally distributed, which rarely happens in nature, and the method inherently gives a less conservative home range estimation (Plummer, 2003). The most recent method of home range estimation is the Kernel Home Range (Worton, 1989) method. This method uses non-parametric statistics to determine the probability of an organism using various locations (Plummer, 2003). This method operates with 95% accuracy because it does not require the data be normally distributed, and it weights the home range boundaries according to the frequency in which the areas are used. The only true drawback of this method is that it requires special software to do the home range calculations.

According to Dodd (2001), most box turtles have fairly stable, well defined home ranges. While the home ranges of many organisms tend to coincide with their territories, *T. c. carolina* has not been found to exhibit any definite signs of territorialism (Stickel, 1989; Dodd, 2001). Since there is no territorialism in *T. c.* the home ranges of these turtles overlap with one another. Cross-study comparisons of male-female-juvenile home range sizes show that there is no definite trend towards which sex or age class will have the smallest or largest home range size (Stickel, 1950; Legler, 1960; Schwartz and Schwartz, 1974; Dodd, 2001). While the exact boundaries of the home range may shift over time, it appears the general area stays the same. Several studies in which turtles were removed from their home ranges documented the displaced turtles returning to their original home range (Breder, 1927; Nichols, 1939; Stickel, 1950).

Habitat

Due to their close proximity to the ground, *T. carolina* are especially sensitive to changes in their surrounding substrate environment (Dodd, 2001); further they have a limited ability to move between isolated habitat patches, resulting in genetic fragmentation ((Mitchell and Klemens, 2000). Reagan (1974) found that thick canopied forests with complex habitat structures offer ideal habitats for *T. carolina* by supplying the turtles with microhabitats which offer cool shelter in the summer and warm protection for hibernating in the winter (Dodd, 2001). While *T. carolina* are generally considered terrestrial in nature, several studies have found that *T. c. carolina* may congregate in freshwater floodplains (Stickel, 1978; Dodd, 2001; Swarth unpublished work). Upon observing *T. c. carolina* in the tidal wetlands in 1998, researchers at Jug Bay Wetlands Sanctuary began telemetring the turtles in order to better understand their use of the habitat, since it is the only known use of a tidal habitat by this species (Swarth, unpublished work). While their overall use of aquatic habitats is not well understood, it is generally agreed that water retention is essential to the survival *T. c. carolina* (Rose, 1969; Riedesel et al., 1971; Dodd, 2001).

Many of the habitats other studies have identified as important to box turtles are becoming endangered: 99% of the original "turtle-rich eastern deciduous forest biome" have been lost, and freshwater wetlands are considered one of the most endangered global ecosystems (Mitchell and Klemens, 2000). The most alarming part about the ever increasing rate of habitat destruction is that habitat-related problems almost always have a synergistic effect (Mitchell and Klemens, 2000).

Study Objective

The purpose of my study was to calculate and better understand the home range and habitat preferences of *Terrapene c. carolina* (Eastern Box Turtle) found at Jug Bay Wetlands

Sanctuary in South-eastern Maryland. Specifically this study hopes to answer the following questions:

- How large are the home ranges of *T. c. carolina*, and do males differ from females?
- What habitats do their home ranges include?
- Does one home range measuring technique appear to be more accurate than another (Telemetry vs. Mark Recapture)?
- What percentage of their observed sightings were the turtles using each habitat?
- Are some habitats preferred overall, or are the preferences individual?

It is my hope that in answering these questions resource managers will be better able to preserve the habitats in which these turtles thrive and depend on.

MATERIALS & METHODS

Study site and habitat differentiation

Our study site of approximately 47Ha is located within the 566Ha Jug Bay Wetlands Sanctuary, located along the Patuxent River in Southeastern Maryland. Jug Bay is an estuarine research center owned by the Anne Arundel County Department of Recreation and Parks. Public access within the sanctuary is limited to hikers, education groups, and researchers (Friebele et al., 2001). The sanctuary encompasses 3 main habitat categories: upland, non-tidal wetlands, and tidal wetlands (Figure 2).

