

Home Ranges and Habitat Selection of Blanding's turtles (*Emydoidea blandingii*) at the Weaver Dunes, Minnesota

Mark G. Hamernick^{1,2}

¹Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, Minnesota 55987;

²Wisconsin Department of Natural Resources, 3550 Mormon Coulee Road, La Crosse, WI 54601

Keywords: *Emydoidea blandingii*, Blanding's turtle, Geographic Information Systems (GIS), ArcView, home range, habitat selection, radio telemetry, long-lived, Weaver Dunes, USA

Abstract

The home ranges and habitat selection of Blanding's turtles (*Emydoidea blandingii*) were examined at an area known as the Weaver Dunes, located in Wabasha County, Minnesota as part of an ecological survey of the species. 38 individual Blanding's turtles (23 females, 12 males, 3 juveniles) were radio monitored from April 15th, 1999 to April 1st, 2000 in an effort to better understand particular characteristics of the species' spatial behavior at this specific locale. Of these 38 radio marked turtles, home range and habitat selection analyses were performed on 24 individuals (16 females, 8 males) with the most complete telemetry records in ArcView GIS. Home ranges were calculated using the Minimum Convex Polygon (MCP), Bivariate Normal Density Kernel (BNK), and Poly-Buff (PB) methods. Home range sizes did not vary significantly between sexes, regardless of method, but were significantly different between separate study-site subsections. There was also a significant difference between the home ranges calculated with the Poly-Buff versus those calculated with the other two home range methods. The Neu habitat selection model was used to statistically analyze preference/avoidance of particular land cover types for the entire radio sampled population, males, females, and inhabitants of 2 of the 3 study-site subsections, resulting in turtles selecting for Emergent, Submergent, Woody Terrestrial, and Submergent-Rooted Floating Aquatic habitats.

Introduction

Blanding's turtles are medium sized, aquatic turtle with a high, dome-shaped shell that inhabit the shallow marshes, lakes and swamps of Minnesota and Wisconsin. This species is distributed throughout the Eastern part of the United States, as well as several states in the upper Midwest where it typically, can be found in shallow, stagnant waters with muddy bottoms and abundant vegetation (Vogt, 1981; Oldfield and Moriarty, 1994). They are currently listed as a state threatened species by the Wisconsin and Minnesota Departments of Natural Resources, as well as Federal 2 Candidates by the US Fish and Wildlife Service; with this status likely to continue into the near future (Coffin and Pfanmuller, 1988; Wisconsin DNR, 1997).

Within the past quarter century, numerous field investigations have been conducted as part of ecological surveys for this species' management and/or for other scientific purposes, but with only a few focusing on the spatial ecology and habitats critical to this species life history requirements (Ross and Anderson, 1990; Rowe and Moll, 1991; Pappas and Brecke, 1992; Piepgras and Lang, 2000). However, with the exception of Pappas and Brecke (1992) these studies dealt with populations in different geographic locations with significantly fewer animals than what exists at the Weaver Dunes. This turtle contains several important life history attributes that make it nonconductive to environmental disturbance and thus highly relevant to conservation initiatives. First of all, Blanding's turtles are

long-lived organisms, easily reaching 40 or more years of age in their natural setting. This longevity trait makes it difficult to study, by complicating the obtainment of an adequate amount of accurate life history data. Secondly, Blanding's turtles have a reproductive strategy of delayed sexual maturity, typically not being able to reproduce until the age of 16 or 17 years. This in turn causes low recruitment into the population, due to the fact that an animal's chance of surviving to a reproductive age is highly unlikely. Finally, Blanding's turtles are temperature-dependent sex determinants, which can easily create a sharp bias in the gender ratio of a population.

In order to conserve and manage properly for this species, a specific understanding of how these animals utilize the surrounding landscape, both terrestrial uplands and aquatic lowlands must be developed. Blanding's turtles are known to inhabit numerous wetland types throughout Minnesota and Wisconsin, ranging from large, contiguous river bottoms to small, isolated potholes. The ability to understand which characteristics of these aquatic habitats they require, specifically land cover/vegetation type is essential for protection. Also, Blanding's turtles are known to make long, overland movements through uplands, especially females during the nesting season. These upland habitats also contain particular land cover/vegetation type components that the turtles select for, and thus are equally important when it comes to understanding and/or modeling their required habitats in conjunction with conservation concerns.

Recently, two major developments occurred that served as the baseline for this study. First of all, the utilization of Geographic Information Systems (GIS) technology has become instrumental in helping wildlife managers during the decision making process. Two important functions of GIS, the ability to accurately calculate home ranges with several well-known methods and accurately assess habitat utilization have specifically lent a hand in helping understand

behavioral and biological characteristics of several wildlife species. However, the majority of these functions have been utilized specifically for animals that have been studied extensively, such as deer or game birds and relatively few have been applied to smaller, less mobile species such as turtles. Thus, the ability to properly understand nongame species such as Blanding's turtles' habitat utilization and spatial patterns by developing new methods/modifying current ones would be an extremely helpful tool in making proper decisions concerning this species' management, which is crucial for its continued survival. Also, a recent study of Blanding's turtles in central Minnesota by Pieprgras and Lang (2000) specifically addressed several of the very same issues facing this particular study, such as space-use patterns and home ranges of Blanding's turtles and their applications for conservation and behavioral purposes. Therefore, it is the goal of this study to follow some of their recommendations in the development of a new home range technique and to compare several of the methods and results from central Minnesota with the Blanding's turtles of the Weaver Dunes to determine their potential applicability to populations of Blanding's turtles in other locations.

Study Area

The radio telemetry study was conducted as part of an ecological survey at an area known as the Weaver Dunes, located near the _____ in _____ of Wabasha County, MN (Figure 1). This approximately 5000 hectare area is a mosaic of public and privately owned wetlands, lowland deciduous forests, and sandy uplands interspersed with agricultural fields, located on the _____ of the Upper Mississippi River System. For the purposes of this paper, the study area has been divided into three subsections: 1) the _____ (UDIW), 2) _____ (ZRML),

and 3) (WBMR). A map of these subsections can be seen in Figure 2. A more complete description of the Weaver Dunes and its natural history is described in Pappas et al. (2000).

