False map, spiny softshell and smooth softshell turtle nest and nest-site habitat characteristics along the lower stretch of the Missouri National Recreation River in South Dakota

BY

Laura A. Dixon

A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Biological Sciences

South Dakota State University

2009

False map, spiny softshell and smooth softshell turtle nest and nest-site habitat characteristics along the lower stretch of the Missouri National Recreation River in South Dakota

This thesis is approved as a creditable and independent investigation by a candidate for the Masters of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Charles D. Dieter 9/15/09

Dr. Charles Dieter Date
Thesis Advisor

9/15/09

Dr. Thomas Cheesbrough Date
Head, Biology/Microbiology

Dedicated To

Kevin M. Honness

1962-2008

Your belief in me and love is what got me through.

“Data, data, data”

Acknowledgments

I would like to thank South Dakota Game, Fish, and Parks for the State Wildlife Grant (T-20, study number 2441) and U.S. Fish and Wildlife Service for the funds to conduct this project. Thank you to the South Dakota State University Graduate School and Biology and Microbiology Department for financial support through travel grants.

I would also like to extend my deepest gratitude to my thesis advisor, Dr. Charles Dieter. Thank you for tolerating me for7 ½ years! To my committee members, Dr. K.C. Jensen (you've been a major support and a great ear for 4 years!) and Dr. Nels Troelstrup (Thanks Chief!) and Dr. Michael Ropp. A BIG thank you to Dr. Jonathan Jenks for all of your help with my statistical analysis and advice and to Dr. Mirela Tulbure for the help with the spatial analysis! A very special THANK YOU to Dr. Fredric (Fred) Janzen; I wouldn't know the majority of what I do about turtles if it wasn't for your mentoring!

I would like to thank Alyssa Kiesow; without your foresight this project would have never happened. To Silka Kempema (South Dakota Game, Fish & Parks Wildlife Diversity), thank you for your patience through this whole process! Thanks a million times over to Colin Dovichin (USGS) and his crew. Without your logistical support and boat training, I don't think any of the data would have been collected, and we may have drowned! Thanks to Galen Jons (USACE), Gene Bormann and the rest of their crew for also helping me get out to sandbars. Many thanks to Stephan Wilson (NPS) for your help and suggestions!

For the invaluable help in the field; Liz Hanson (Dennis, Bertha and Gorgeous

too!) and Andrew Kopp (no, I don't hate you!). I would also like to thank the SDSU Biology and Microbiology Department for their support; Kendra Hill, Dr. Scott Pederson, Dr. Thomas Cheesbourgh, Andrew Ellis, Dr. Jerry Krueger, Dr. Paul Johnson and Vickie Molengraaf.

A very big thank you is due to all the graduate students I have had a chance to get to know during my time in grad school; Matt Bahm, Nathan Baker, Nick Docken, Kris Dozark, Mark Fincel, Emily Fischer, Cari-Ann Hayer, Ashley Hitt, Mellissa Hough, Mitch Greer, Jen Gutscher-Chutz, Katie Herman-Brunson, Dr. Jeff Jolley, Nick Kaczor, Jessica Lee, Troy Radtke, Narayana Raj, Steve Ranney, Eric Rassmussen, Madeline Schickel, Josh Smith, Brian Spindler, Dan'squishy-squishy' Thompson, Ross VanderVorste and Mellissa Wuellner. Your support and friendship has gotten me through a lot of different things over the years!

I would also like to thank Anita Dixon-Dueis (female parental unit; yes you will always need a new brain!) and Dean Dixon (I know this isn't a singing card or a t-shirt, but I hope it's just as impressive!) for their unconditional love and support through the 26 years it took me to get here, I love you! I would also like to extend my love and thanks to the Loveless/Honness family for loving me like one of their own, and as Pam would say "Having a special place for me in their hearts". I have a VERY special place for you in my heart! Also to the Read's; you are the best other family a girl could hope for!

And lastly, but definitely not least, to my best friends; Dottie Barnes, Dr. Liz Boos, Leslie Cooper, Brittany Henry, Roxy Larsen, Alicia Roesler, Carly Wettlaufer, and

Soliel ‘Kyla’ Wood. You have all been there for me and there is no way I will ever be able to express my thanks! My friends are going to save the world!

Abstract

False map, spiny softshell and smooth softshell turtle nest and nest-site habitat characteristics along the lower stretch of the Missouri National Recreation River in South Dakota

Laura A. Dixon

March 2009

Little is known about the ecology and reproductive habits of turtles in South Dakota. The spiny softshell (*Apalone spinifera*) and smooth softshell (*A. mutica*) are listed as species of concern in South Dakota and the false map turtle (*Graptemys pseudographica*) is listed as state threatened. Information relating to habitat and nest site characteristics is needed to form sound management plans.