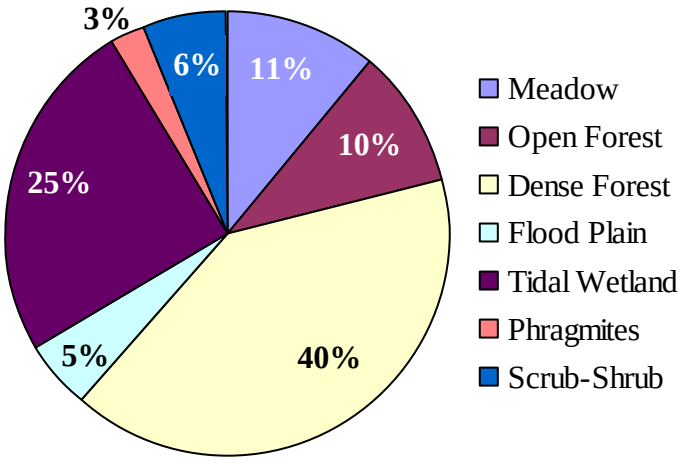

Figure 2. A rough estimate of the percent occurrence of the 7 sub-habitats of the 3 main Habitat categories. Upland: Meadow, Open and Dense Forest; Non-Tidal Wetland: Flood Plain; and Tidal Wetlands: Tidal Wetlands (Marsh), Phragmites, and Scrub-Shrub.

Upland habitats consist of meadows (M), Open and Dense forests (OF and DF respectively). The meadows are made up of warm season grasses, wire grasses, forbs, and shrub patches (Marchand et al., 2003). Both types of forest consist predominantly of the following 30 to 80 year-old hardwood trees: *Quercus falcata* (Spanish Oak), *Carya* spp. (Hickory), *Liquidambar styraciflua* (Sweet gum), *Fagus grandifolia* (American beech), *Liriodendron tulipifera* (tuliptree), *Acer rubrum* (red maple), and *Sassafras albidium* (sassafras) (Burke and Swarth, 1997); with an understory of *Ilex opaca* (American Holly) and *Smilax rotundifolia* (Common Greenbriar). Open and dense forests vary only by their degree of canopy and understory density.

Within the sanctuary there are several areas classified as non-tidal wetlands: the most prominent of these areas is Two Run Creek which runs through the center of the property; followed by several ponds and vernal pools. These area are non-tidal and are fresh in nature. For the purposes of this study these areas will be referred to as flood plain (FP) habitats.

The tidal freshwater habitats are formed by the Patuxent River (a Chesapeake Bay tributary), which are influenced by a salinity range of 0 to 1.0 ppt and 0.6m semi-diurnal tide fluctuations. The tidal habitats are differentiated by the dominating vegetation: Scrub-Shrub (SS), Phragmites (PH), and Tidal Wetlands (TW). The local SS wetlands are made up of hummocks and the following woody shrubs and trees: *Alnus* spp. (Alder), *Fraxinus pennsylvanica* (Green ash), and *Cornus amomum* (Silky Dogwood). The PH wetlands are dominated by a common reed, *Phragmites australis* (phragmites). The wetland habitat (TW) consists of the following marsh vegetation: *Peltandra virginica* (Arrow-Arum), *Nuphar luteum* (Spadderdock), *Zizania aquatica* (Wild Rice) and *Typha* spp. (Cattails).

Analytical method

Habitat preference and home range size will be calculated based on data obtained between 1995 and 2004 (Swarth, unpublished data) using two observation techniques: Mark recapture and Radio-telemetry. Mark recapture is the most common form of box turtle monitoring in the sanctuary because it is low-cost and provides general information on the size of the home range and habitat use. In order to obtain more extensive information on home range and habitat use radio telemetry was initiated in 1998. Telemetried turtles are affixed with a 2.5cm radio-transmitter, and then tracked every 2^{nd}-3^{rd} day by an antennae attached to a R4000 ATS receiver. For the purposes of this study, turtles found using purely the mark recapture method will be deemed "random" sightings, since observations resulted from an observer randomly encountering a turtle.

My study makes use of the 445 box turtles that have been marked by sanctuary staff, interns and volunteers. In 1995 Jug Bay began marking *T. c. Carolina* by bringing the turtles back to the lab where they were processed. The turtles are weighed with an Ohaus spring scale, then their carapace length and width are measured with veneer calipers to the nearest mm. The turtle is then assigned an identification number and a unique notch code. The notch code is a combination of triangularly filled notches on the marginal scutes (Cagel, 1939). Various sex determining characteristics are recorded, along with a photograph of the plastron and a precise description and map of the location in which it was found. In order to increase the accuracy of the sightings data, PVC pipe poles were installed using GPS in 2002 around the sanctuary marking off 1 Ha^2 grid system.

This study sample consists of 20 females, 17 males, and 3 juveniles. These turtles were chosen because there were a large number of sightings (10 minimum, average 29) which could be plotted on a grid map with confidence, and most of which had been found using both home

range methods. Home range size is calculated for each turtle using the Minimum Convex Polygon method. The polygon method estimates home range size by connecting the peripheral sighting locations with a straight line. The size of each home range was found by cutting out area of each mapped home range and weighing it on a Sartorius analytical balance. The area size was found by dividing the range weight by the weight of a cut out of a Ha^2 plot scaled to their map.