Location information removed

deciduous forest remaining from the original , and is bordered to the immediate and the . This subsection consists of an estimated 750 hectares of both shallow wetland and lowland forest habitat types, and is dominated by aquatic plant species such as sedges (*Carex* spp.) and cattail (*Typha* spp.), as well as floodplain forest species such as maple (*Acer* spp.), ash (*Fraxinus* spp.) and cottonwood (*Populus* spp.). The majority of the ZRML subsection (~90 percent) is state property. To the of both the UDIW and ZRML subsections lies the largest subsection in the study area, the (WBMR) subsection. This consists of large backwater areas such as the and numerous interspersed marshes and open channels that lie within a vast network of forested islands and sand bars. In total, the WBMR subsection encompasses almost 3000 hectares, of

Figure 1. Location of the Weaver Dunes area in SE Minnesota

The (UDIW) subsection is an elevated, dry-sand area intermixed with small, pothole wetlands, sandy dunes and a few agricultural fields. The actual sand dune complex is a slightly elevated sand formation consisting of crater-like crests and depressions resultant from the historical confluence of Rivers. It is dominated by dry prairie and oak savanna plant communities and is roughly 600 hectares in size (Pappas et al. 2000). The Nature Conservancy (TNC) and MN DNR own about 30 percent of these uplands, while the remainder currently resides in private ownership.

(ZRML) subsection. It is a vast, shallow wetland area mixed with lowland

Location information removed

Figure 2. Location of the 3 study-site subsections within the Weaver Dunes The number 1 represents the ZRML study-site subsection, while the numbers 2 and 3 represent the UDIW and ZRML study-site subsections, respectively

Methods

Blanding's turtles were either collected with aquatic hoop net traps baited with sardines, by hand crossing overland, or in the water using a muddling technique similar to the one described by Vogt (1981). Once captured, turtles were transported back to the research quarters where they were assigned an individual identification code and their age, sex, weight, length, width, reproductive status, date and point of capture were measured and recorded. Individual identification codes derived from the system created by Cagle (1939) were either file notched or drilled with a small, circular drill bit into the turtles' marginal scutes. The age of each turtle was determined by counting the distinct growth annuli on the plastron scutes and was considered to be accurate within one year. Unfortunately, the ages of turtles older than 20 years of age were unable to be accurately assessed, and thus were placed in a single category of 20+ years of age. Sex was determined by secondary morphological characteristics such as concavity of the plastron, tail width, and pre-anal tail length in respect to the posterior margin of the carapace. Individuals with a carapace length of 165 millimeters or greater were classified as adults, while those with a carapace shorter than 165 millimeters were considered juveniles. Females with a carapace of greater than 165 mm in length were palpated in the cavity for the presence of shelled eggs, and listed as either gravid or not. Each turtle's height, carapace length and width, and plastron length and width were measured with calipers to the nearest millimeter. Weight was measured with an electronic balance accurate to the nearest tenth of a pound, and converted to metric units. After these data were recorded, turtles were either released at their original point of capture or certain selected individuals were held over for radio transmitter attachment.

38 individual Blanding's turtles (23 females, 12 males, 3 juveniles) were fitted with radio transmitters manufactured by

Advanced Telemetry Systems (ATS) of Isanti, MN and monitored from April 15, 1999 to April 1, 2000. The transmitters, on FM frequency 150 and 151, were attached to the shell midway between the dorsal line and the marginal scutes with a fast drying epoxy compound. After being allowed to dry for 24 hours, the turtles were released at or near their point of capture, and located 2-8. times per week from April to November, as well as intermittently throughout the overwintering period. Each location was determined by triangulating the turtle's position with a 3element, directional antenna and hand-held receiver. Each position, estimated within 5 meters was then plotted onto a tracing of a Digital Orthophoto Quarter Quadrangle map (DOQQ) in the field and eventually incorporated as an X,Y coordinate in ArcView GIS (E.S.R.I., 1999).

Home range and habitat utilization analyses were performed on 24 adult individuals (16 females, 8 males) with the most complete telemetry records in ArcView GIS with the MN DNR ArcView tools, Xtools™, Spatial Analyst™, and Animal Movement Analysis extensions (Hooge and Eichenlaub, 1997; E.S.R.I., 1999). The conditions that were met by these individuals were that they must have 1) a minimum of 25 locations recorded, including 2 overwintering locations, and 2) have been followed from no later than June 10th through at least December 1st 1999, thus representing the overall active season and 3) have movements associated with nesting observed for females. The analyses were accomplished by positioning the X,Y locations for each individual on top of remotely sensed, land cover data representing navigation

(Figure 3). The land cover data, created from 1989 aerial photography by the USGS in Onalaska, WI was subdivided into polygons representing 12 land cover classification types. Although seasonal dynamics such as floods and droughts have had noticeable affects on the vegetation of , this particular data was utilized because it was the most recent, accurate land cover data representing the entire area of

Location information removed

study available at the time of this paper and considered to be adequate for the intended purposes of this study. The study site's composition of each land cover type can be seen in Table 1.

Three different methods were used to calculate home range to compare accuracy. Two of these, the Minimum Convex Polygon (MCP) (Mohr, 1947; Hooze and Eichenlaub, 1997) and Bivariate Normal Density Kernel (BNK) with a 95 percent probability (Silverman, 1986; Worton, 1989; Hooze and Eichenlaub, 1997) are conventional methods that have been used in spatial analyses of wildlife species for the past several decades. They are considered established measures of

calculating home range and adequate for the purposes of delineating broader habitat types, and have been used in a similar comparison of home ranges in Blanding's turtles in central Minnesota (Piegras and Lang, 2000). The third method, called the Poly-Buff method (PB), consists of combining the areas within minimum convex polygons calculated around each individual's aquatic locations with a 20 meter buffer covering each overland movement path. The Poly-Buff is a new method devised by the author and is similar to the Cluster Analysis method described by Edmonds (1998) and Carter et al. (1999) and Grid-Summation method utilized by Piegras

and Lang (2000). The PB method is mainly a derivative from the suggestion by Piepgras and Lang (2000) to develop a home range method for Blanding's turtles (and other aquatic chelonians) that accurately combines aquatic areas of activity with buffered overland movement paths, and is thus more biologically and behaviorally relevant. Examples of each home range method used in calculation can be seen in Figure 4 for female 1618. Home range length (HRL) to the nearest meter was also calculated by measuring the straight-line distance between the two furthest locations for each individual.