Surveys were conducted for turtle nests along the Missouri National Recreation River from just above Lewis and Clark Lake (river mile (RM) 835) to Ponca State Park (RM 753) in 2006 and 2007. Turtle nests were located by walking shorelines and sandbars while searching for tracks, scrapes and nesting turtles. Once located, each nest was identified to genus and recorded on global positioning system (GPS). Nest characteristics taken were number of eggs, egg size, depth to top egg in nest, and distance from water. To determine habitat variables female turtles were selecting for, I examined nest site, on-site location and off-site location land cover classification and habitat

vegetation variables including type, height, and percent cover. Substrate composition and debris were also assessed.

Turtles were first observed nesting in 2006 on 6 June and nesting continued until 23 July 2006. During 2007 the first nest was found on 28 May and the last nest located was 28 June. In 2007, 230.5 hours were spent searching sandbars resulting in a detection rate of one nest every 5.5 hours. I found 17 false map and 45 softshell nests intact and excavated them for measurements.

The mean number of eggs in an *Apalone* sp. clutch was 14.61, mean egg diameter was 23.97 mm, and mean depth to the top egg was 9.09 cm. The mean number of eggs in a *G. pseudogeographica* nest was 10.5, mean egg width was 23.16 mm, mean length was 34.42 mm + 0.210 and the mean depth to the top egg was 9.95 cm. The mean straight line distance to water traveled by nesting *Apalone* sp. was 61.27 m and the mean straight line distance to water traveled by nesting *G. pseudogeographica* was 54.24 m. There was no difference in straight line distance to water between *Apalone* sp. and *G. pseudogeographica* ($p = 0.552$, $t = 0.601$, $df = 36.47$).

There was a difference between slopes of man-made sandbars and natural sandbars ($p = 0.003$, $t = -3.699$, $df = 13.35$). When the mean slope of a sandbar was compared to the mean straight line distance from nest to water on the same sandbar *Apalone* sp. had a R^2 value of 0.1487 ($n = 13$) and *G. pseudogeographica* had an R^2 value of 0.2471 ($n = 7$).

In 2007, the depredation rate of monitored nests was 36%. There was no depredation of nests on the man-made sandbars. Straight line distance to the water and

habitat characteristics at the nest site had no effect on nest depredation rates of located nests. I found 184 depredated nests (175 *Apalone* sp. and nine *G. pseudogeographica*).

Apalone sp. nested exclusively in bare sandy areas while *G. pseudogeographica* tolerated sparse vegetation around the nest site. A nest-site selection model was constructed using a matched-pair stepwise logistic regression at the off-site level for *Apalone* sp. using the habitat variables that had a difference ($p \leq 0.05$) between the nest site and the off-site. The habitat variables used included: terrestrial herbaceous vegetation ($p = 0.046$), woody vegetation ($p = 0.008$), woody vegetation stem number ($p = 0.020$), mean vegetation height ($p = 0.032$), max vegetation height ($p = 0.025$) and leaf debris ($p = 0.046$). The final calculated model included max vegetation height and leaf debris ($p = 0.007$, McFadden $Rho^2 = 0.123$). A habitat nest-site selection model could not be constructed for *Apalone* sp. at the on-site level or for *G. pseudogeographica* at either the on-site or off-site level because there were no differences between habitat variables. Spatial analyses of the depredated nests at RM 804.5 suggest those turtle nests are clustered in bare open sand. Three *Apalone* sp. nests hatched before surveys were completed in 2007. Based on this data, an estimate incubation length for *Apalone* sp. turtles was 70-71 days. Vegetation surrounding the nest site may have decreased incubation length by causing an increase in nest cavity temperature.

Both *Apalone* sp. and *G. pseudogeographica* utilize natural and man-made sandbar habitat for nesting. However, natural nesting beaches are being reduced at a rapid pace, and man-made sandbars may not provide the most ideal conditions for hatchlings and adult turtles. Turtle populations along the Missouri National Recreation

River are at risk for further decrease if management and conservation efforts are not focused on providing quality nesting habitat.