Habitat preference was calculated by determining the percent habitat use based on the total number of sightings of each turtle in each of the seven habitats. As with the home range calculations, the habitat percentages were calculated according to random, telemetry, and compiled data. To limit observer error, the original habitat descriptions for the turtle locations will be ignored; instead grid locations used for the home range estimates will be plotted on a habitat color-coded map made by State Department cartographer and sanctuary volunteer Dave Linthicum (Appendix II). The habitat categories, as described above, are Meadow (M), Open forest (OF), Dense forest (DF), Flood Plain (FP), Tidal Wetland (TW), Phragmites (PH), and Scrub-Shrub (SS).

Data Analysis

T-tests were used to determine if there was a significant difference between male and female home range sizes. The two home range measurement methods were also compared using T-tests. Due to a low sample size (n=3) juveniles were excluded from the statistical analysis.

RESULTS

Home Range Size

Analysis of data compiled over a 9-year period (1995 – 2004) of 40 *T. c. carolina* resulted in 1,153 sightings. Males exhibited the smallest mean home range and were localized to a grid area of 49 Ha. Females and juveniles encompassed a much larger grid area, 130 Ha and

84 Ha respectively (Appendix III). Juveniles had the largest mean home range (8.96Ha), followed by females (5.92Ha) and males having the smallest mean home range (1.51 Ha) (Table 1). Females had the largest home range size (30.11 Ha Maximum) while males had the smallest

Table 1. Home range size for female, male and juvenile *T. c. carolina*

	Mean	SD	SE	n	Sample Variance	Confidence Level (95%)
Females	5.92 Ha	7.49 Ha	1.67 Ha	20	56.07	3.50
Males	1.51 Ha	1.33 Ha	0.32 Ha	17	1.77	0.68
Juveniles	8.96 Ha	12.80 Ha	7.39 Ha	3	163.79	31.79

home range (0.34Ha Minimum). As well as having the largest home range size females also exhibited the largest range in home range (29.10 Ha), followed by juveniles (23.30 Ha); while males had a substantially smaller range (5.62 Ha).

Figure 3 shows the variance between the two age-sex categories and the two methods of home range estimation as well as the total (compiled) home range size for all 40 turtles. Figure 4

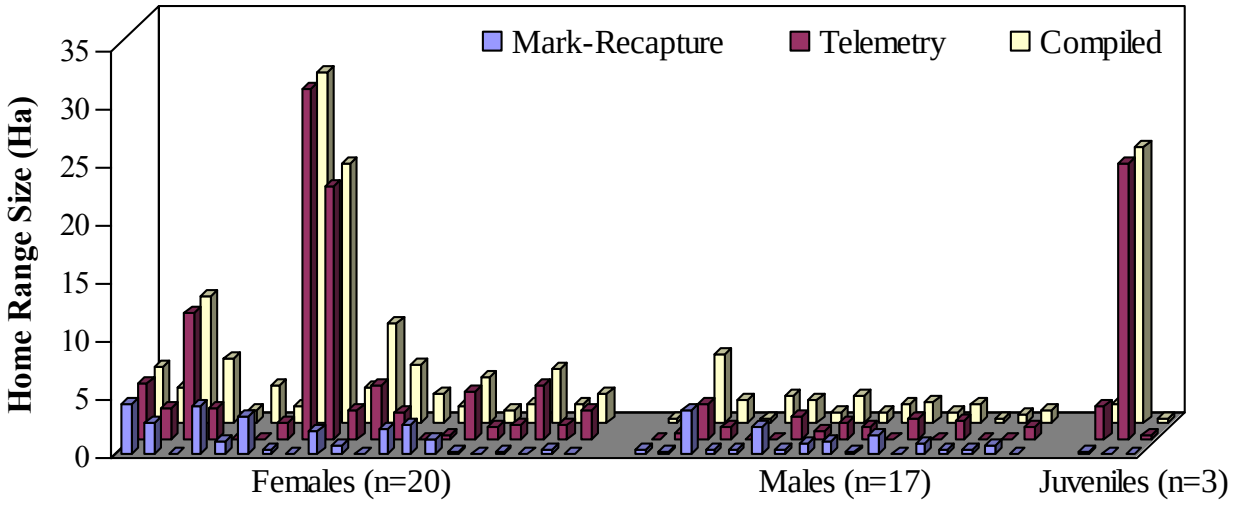

Figure 3. Comparison of home range size using mark-recapture and telemetry sightings, as well as the compiled sightings data.

simplifies the above figure by comparing the mean home range size for the three categories of turtles. T-tests showed a significant difference between overall Female and Male home ranges

(t(20)=2.589, p=0.018) as well as those measured using telemetry (t(16)=2.234, p=0.040) (Table 2). Female Random and Compiled home range estimates were also shown to be significantly different (t(21)=-2.465, p=0.022). The female random and telemetry comparison appeared to be strong but it was not statistically significant; while the remaining categories showed no strong or significant differences in home range size.