The habitat selection analysis was performed via the statistical model created by Neu et al. (1974). This method determines whether a particular habitat category (land cover type) is either selected, avoided, or neither for pooled individuals that share a common attribute, such as origin or sex. It accomplishes this by partnering a Chi-square goodness of fit statistical examination with a Bonferroni Z-statistic. The Chi-square is executed to determine if each habitat category is used in proportion to its availability within the entire study area (), while the Bonferroni Z-statistic creates a normal approximation confidence interval for the Chisquare statistic to determine which habitat types were either selected, avoided, or neither (Neu et al. 1974; Miller, 1981; Alldredge and

Ratti, 1992). This technique is by far one of the most commonly employed methods for determining habitat selection by wildlife species due to its relative ease of calculation and straightforward results, and is well documented in the literature (Thomas and Taylor, 1990; Alldredge and Ratti, 1992; Samuel and Kenow, 1992; McClean et al., , 1998). It should be noted that habitat selection was analyzed at the level of the entire study area () and not at each individual subsection level due to the difficulty in delineating exact boundaries of each subsection, and because the overall Weaver Dunes study area consists of roughly 50 percent of the total area of the 1989 land cover created by the USGS.

The home ranges were compared with the statistical software package SPSS for Windows operating systems. Mann-Whitney U (MWU) examinations were performed to compare home range sizes between males and females, for differences between each home range method, and for differences in PB home range size between inhabitants of each subsection. KruskalWallis (KW) tests were also used to compare the home range methods regardless of sex, as well as between PB home range sizes contained within each subsection. All statistical examinations were considered significant with alpha = .05.

Table 1. 1989 land cover data for navigation in hectares

Class Abbreviation	Land Cover Classification	Area (Ha)	Area (proportion)
A	Agriculture	1920.51	16.85
E	Emergents	795.77	6.98
EG	Emergents-Grasses	85.02	0.75
GF	Grasses/Forbs	1265.70	11.10
OW	Open Water	2482.60	21.78
RFAE	Rooted Floating Aqua-Emergents	18.96	0.17
RFA	Rooted Floating Aquatics	98.22	0.86
SM	Sand/Mud	52.09	0.46
S	Submergents	1083.41	9.51
SRFA	Submerg. Rooted Floating-Aquatics	528.56	4.64
UD	Urban/Developed	562.62	4.94
WT	Woody Terrestrial	2504.27	21.96
Total		11397.73	100.00

Location information removed.

Results

38 adult and juvenile Blanding's turtles were located via radio telemetry from 10 to 62 times (mean=34) throughout the active season of 1999 and overwintering period of 1999-2000. Of the 38 turtles radio tracked, 24 individuals (16 females, 8 males) with the most complete telemetry records (>25 locations, ≥ 2 overwintering locations, movements associated w/nesting for all females) were selected for home range and habitat selection analyses.

Home Range

The calculated home ranges resulted in

a wide variety of sizes, as can be seen in Tables 2 and 3. Among males (n=8), the mean home range area value was 56.89 ha, min=2.20, max=291.80, SD=97.27 when calculated with the Poly-Buffer method (Table 2). While the mean MCP and BNK home ranges for males were relatively similar to each other in size, their means were roughly twice the size of the mean Poly-buffer home range. The mean male home range length measured 1794.0 meters, min=555.0, max=5183.0, SD=1549.0 (Table 2).

Female home range area also varied greatly (n=16), with a calculated mean PolyBuffer home range of 18.89 ha, min=2.44, max=67.43, SD=19.29 (Table 3). As apparent in males, the mean MCP and BNK

Table 2. Calculated home range sizes in hectares for males utilized in the home range analysis

Turtle ID	Sex	# Locations	MCP	BNK-95%	Poly-buff	Length (m)
N8-2	M	48	2.86	2.77	2.20	555.0
AR	M	36	18.37	14.91	7.12	615.0
N7-24	M	30	13.95	20.41	11.12	817.0
N7-23	M	48	20.00	4.49	12.90	794.0
N8-12	M	37	50.09	147.90	26.28	2112.0
N7-11	M.	53	66.33	130.47	35.21	1905.0
N7-9	M	50	90.93	128.73	68.52	2372.0
N7-22	M	39	496.79	534.05	291.80	5183.0
Mean			94.92	122.96	56.89	1794.0

Table 3. Calculated home range sizes in hectares for females utilized in the home range analysis

Turtle ID	Sex	# Locations	MCP	BNK-95%	Poly-buff	Length (m)
N8-9	F	47	2.23	1.62	2.44	370.0
N8-15	F	62	3.02	1.68	2.87	412.0
RF10-13	F	26	18.35	26.37	6.19	805.0
N7-15	F	50	13.66	9.19	6.35	850.0
N1-7	F	27	30.50	40.85	8.35	781.0
AHQ	F	27	13.90	24.07	8.90	738.0
16-18	F	47	32.71	8.10	10.37	954.0
2--8	F	25	75.12	36.09	11.54	1905.0
N 11-22	F	39	89.32	28.60	12.66	2030.0
AHI	F	39	35.13	40.25	15.47	1545.0
N11-21	F	38	73.81	56.15	15.53	2580.0
N8-11	F	27	69.35	210.01	21.41	2478.0
N11-23	F	25	112.95	58.69	23.17	1683.0
N8-16	F	47	175.54	148.41	27.19	2300.0
N3-7	F	46	118.05	182.64	62.33	1770.0
RF14	F	43	108.32	61.01	67.43	2350.0
Mean			60.75	58.36	18.89	1472.0

were also very similar in size, while the mean PB was less than half of those calculated with the previous two methods, as shown in Table 3. The mean female home range length was 1471.0 meters, min=370.0, max=2580.0, SD=765.0, (Table 3).