Table of Contents

Abstract vii

List of Tables xiv

List of Figures xv

Literature Review 1

Introduction 1

Distribution 1

Life history 2

Nest site selection 5

Nest site characteristics 8

Hatchling emergence 9

Depredation 10

Man-made sandbars 11

South Dakota riverine turtle demographics 12

Justification of study 13

Methods 15

Study area 15

Surveys 16

Excavations 18

Habitat 18

Statistical analysis 22

Spatial analysis 24

Results....26
Number of nests located....26
Length of nesting season....26
Estimated number of nests....27
Nest cavity characteristics....29
Distance traveled from water to nest site....36
Nest mortality....41
Depredation....41
Flooding....41
Incubation length....44
Nest site selection....44
Sandbar....44
Man-made vs. natural sandbars....45
Habitat characteristics....45
Habitat model....48
Spatial analysis....50
Discussion....53
Length of nesting season....53
Number of nest located....53
Estimated number of nests....54
Nest cavity characteristics....54
Distance traveled from water to nest site....55

Nest mortality 56

Depredation.....56

Flooding 58

Incubation length 59

Nest site selection 60

Sandbar 60

Man-made vs. natural sandbars.....60

Habitat characteristics.....61

Habitat model.....63

Apalone sp.....63

G. pseudogeographica 64

Spatial analysis.....64

Management Implications.....66

Introduction.....66

Depredation.....67

Habitat management 68

Future recommendations.....70

Literature cited.....72

Appendix.....78

Location of nest on individual sandbars 78

List of Tables

Table Page

1 Land cover classes used to compare habitat compositions near turtle nests found on sandbars along the Missouri National Recreational River.....21

2 Daubenmire classification used to measure vegetation variables along the Missouri National Recreation River 23

3 Classes used to measure height of vegetation near turtle nests found on sandbars along the Missouri National Recreational River.....23

4 Nest site characteristics for *Apalone* sp. during 2006 and 2007 31

5 Nest site characteristics for *G. pseudogeographica* during 2006 and 2007 33

6 T-test of habitat characteristics around the nest site between predated and intact nest in 2007 42

7 Mean and standard error of the mean (S.E.M.) of habitat characteristics around the nest site between predated and intact nest in 2007 43

8 Mean and standard error of mean (S.E.M) of habitat characteristics around the nest site, on-site site and off-site for *Apalone* sp. in 2007 47

9 Mean and standard error of mean (S.E.M) of habitat characteristics around the nest site, on-site and off-site for *G. pseudogeographica* in 2007 49

List of Figures

Figure Page

1 Map of location of the survey area in South Dakota 17

2 The 1m x 1m quadrant used to assess vegetation at turtle nest sites in 2007 20

3 Length of nesting season and number of nests per week for *Apalone* sp. and *G. pseudogeographica* during the 2007 nesting season 28

4 Distribution of clutch size for *Apalone* sp. nests during 2006 and 2007 30

5 Distribution of clutch size for *G. pseudogeographica* nests during 2006 and 2007.....32

6 Mean number of *Apalone* sp. eggs per clutch per week during the 2007 nesting season. 34

7 Mean number of *G. pseudogeographica* eggs per clutch per week during the 2007 nesting season 35

8 Distribution of the straight line distance (m) from nest site to water for *Apalone* sp. in 2006 and 2007 37

9 Distribution of the traight line distance (m) from nest site to water for *G. pseudogeographica* nests in 2006 and 2007 38

10 Linear regression of average distances (m) traveled per sandbar by nesting *Apalone* sp. females versus average slope per sandbar that were used for nesting in 2007. 39

11 Linear regression of average distances (m) traveled per sandbar by nesting *G. pseudogeographica* females versus average slope per sandbar used for nesting in 2007 40

12 Density of *Apalone* sp. nests (number of nests per meter) on sandbar RM 804.5 51

13 Univariate Ripley's Lhat statistic (black line) for predated softshell nests, with 90% confidence envelopes (blue and green lines) generated from 999 simulations under a null model of complete spatial randomness (CSR).....52

Literature Review

Introduction

Throughout the world, turtle populations that rely on rivers are in decline, with softshell turtles (Trionychidae) facing the greatest risk of extinction (Ernst et al.1994, DonnerWright et al. 1999, Bodie 2001). This decline has been attributed to river degradation and unregulated turtle harvest. However, little research has been conducted because of the difficulty in surveying larger river systems (Moll and Moll 2000).

In South Dakota, little is known about the ecology and reproductive habits of turtle populations with no major research done in the last 40 years since Timken's study in 1968. The three species of turtles of greatest concern in the state are the spiny softshell (*Apalone spinifera*), smooth softshell (*A. mutica*) and false map turtle (*Graptemys pseudogeographica*) (Stukel *et al*. 2006). Today, *G. pseudogeographica* is listed as state threatened and both *A. mutica* and *A. spinifera* are listed as species of concern because of putatively reduced populations. In South Dakota, all three species can be found in the Missouri River and its tributaries (Timken 1968, Bandas 2003, Kiesow 2006). Declines in the populations of these turtles are thought to be a result of habitat loss along the Missouri River due to human exploitation. Timken (1968) noted that all three species of turtles were found in relatively high numbers along the lower stretch of Missouri river.