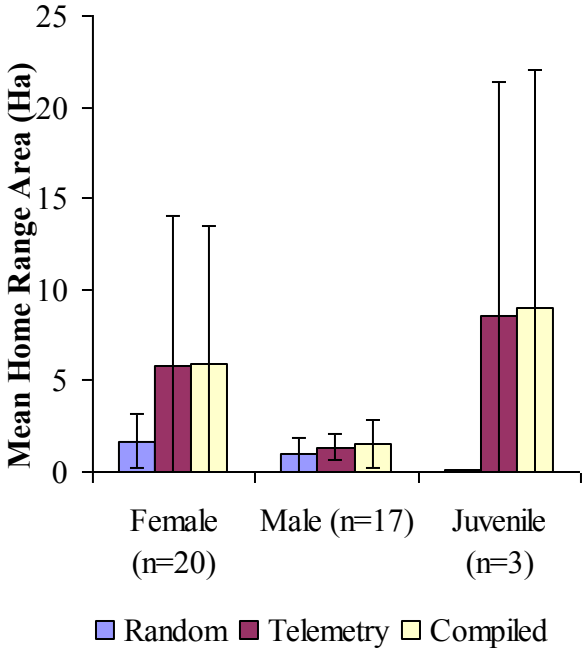

Figure 4. Mean home range size with standard deviation plotted in the error bars.

Figure 5 compares the male and female home overlapping ranges in the same 5 acre plot, with overlapping male and female home ranges in the same size plot, documented by Stickel in 1950. Overall home range sizes were found to be much larger than those found in past studies (Table 3).

Table 2. Home range statistical comparisons

	Factors being compared	df	T-Stat
Female vs. Male	Random	25	1.706
	Telemetry	16	2.234
	Compiled	20	2.589
Female	Random vs. Telemetry	17	-2.036
	Random vs. Compiled	21	-2.465
	Telemetry vs. Compiled	33	-0.063
Male	Random vs. Telemetry	23	-1.217
	Random vs. Compiled	29	-1.412
	Telemetry vs. Compiled	25	-0.411

** indicates a significant difference*

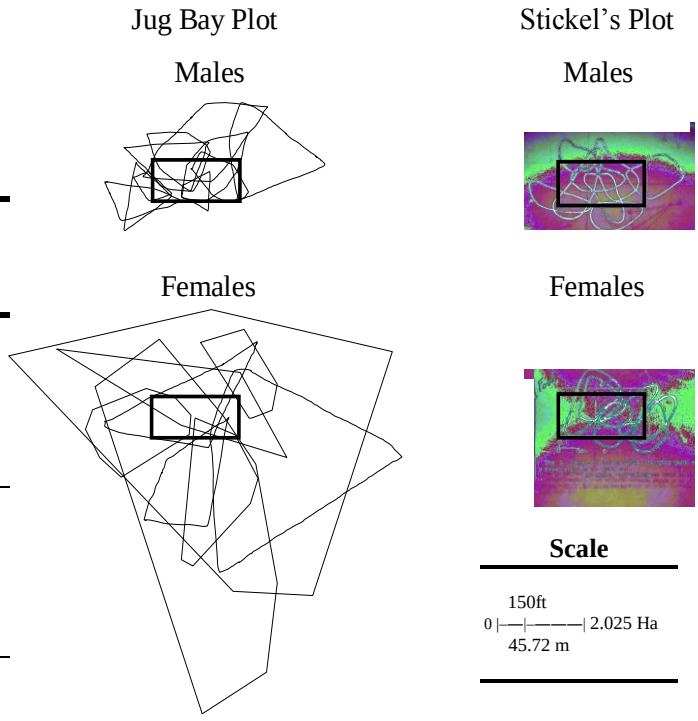

Figure 5. Comparison of Jug Bay Male and Female home ranges in 5 acre (2.025 Ha) plots with the plotted areas from Stickel's 1950 study of male and female *T. c. carolina* in the same size plot.

Table 3. A comparison of *T. c. carolina* home ranges using different measuring and computation methods (adapted from Dodd, 2001).