Although they were highly variable, there were no significant differences in home range size between the sexes, regardless of method used in their calculation (NIWU: MCP $z=-.306$, $P=.759$; BNK $z=-.184$, $P=.854$; PB $z=-.919$, $P=.358$). However, different patterns of movements between the sexes were

observed during the course of this study but were not specifically quantified due to time and resource constraints. Males generally moved more often over shorter distances, while females moved from areas of activity less often but made longer distance movements, particularly those overland associated with nesting. There was also no significant difference between male and female home range lengths (MWU: HRL $z=.092$, $P=.927$).

Furthermore, numerous statistical analyses of home range size were also

performed at the subsection level by comparing the Poly-Buffer home ranges of pooled inhabitants from each study-site subsection (Table 4). With the sexes combined, statistical significances were observed between home ranges of the 3 subsections (UDIW, ZRML, WBMR; KW: $P=.011$) as well as when the ZRML and WBMR results were compared (MWU: $z=2.123$, $P=.034$). This also was apparent when only female home ranges of the three subsections were compared (KW: $P=.011$) as well as when ZRML and WBMR subsections were compared with each other (MWU: $z=2.242$, $P=.025$). However, there were no significant differences observed in male home ranges between any of the subsections (KW: $P=.40$).

Several statistical comparisons between home ranges were also performed with the sexes combined ($n=24$) to compare differences between methods of calculation. A Kruskal-Wallis test was used to compare between the three home range methods. This examination resulted in a significant difference (KW: $P=.025$), most likely due to the fact that the means of the MCP and BNK methods were much larger than that of the PB method (MCP=42.08, BNK=40.33, PB=27.08). The three methods were also compared two at a time. No significant difference was found between the MCP and BNK methods (MWU: $z=-.062$, $P=.951$). However, a significant difference was discovered between the MCP and PB methods (MWU: $z=-2.701$, $P=.007$) and the BNK and PB methods (MWU: $z=-1.959$, $P=.050$).

Habitat Selection

Bonferroni statistical examinations of habitat utilization data were performed at several different levels to confirm selection of the 12 different land cover types (USGS data, Table 1). This resulted in turtles either utilizing each habitat category more than expected (selected), less than expected

(avoided), neither selected nor avoided, or not utilized at all. The first level of habitat selection was examined with all 24 individuals pooled together, thus representing the entire sampled population. Of the 12 different land cover habitat categories, Emergent (E), Submergent-Rooted Floating Aquatic (SRFA), and Woody Terrestrial (WT) habitat categories were selected for, while the 9 remaining habitat categories were neither selected nor avoided or used less than expected (Table 5).

Moreover, Bonferroni statistical examinations were also performed on pools of the sampled individuals of the same sex. For males, the Submergent (Sub), Emergent (E), and Woody Terrestrial (WT) categories were selected for, while the remaining 9 habitat types were either avoided, or neither selected nor avoided. Meanwhile, in consistency with the results for males and the total sample population, analysis of females indicated selection for Emergent and Woody Terrestrial habitat types. However, these two land cover categories were the only two indicating selection, while the remaining 10 were either avoided or neither selected nor avoided.

Furthermore, individuals with the majority of their home range (>90%) lying within either the WBMR (6 females, 4 males) or the ZRML (6 females, 3 males) subsections were pooled together and subsequently analyzed for habitat selection. As consistent with the previous habitat selection results reported, turtles from both subsections selected Emergent and Woody Terrestrial habitat types, while the remaining 10 habitat categories were either avoided or neither selected nor avoided. The five remaining individuals that resided in both subsections intermittently, as well as the UDIW subsection were not analyzed due to spatial and temporal factors, as well as the difficulty involved with delineating exact boundaries between the three subsections. Therefore statements about their habitat selection were avoided.

Table 4. A comparison of Poly-Buff home ranges between pooled inhabitants from each of the three different study-site subsections

Sex	ZRML subsection	UDIW subsection	WBMR subsection
Female	2.44	15.47	6.35
Female	2.87	21.41	10.37
Female	6.19	27.19	12.66
Female	8.30	67.43	15.53
Female	8.90		23.17
Female	11.54		62.33
Female mean	6.71	32.89	21.74
Male	7.12	26.28	2.20
Male	11.12		35.21
Male	12.90		68.52
Male			291.80
Male mean	10.38	26.28	99.43
Total mean	20.12	31.56	52.81

Table 5. Habitat selection for each of the 5 levels of analysis

Level of Analysis	Selected	Avoided	Neither selected nor avoided
Males	E, WT, SUB	OW, RFAE, AG, UD, SM	SRFA, RFA, EG, GF
Females	E, WT	OW, RFAE, GF, AG, UD, SM	SUB, SRFA, RFA, EG
ZRML	E, WT	OW, SRFA, RFAE, RFA, EG, AG, UD, SM	SUB, GF
WBMR	E, WT	OW, RFAE, AG, UD, SM	SUB, SRFA, RFA, EG, GF
Pooled	E, WT, SRFA	OW, SUB, RFAE, RFA, AG, UD, SM	EG, GF

Discussion

It has recently been brought to the attention of those responsible for the management and conservation of wildlife species, especially long-lived vertebrates, that chelonians embody an intricate link between both aquatic and terrestrial habitats, due to their reliance upon both parameters throughout their life cycle (Bodie and Semlitsch, 2000; Piepgras and Lang, 2000). This is especially true in Blanding's turtles, because they're known to be primarily aquatic, but also make long, migratory overland movements throughout upland habitats at several stages of their life history, as well as being known as one of the longer-lived North American Emydids. All in all, Blanding's turtles exhibit relatively consistent home range sizes throughout previously reported studies, with the exception

of the population observed at Camp Ripley in north-central Minnesota (Piepgras and Lang, 2000). Conversely, the Blanding's turtles of the Weaver Dunes were long thought to have tremendously larger home ranges than those reported by previous investigators (Mike Pappas, pers. comm. 1999) but were never examined nearly to the extent that is now possible with current telemetry technology. Also, several key ecological factors associated with home range size, such as habitat composition and available resources were also considered to be significantly different at the Weaver Dunes than what has been documented in previous investigations. It were these key factors, along with a few others that were the catalysts in the investigation that took place concerning the spatial behavior of this species at this tremendously distinctive location.