Location	Collection Method	Computation Method*	Area (Ha)		n	Reference
			Mean	Range		
MD	Mark-recapture	MCP	♀1.70; ♂0.93	♀4.22; ♂3.55	♀15; ♂15	This study
	Telemetry		♀5.76; ♂1.35	♀29.75; ♂2.43	♀17; ♂10	
	Combined		♀5.92; ♂1.50	♀29.10; ♂5.62	♀20; ♂17	
MD	Mark-recapture	BNE	♀1.13; ♂1.20		♀52; ♂51	Stickel (1989)
MD	Thread trailing	CP	0.20	0.48	11	Hallgren-Scaffidi (1986)
VA	Telemetry	MA	1.25	1.80	6	Bayless (1984)
		O-U	2.47	3.30		
MO	Mark-recapture	--	♀5.1; ♂5.2	10.00	♀16; ♂21	Schwartz et al. (1984)
TN	Telemetry	CP	0.38	0.30	4	Davis (1981)
NY	Telemetry	BNE	6.95	17.80	23	Madden (1975)
		MP	2.12			
		CP	4.05			
MO	Mark-recapture	--	♀1.45; ♂1.53	3.50	♀64; ♂79	Schwartz & Schwartz (1974)

**Computation Method Key: Bivariate Normal Elipse (BNE); Minimum Polygon (MP); Convex Polygon (CP); Minimum Convex Polygon (MCP); Minimum Area (MA); Ornstein-Uhlenbeck (O-U)*

Habitat Preference

The upland habitats (open and dense forest) were used the most by all three age-sex categories, while the tidal wetlands (marsh, Phragmites, and scrub-shrub) were used the least (Figure 6). Even though turtles used the other two tidal wetlands there were no observations of males in Phragmites; the freshwater flood plain, however, proved to be male's preferred aquatic environment. Females used all seven habitats, using the meadow more than the males and

showing no significant preference over the type of tidal wetland habitat. The juvenile's habitat preferences are not conclusive due to the small sample size and non-overlapping home ranges.

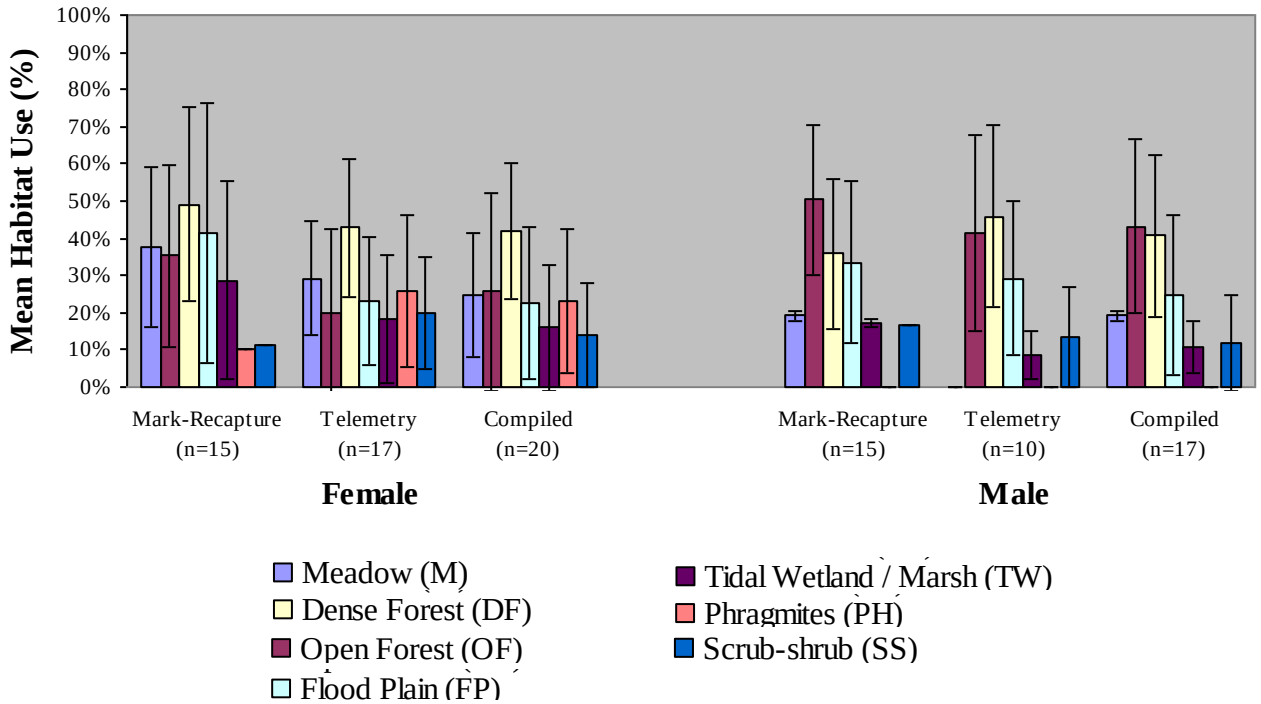

Figure 6. Habitat preference comparison between the data collection methods

DISSCUSSION

Home range

T. c. carolina are known for their well-defined and fairly consistent home ranges. Generalizations about annual changes in home range as well as shifts in habitat use are common in *T. c. carolina* studies (Stickel, 1950; Strang, 1983; Dodd, 2001; Swarth, unpublished data); however, strong comparisons in home range size and habitat use are much more difficult because of the different methods researchers have used to define measure home range. Table 3 summarizes Dodd's (2001) information, comparing it with the home ranges I found in this study. The table shows that in the past 30 years at least six different computational methods have been

used to measure home range size. The table shows the great degree of variation in reported home range sizes, even within the same study areas.

Overall, the ranges of the Jug Bay *T. c. carolina* were much larger than those reported elsewhere, while having the third largest sample size. The difference in home range size may be due to how each study defined home range, whether it was the total home range or the "utilized home range" (Madden, 1975 in Dodd, 2001). Another difference may be in how strong the mean areas were for the past studies. Stickel (1950) used turtles who had 6+ sightings (8 on average), whereas, my study uses turtles with 10+ sightings (29 on average), thus making the confidence of my home ranges stronger. Past studies have found an inverse relationship between population size and home range size (Stickel, 1989), which would indicate that the large home ranges of the Jug Bay *Terrapenes* indicates a small population. However, the nine year on-going study at the sanctuary indicates a large *T. c. carolina* population with at least 445 turtles (as of July 2004). Being non-territorial by nature, *T. c. carolina* are always found with overlapping home ranges (Stickel, 1950; Dodd, 2001). Interestingly, despite the large home range size the degree of overlap within the sanctuary is much larger than in Stickel's 1950 study (Figure 4). Given the contrary findings of no inverse population-home range relationship, Jug Bay's high density-high home range size relationship is more likely explained by Madden's (1975) theory that high turtle densities in specific areas reflect the criticalness of that specific habitat.

Habitat Preferance

As has been the case in past studies (Strang, 1983), there was no significant preference among the seven habitat types. The *T. c. carolina* were found to be more abundant in upland habitats but not to a significant degree. It is very clear that females occupy a much larger and more diverse area of the Sanctuary, than the males. This is due to the nesting requirements of females. As Figure 4 shows, there is significant overlap among home ranges within a relatively

small area (~2 Ha). The plot in Figure 5 is made up of the three most used habitats: flood plain, open and dense forest. It is therefore no surprise the high degree of overlap within this area. Females overall were seen using more habitats than males, which is most likely because of they require the meadow and wetlands in their nesting preparations. It is important to note that while the turtles are clearly using the tidal wetlands to a lesser extent than the upland habitats, there is a very strong observer bias against finding the turtles in this habitat through the mark-recapture method for the simple reason that the marshes are very dense and difficult to walk around in.

Study Limitations

Home Range estimates. The Bivariate Normal method was one of the most commonly used home range measuring methods; however, it has been found to greatly exaggerate the home range size by including areas the turtle never visits. The Minimum Convex Polygon (MCP) method is also popular, thus making it the preferred estimate method for comparing reported home ranges of *T. c. carolina*. It is important to acknowledge that there is a more accurate home range measuring method available today, the Kernel Home Range method. While fewer studies have used this method due to its relatively recent development, it by nature defines home ranges more accurately than MCP by weighting the importance of certain, more frequented, areas of the home range. Given more time it would be interesting to run Kernel estimating software on the data set and compare the MCP home ranges with KNL models.

Conclusion

The most important findings of my study were that females' home range was significantly larger than that of males. This has important conservational implications, because larger, more diverse areas need to be protected in order to insure population health. It is therefore dangerous to average male and female home ranges, as past research has done, because it risks the omission of crucial nesting habitats.

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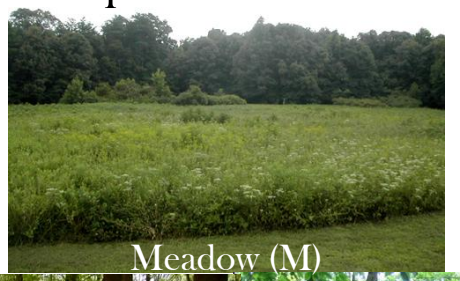
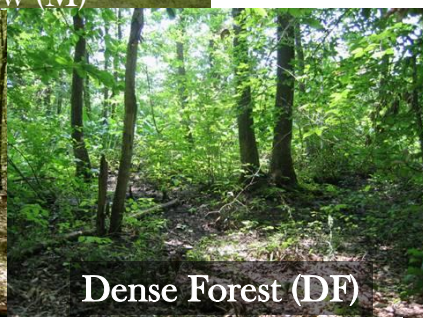
APPENDIX I

Upland Habitats



Meadow (M)

Open Forest (OF)



Dense Forest (DF)