Home Range

Although dissimilar patterns of movement were observed between the two sexes, no significant differences between male and female home range sizes occurred, regardless of which methods were used in their calculation. This consequence is consistent with the reports of such surveyed characteristics in Blanding's turtles elsewhere (Ross and Anderson, 1990; Rowe and Moll, 1991; Piepgras and Lang, 2000), including a similar comparison between 3 home range techniques conducted within the same state (Piepgras, 1998). The straightforward explanation for this is that the radioed females typically only moved once or twice overland during the active season, which ordinarily was associated with nesting. On the other hand, males made much shorter overland movements and moved more often than their sexual counterparts, presumably associated with mate searching behavior the majority of the time (Rowe and Moll, 1991; Bodie and Semlitsch, 2000; Piepgras and Lang, 2000). Gibbons et al. (1990) and Brown and Brooks (1993) concluded that females don't necessarily gain a reproductive advantage from multiple mates like males do and thus are less apt to move overland because of energy constraints, risk of dehydration, depredation and so forth. Therefore, the movement patterns specific to both sexes (males moving more often but shorter overland movements while females moved less often, but made lengthy overland excursions) at the Weaver Dunes appear to cancel each other out.

In comparison with several other studies concerning the size of Blanding's turtle home ranges, the Weaver Dunes population exhibited much larger home ranges and home range lengths than previously reported (Rowe, 1987; Ross and Anderson, 1990; Rowe and Moll, 1991; Joyal, 1996; Piepgras and Lang, 2000), as is evident in Table 6. Once again method of calculation was not a factor. This is more than likely due

to numerous abiotic and biotic influences factored collectively, as opposed to one or a few singled-out persuasions. For example, conventional wisdom concerning the spatial behavior of turtles indicates that home range size is a reflection of numerous ecological phenomena, such as population density, carrying capacity, habitat composition, and distribution of crucial resources such as food, refugia, potential mates and so forth (Pettit et al,

1995; Carter et al., 1999; Piepgras and Lang, 2000). The fascinating thing is that the Weaver Dunes animals appear to have plenty of food which is evident by their rapid growth rates in many individuals (Lang, pers. comm., 2000), an abundance of suitable habitats and potential mates, as well as a high population density (-31 turtles/ha) (Pappas and Brecke, 1992). Therefore, one can only draw the conclusion that there is something else causing these animals to exhibit such large home range behavior. One possible factor is the impact the lock and dam system implemented by the U.S. Army Corps of Engineers during the 1930's has had on these long-lived organisms. Historical records show that the landscape of the Weaver Dunes area was at one time very different from what it was during the time of this study, with the most noted discrepancy concerning the lack of homogeneity of aquatic habitats prior to the implementation of the lock and dam system in the 30's versus the large, vast wetland expanses that exist at the end of the 20'h century. This coincides directly with what Ross and Anderson (1990) reported for Blanding's turtles in central Wisconsin, where turtles appeared to have larger activity areas in vicinities consisting of more available aquatic habitats of preference. Furthermore, Piepgras (1998) concluded that a population of Blanding's turtles at Camp Ripley, MN (-200 miles north of Weaver) had large home ranges due to a low population density, patchy resources, and widely dispersed, extensive habitats. Thus, the one reported similarity between these two study sites and the one in question are the extensiveness of the aquatic

Table 6. A comparison between reported home range sizes and lengths of Blanding's turtles from previous studies. The three methods used in this study were Minimum Convex Polygon (MCP), Bivariate Normal Density Kernel with a 95% probability (BNK95%), and Poly-Buff (PB). Methods utilized in other studies are: GS = Grid Summation method, AK(95%) = Adaptive Kernel with a 95% probability, and MPM = MCP method. The last column indicates whether or not a statistical significance was detected between the sexes

Investigators	Location	Mean HR Size (Ha)	Method	Mean HR Length (m)	Signif. M v F?
Hamernick, 2001	SE MN	Male=94.92, Female=60.75	MCP	370-5183(1579)	N
"	"	Male=122.97, Female=58.36	BNK(95%)	NA	N
"	"	Male=56.89, Female=18.89	PB	NA	N
Piepgas and Lang, 2000	Central MN	Male=7.8, Female=7.8	GS	208-2700(835)	N
"	"	Male=38.4, Female=35.4	MCP	243-2987(906)	N
"	"	Male=53.4, Female=63.0	AK(95%)	292-3100(985)	N
Joyal, 1996	Maine	0.91*	MPM*	90-2050(680)	?
Rowe and Moll, 1991	NE Illinois	Male=1.4, Female=1.2*	MPM**	630-800	N
Ross and Anderson 1990	Central WI	Male=.76, Female=.64	MPM**	489	N
Rowe 1987	NE Illinois	9.5	MCP	NA	?

* = derived from summed centers of activity (Piepgas and Lang, 2000)

** MPM is equivalent to the MCP method

habitats, which may or may not be an influential factor because the animals at Weaver appear to have high home range fidelity, so the odds that individuals aimlessly move around are against them both behaviorally, as well as energetically:

Also, previous studies concerning the spatial ecology of vertebrate organisms typically have resulted in studied individuals displaying much larger home ranges in areas of fragmented habitats versus contiguous habitats, especially for aquatic species (Edmonds, 1998). However, this does not appear to be the case in this particular situation. At the Weaver Dunes there are vast wetland complexes throughout the entire study area consisting of a plethora of shallow aquatic habitat types that are hardly fragmented in any manner. Thus one must consider other options when attempting to explain this occurrence. One of these other factors could be due to a distinct uniqueness between Blanding's turtles' specific biological requirements at this location versus those previously examined at other locations. Whether or

not this is the case was beyond the abilities of this particular author and could not be addressed at this juncture.

Another interesting notation of this study has been the discovery of a significant difference in home range sizes of individuals that inhabit different study-site subsections. Macdonald (1983) and Edmonds (1998) state that mobile species in locations of lowproductivity will have larger home ranges in order to fulfill their biological requirements. This would appear to coincide with the significant difference discovered between animals that use the ZRML subsection, which has more suitable habitats with emergent vegetation versus the animals that spend the majority of the active season in the WBMR subsection. Historical records show that the Weaver Bottoms area has progressively become less and less productive in regards to biomass such as emergent vegetation since the implementation of the lock and dam system due to several causations. This specific dilemma has become the center of crucial debate between private citizens and public resource

agencies for the past several years concerned with the lack of vegetation and biological productivity in the Weaver bottoms area. Thus, the discovery of turtles displaying larger home ranges in the WBMR subsection versus the ZRML subsection is most likely related to the fragmenting of and growing distances between areas of more suitable habitats with the turtles' preferred habitat characteristics such as emergent vegetation and higher biological productivity.

Associated with the significant difference in home range sizes between animals of separate subsections are the significant differences between the methods used in home range calculation. According to the literature, both the MCP and BNK methods have numerous positives and negatives such as statistical and operator induced limitations in regards to calculation of home range size for mobile species (Jennrich and Turner, 1969; Anderson, 1982; Worton, 1989; Naef-Daenzer, 1993; Worton, 1995; Piepgras, 1998; Seaman et al., 1999; Piepgras and Lang, 2000). For the most part, these traditional methods are known to greatly overestimate home range sizes of aquatic chelonians, mainly due to the incorporation of large tracts of unused terrestrial habitats, and thus are relatively useless for understanding the spatial behavior of such organisms (Edmonds, 1998; Piepgras, 1998; Carter et al., 1999). This also appeared to be the case at the Weaver Dunes, resulting in large discrepancies between the MCP and BNK home ranges versus the more conservative Poly-Buffer method, which proved to be the most ecologically and behaviorally relevant method. Although the MCP and BNK appear to have some weight from a conservation viewpoint, their use in understanding parametrical characteristics of semi-aquatic to aquatic turtles should be avoided.

The observed divergences between the MCP and BNK versus the Poly-Buffer method in this study, as well as those reported in other studies comparing similar methods (Edmonds, 1998; Piepgras, 1998; Carter et al., 1999; Ostro et al., 1999) were somewhat expected, especially due to the similar results observed in Blanding's turtles by Piepgras and Lang (2000). These results, along with the suggestions to modify the GridSummation

method by combining it or a similar method with buffered overland movement paths were exactly what prompted the author to devise a new, easily calculated method of home range definition more applicable to aquatic turtles, specifically those that also make long, overland movements such as Blanding's turtles. The size and location of home ranges are considered crucial factors in the management of wildlife species (Kantola and Humphry, 1990; Sherry and Holmes, 1996; Sauer et al., 1999; Piepgras and Lang, 2000) and although they contain some degree of inaccuracy, methods such as the Poly-Buffer are much more relevant behaviorally and better for understanding things like home range and habitat utilization than the methods of old (MCP, BNK) that were developed for larger, terrestrial vertebrates and are better for broader, more general purposes such as conservation. Methods such as these should continue to be developed further by investigators in the future, especially with the ease of calculation due to the development of GIS protocols and computer technology.

Habitat Selection

In order to statistically assess the preference/avoidance of individual habitat types, habitat selection analysis was conducted by comparing the proportion of turtle locations within each particular habitat versus the proportion of that habitat's availability within the entire study area (). This is known as the Neufuss resource selection method, and is considered the most commonly used method for determining habitat selection in wildlife species (McClellan et al., 1998). The reasons for conducting such an analysis are straightforward. First, of all, in order to properly understand the species in question, a landscape-level analysis of which habitats are critical is extremely important for ecological, conservation and management reasons (McClellan et al., 1998). Secondly, a knowledge of which habitats are necessary at all times of the year is also crucial. Historically floodplain and wetland managers

have lacked appropriate data for creating management and conservation decisions and thus need to recognize the importance of both aquatic and terrestrial habitats throughout the entire year (Bodie and Semlitsch, 2000). This is especially important in long-lived organisms such as Blanding's turtles that rely upon both aquatic and terrestrial habitats for numerous reasons throughout different parts of the annual cycle. Finally, the intricate blend of different habitat components at the Weaver Dunes obviously plays a key role in the unique success of the Blanding's turtle population in this area. Therefore, if a better understanding of the key habitat components can be better understood, possibly this knowledge may be applied to other areas containing similar habitats where Blanding's turtle populations are declining.

The most evident theme in the analysis of habitat utilization at the Weaver Dunes was the selection for Emergent and Woody Terrestrial habitat types by Blanding's turtles, regardless of classification or grouping of individuals. The selection for Emergents comes as no surprise, considering that most emergent plants such as sedges (*Carex* spp.) and cattails (*Typha* spp.) are associated with shallow, stagnant wetlands with mucky substrate and several past investigations concerning Blanding's turtles have documented this species as relying heavily upon shallow water habitats with emergent vegetation throughout the active season (Congdon et al. 1983; Rowe and Moll, 1991; Pappas and Brecke, 1992; Hamernick, 1998; Sajwaj et al. 1998; Piepgras and Lang, 2000; Sajwaj and Lang, 2000). Voigts (1976) reported that shallower, emergent marshes contain more invertebrate species and biomass than most other habitats and therefore the Blanding's turtles at the Weaver Dunes were more than likely selecting for Emergent habitats for food, as well as refugia, thermoregulation, and other potential resources. However, although Blanding's turtles were discovered to be selecting for these particular habitats within the state of Minnesota (Pappas and Brecke, 1992;

Hamernick, 1998), the selection of a particular habitat type may be more related to its associated structural characteristics such as water depth or substrate type/depth. Carter et al. (1999) believed that another species representing the family Emydidae (bog turtles) in southwestern Virginia responded more to structural habitat components versus actual vegetation type, and therefore conclusions made about the vegetation selection of Blanding's turtles at the Weaver Dunes should not be made without supplemental microhabitat data and thus current conclusions about selection for specific land cover types are only speculative, and not concrete.

On the other hand, the turtles also showed a high preference for Woody Terrestrial habitats, which can be interpreted in a number of ways. Blanding's turtles were indeed frequently found in Woody Terrestrial habitats, but nowhere near as regularly as the habitat selection data suggests, and probably not quite to the extent where WT could be considered statistically selected. Although previous studies concerning spatial behavior of Blanding's turtles have reported brief forays by individuals into deciduous woodlands for numerous presumptuous reasons (Sajwaj et al., 1998; Piepgras, 1998) this only was observed in the Weaver population on a highly limited basis. The few observations that actually indicated animals inhabiting true WT land cover types were observed mainly in transient females during the nesting season, by a few other individuals moving in a non-reproductive related fashion, or by animals actually residing in the waters of flooded deciduous woods.