Non-Tidal Wetland

Flood Plain (FP)

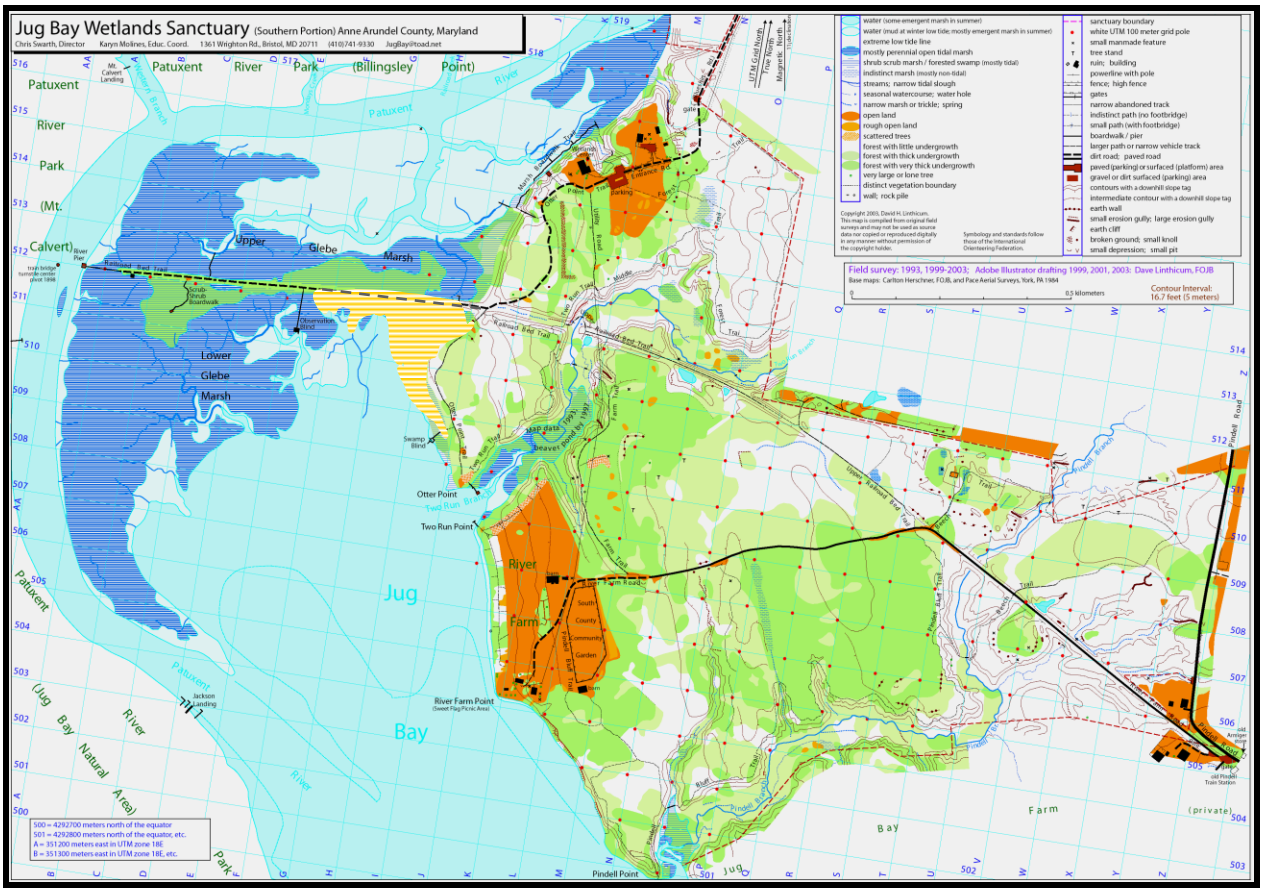
Tidal - Wetlands Habitats

Tidal Wetlands (TW)

Scrub - Shrub (SS)