The more explanatory reasons for these results are more than likely due to several issues concerning the actual creation, interpretation, and accuracy of the GIS land cover data. First of all, several polygons within the interpreted GIS data that were labeled WT were in all actuality more like Grasses/Forbs and Emergent habitats in lowland, moist areas. However, due to a few scattered, small trees these areas were

misclassified as WT and not their true habitat type. Another reason has to do with a discrepancy between the spatial error involved with both the telemetry points and the land cover data polygons. The error associated with the actual telemetry locations was estimated to be within 5 meters, while the GIS data has a 15-meter error association. Therefore, the combined error between the two is potentially as high as 20 meters, and thus some points would result in an obvious misclassification. Regrettably this error association resided outside of the bound of this author's current abilities and was unsolvable, but nonetheless needed to be addressed in some manner. Finally, one very important component is that turtles that were classified as lying within WT habitats were in all actuality inhabiting small, pocket wetlands within the WT floodplain forest, and consequently were actually selecting for the wetland vegetation types on a micro scale within the WT habitats. Unfortunately, these pocket wetlands are smaller than the minimum mapping unit (< 1 acre) and therefore a misrepresentation occurred. Thus, these results point out some of the limitations and errors associated with current GIS technology, and easily warrant the necessity for reputable results from a habitat selection survey to be conducted at the micro scale, instead of the macro scale that most current GIS data layers representing land cover allow.

In association with the preference of Emergent and Woody Terrestrial habitats by each of the particular groups in question was the actual avoidance of some habitat types, most notably Open Water, Rooted Floating Aquatic-Emergents, Agricultural, Urban/Developed, and Sand/Mud. These results have several potential explanations. The most obvious reason (with the exception of RFAE category) is that all of these lack the particular structural characteristics associated with the typical shallow, swampy aquatic habitats that Blanding's turtles prefer throughout their range in the Upper Midwest. Aquatic habitat types such as Open Water contain relatively no cover for

thermoregulation nor refuge from predators and thus the turtles would potentially not be able to properly regulate their body temperature and would be vulnerable to depredation if they actually spent a significant amount of time in this habitat category. Also, as pointed out earlier, Open Water typically lacks the abundance of potential food sources that habitats with more vegetative biomass contain, so turtles would potentially avoid such a habitat type for nutritional reasons. Finally, the Blanding's turtles at the Weaver Dunes demonstrated highly aquatic tendencies during this investigation. Turtles were easily monitored in aquatic habitats more than 90 percent of the time. Therefore, the consequence that Blanding's turtles statistically avoided each of the true terrestrial habitat types was to be expected.

Acknowledgements

Many people were intricate members in the completion of this project and cannot go unnoticed. First and foremost, I'd like to thank my adjunct adviser Dr. Jeffrey W. Lang, Professor of Biology, University of North Dakota-Grand Forks for all of his time, energy, patience and countless resources and support for helping make the turtle research possible, as well as for putting up with my antics for the last five years. Secondly, I'd like to thank the Resource Analysis staff at St. Mary's University, particularly my adviser Dr. David McConville for his useful insight and encouragement with this manuscript and GIS. Thirdly, thanks to Gretchen Chesley-Lang, Nancy Falkum and numerous volunteers for their assistance with logistics and in the field, and especially an indebted thank you to Michael Pappas of Rochester, MN for his continued dedication, ideas, support, and enthusiasm for the Blanding's turtles at the Weaver Dunes. Finally, I'd like to thank the Minnesota Chapter of The Nature Conservancy for funding and the friendly people of the lower sand-prairie area for allowing us unconditional access to their property.

References

- Allredge, J.R. and Ratti, J.T. 1992. Further comparison of some statistical techniques for analysis of resource selection. *Journal of Wildlife Management* 56(1): 1-9.
- Anderson, J.D. 1982. The home range: a new nonparametric estimation technique. *Ecology* 63(1): 103-112.
- Bodie, J.R., and Semlitsch, R.D. 2000. Spatial and temporal use of floodplain habitats by lentic and lotic species of aquatic turtles. *Oecologia* 122: 138-146.
- Brown, G.P., and Brooks, R.J. 1993. Sexual and seasonal differences in activity in a northern population of snapping turtles, *Chelydra serpentina*. *Herpetologica* 49:311-318.
- Cagle, F.R. 1939. A system for marking turtles for future identification. *Copeia* 1939: 170-173.
- Carter, S.L., Haas, C.A., and Mitchell, J.C. 1999. Home range and habitat selection of bog turtles in Southwestern Virginia. *Journal of Wildlife Management* 63(3): 853-860.
- Chase, J.D., Dixon, K.R., Gates, J.E., Jacobs, D., and Taylor, G.J. Habitat characteristics, population size, and home range of the bog turtle, *Clemmys muhlenbergii*, in Maryland. *Journal of Herpetology* 23:356-362.
- Coffin, B., and Pfannmuller, eds. 1988. Minnesota's Endangered Flora and Fauna. University of Minnesota Press, Minneapolis. 464 pp.
- Congdon, J.D., Tinkle, D.W., Breitenbach, G.L., and van LoBen Sels, R.C. 1983. Nesting ecology and hatchling success of the turtle, *Emydoidea blandingii*. *Herpetologica* 39: 417-429.
- Edmonds, J.H. 1998. Population ecology of the stinkpot turtle (*Sternotherus odoratus*) in Georgian Bay, Ontario. MS Thesis, University of Guelph.
- Environmental Systems Research Institute, Inc. 1999. ArcView software version 3.2. Redlands, California.
- Gibbons, J.W., Greene, J.L., and Congdon, J.D. 1990. Temporal and spatial movement patterns of sliders and other turtles. In: Gibbons, J.W.(Ed.). Life History and Ecology of the Slider Turtle. Washington, DC: Smithsonian Institution Press, pp. 201-215.
- Hamernick, M.G. 1998. Summer aquatic microhabitats of Blanding's turtles (*Emydoidea blandingii*) in Central Minnesota. Unpublished Undergraduate Thesis. University of Wisconsin-Eau Claire.
- Hooge, P.N., and Eichenlaub, B. 1997. Animal movement extension to arcview. ver. 1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, AK, USA.
- Jennrich, R.I., and Turner, F.B. 1969. Measurement of non-circular home range. *Journal of Theoretical Biology* 22: 227-237.
- Joyal, L.A. 1996. Ecology of Blanding's (*Emydoidea blandingii*) and spotted (*Clemmys guttata*) turtles in southern Maine: population structure, habitat use, movements, and reproductive biology. M.S.. Thesis, University of Maine.
- Kantola, A.T., and Humphry, S.R. 1990. Habitat use by Sherman's fox squirrel (*Sciurus niger* Sherman) in Florida. *Journal of Mammalogy* 71: 411-419.
- Macdonald D.W. 1983. The ecology of carnivore social behavior. *Nature* 301: 379-384.
- McClellan, S.A., Rumble, M.A., King, R.M., and Baker, W.L. 1998. Evaluation of resource selection methods with different definitions of availability. *Journal of Wildlife Management* 62(2): 793-801.
- Miller, R.G., Jr. 1981. Simultaneous statistical inference. Second edition. Springer-Verlag, New York, New York, USA.
- Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. *American Midland Naturalist* 37:223-249.
- Neu, C.W., Byers, C.R., and Peek, J.M. 1974. A technique for analysis of utilization availability data. *Journal of Wildlife Management* 38(3): 541-545.
- Naef-Daenzer, B. 1993. A new transmitter for small animals and enhanced methods of

- home-range analysis. *Journal of Wildlife Management* 57(4): 680-689.
- Ostro, L.E.T., Young, T.P., Silver, S.C., and Koontz, F.W. 1999. A geographic information system method for estimating home range size. *Journal of Wildlife Management* 63(2): 748-755.
- Oldfield, B., and J.J. Moriarty. 1994. *Amphibians and Reptiles Native to Minnesota*. Minneapolis: University of Minnesota Press, 237 pp.
- Pappas, M.J. and Brecke, B.J. 1992. Habitat selection of juvenile Blanding's turtles (*Emydoidea blandingii*) *Journal of Herpetology* 26:233-234.
- Pappas, M.J., Brecke, B.J., and Congdon, J.D. 2000. The Blanding's turtles (*Emydoidea blandingii*) of Weaver Dunes, Minnesota. *Chelonian Conservation and Biology* 3(4):557-568.
- Pettit, K.E., Bishop, C.A., and Brooks, R.J. 1995. Home range and movements of the common snapping turtle, *Chelydra serpentina serpentina*, in a coastal wetland of Hamilton Harbour, Lake Ontario, Canada. *Canadian Field-Naturalist* 109: 192-200.
- Pieprgras, S.A. 1998. Summer and seasonal movements and habitats, home ranges and buffer zones of a central Minnesota population of Blanding's turtles. M.S. Thesis, University of North Dakota.
- Pieprgras, S.A. and Lang, J.W. 2000. Spatial ecology of Blanding's turtle in central Minnesota. *Chelonian Conservation and Biology* 3:589-601.
- Ross, D.A. and Anderson, R.K. 1990. Habitat use, movements, and nesting of *Emydoidea blandingii* in central Wisconsin. *Journal of Herpetology* 24: 6-12.
- Rowe, J.W. 1987. Seasonal and daily activity in a population of Blanding's turtles (*Emydoidea blandingii*) in northern Illinois. M.S. Thesis, Eastern Illinois University.
- Rowe, J.W. and Moll, E.O. 1991. A radiotelemetric study of activity and movements of the Blanding's turtle (*Emydoidea blandingii*) in northeastern Illinois. *Journal of Herpetology* 25: 178
- 185.
- Samuel, M.D. and Kenow, K.P. 1992. Evaluating habitat selection with radiotelemetry triangulation error. *Journal of Wildlife Management* 56(4): 725-734.
- Sajwaj, T.D., Pieprgras, S.A., and Lang, J.W. 1998. Blanding's turtles (*Emydoidea blandingii*) at Camp Ripley: critical habitats, population status, and management guidelines. Final report to the MN DNR Brainerd and Camp Ripley Environmental Office, Little Falls, Minnesota, 190 pp.
- Sajwaj, T.D. and Lang, J.W. 2000. Thermal ecology of Blanding's turtle in central Minnesota. *Chelonian Conservation and Biology* 3(4): 626-636.
- Sauer, T.M., Ben-David, M., and Bowyer, R.T. 1999. A new application of the adaptive kernel method: estimating linear home ranges of River Otters, *Lutra canadensis*. *Canadian Field-Naturalist* 113 (3):419-424.
- Seaman, D.E., Millsbaugh, J.J., Kernohan, B.J., Brundige, G.C., Raedeke, K.J., and Gitzen, R.A. 1999. Effects of sample size on kernel home range estimates. *Journal of Wildlife Management* 63(2): 739-747.
- Sherry, T.W., and Holmes, R.T. 1996. Winter habitat quality, population limitation, and conservation of neotropical-nearctic migrant birds. *Ecology* 77: 36-48.
- Silverman, B.W. 1986. *Density estimation for statistics and data analysis*. Chapman and Hall, London, UK.
- Thomas, D.L. and Taylor, E.J. 1990. Study designs and tests for comparing resource use and availability. *Journal of Wildlife Management* 54(2): 322-330.
- Vogt, R.C. 1981. *Natural History of Amphibians and Reptiles of Wisconsin*. Milwaukee Public Museum, Wis. 205pp.
- Voigts, D.K. 1976. Aquatic invertebrate abundance in relation to changing marsh vegetation. *The American Midland Naturalist* 95: 313-322.
- Wisconsin Endangered and Threatened Species Laws and List. Wisconsin Department of Natural Resources, Bureau of Endangered Resources. Publication No.

ER-001 1997rev. 4pp.

Worton, BT 1989. Kernel methods for estimating the utilization distribution in home range studies. *Ecology* 70:164-168.

Worton, B.J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. *Journal of Wildlife Management* 59: 794-800.