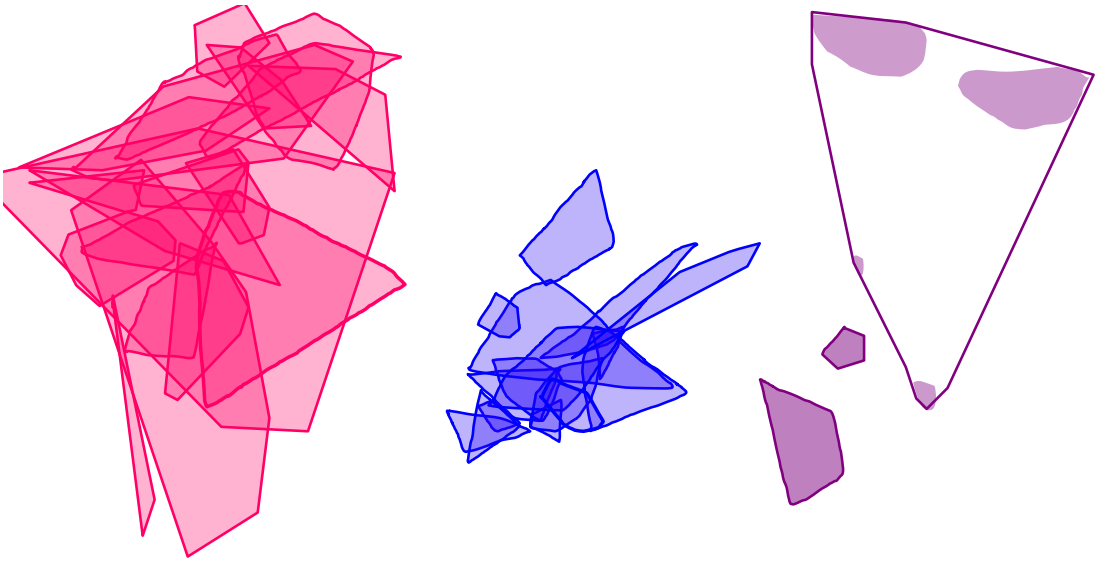
Phragmites (PH)

APPENDIX II

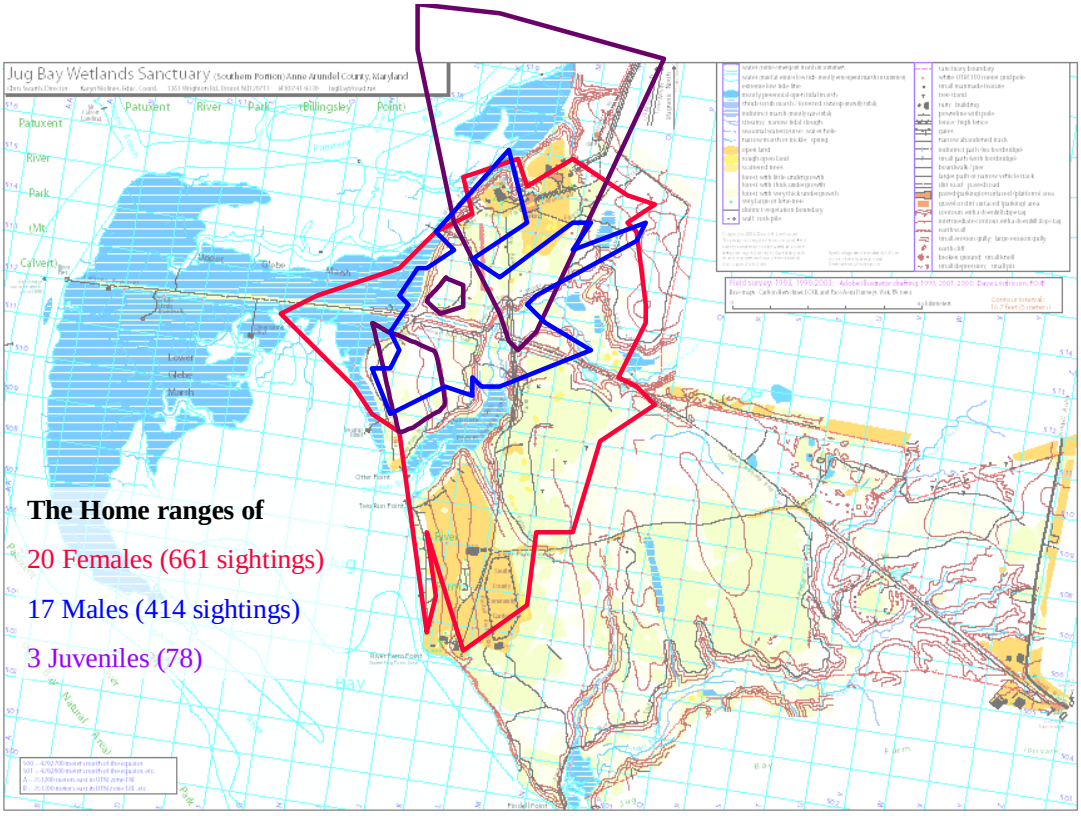


Upland Habitats	Non-Tidal Wetlands	Tidal Wetlands
Meadow (M)	Flood Plain (FP)	Scrub-Shrub (SS)
Open Forest (OF)		Phragmites (PH)
Dense Forest (DF)		TidalWetland (TW)

APPENDIX III



Female	Male	Juvenile
41.53 Ha	12.57 Ha	23.72 Ha (discontinuous)



Areas encompassing the home ranges of the 40 analyzed turtles