Distribution

There are six subspecies of *A. spinifera* (LeSueur 1827) found in rivers throughout the central, eastern and southern United States as well as in Montana. In

South Dakota, the recognized subspecies is *A. s. spinifera* (McGaugh et al. 2008). There are two subspecies of *A. mutica* (LeSueur 1827) which can also be found in rivers throughout the central and southern United States. *A. m. mutica* is the subspecies recognized in South Dakota. *A. spinifera* and *A. mutica* are sympatric throughout the majority of their range in the United States and are two of the three species in the genus *Apalone* that are found in North America (Conant and Collins 1998,).

G. pseudogeographica (Gray 1831) is part of Emydidae, the most populous turtle family found in North America. *G. pseudogeographica* can be found throughout the southern United States and in the Missouri River into North Dakota and in the Mississippi River into Minnesota. There are three subspecies of *G. pseudogeographica* in the United States. In South Dakota the recognized subspecies is *G. p. pseudogeographica* (Conant and Collins 1998).

Life history

Turtles have a life cycle characterized by slow sexual maturity and long life, which can often make it difficult to gather complete life history characteristics (Congdon et al. 1983). Turtle populations are generally characterized as having low survivorship from hatching through the first year of life (Packard et al. 1987, Congdon et al. 1994). However, they are a long-lived and have high fecundity allowing them to remain relatively stable in the absence of unusual events (Bolton and Brooks 2007).

As latitude increases, the length of turtle nesting seasons decrease (Moll 1973, Congdon and Gibbons 1990, Doody 1995) and as length of season decreases, clutch

frequency decreases (Gibbons and Greene 1990). Some researchers have found a positive correlation between female body size and clutch size, especially in northern populations (Webb 1962). However, other researchers have not observed this relationship (Cagle 1954, Gibbons and Tinkle 1969, Tinkle et al. 1981, Frazer and Richardson 1986). Gibbons and Greene (1990) suggest two hypotheses as to why they found no relationship between body size and clutch size: (1) that larger females have larger eggs and that causes a limit on the number of eggs that can be carried and (2) there is an upper limit to the amount of resource that a female turtle can put towards a clutch.

As in most turtle species, males of *A. spinifera*, *A. mutica* and *G. pseudogeographica* reach sexual maturity at a smaller size and younger age than females. Male *A. spinifera* become sexually mature between four to six years of age (Ernst et al. 1994) and females become sexually mature at approximately age eight (Vogt 1980). Male *A. mutica* reach sexual maturity at four years of age and females reach sexual maturity at age six (Plummer 1977a). Male *G. pseudogeographica* become sexually mature between four to six years of age and females reach sexual maturity at approximately 8 years of age (Vogt 1980).

G. pseudogeographica and *Apalone* sp. reproductive cycles vary based on geographical climate conditions and photoperiod (Porter 1972). In South Dakota, the reproductive cycle for females begins after emergence from hibernation in the spring. After emerging from hibernation, females must gather resources necessary to produce the amniotic fluid, yolk and shell of the eggs (Timken 1968, Ernst et al. 1994).

The number of immature ova in females is highest in spring (April-May) and then drastically decreases during the laying season (mid May until the end of June). Mid-spring is also when ovulation and mating occur. Copulation occurs in the water with the male approaching the female from behind (Ernst et al. 1994). Female turtles have the ability to store sperm allowing for fertilization of multiple clutches by one mate (Orenstein 2001). After nesting is completed in July, numbers of immature ova increase before hibernation (Timken 1968, Plummer 1977a, Robinson and Murphy 1978).

In males, the reproductive cycle begins in the late summer when testes size increase. Sperm production occurs in the fall to insure viable sperm are available during ovulation in the spring and is stored while the male is hibernating (Orenstein 2001). In the spring, testes size decreases; however, live sperm are present in the testes until July when mating ends (Timken 1968, Plummer 1977a).

Apalone sp. and *G. pseudogeographica* in their northern range can produce a maximum of two clutches per nesting season (Timken 1968, Plummer 1976b, Graham and Graham 1997). However, nesting *Apalone* sp. have been known to split a clutch between two nest cavities (Fitch and Plummer 1976b, Doody 1995). Turtles in their northern ranges produce a maximum of two clutches per year because of shorter summers; females are unable to gather the resources needed to lay three clutches and survive hibernations. In addition, clutches laid in late summer would not have time to develop and hatch before winter (Moll 1973).

Nest site selection

Nest site selection is non-random and sites are chosen by a nesting female based on particular microhabitat characteristics. Nest location can have a great influence over the microclimate and therefore incubation conditions within the nest (Burger 1976, Burger 1977, Janzen 1994, Kolbe and Janzen 2001). Incubation conditions (gas exchange, water exchange and temperature) influence many hatchling phenotypic traits including hatchling sex, size, developmental rate, growth rate, locomotor behavior, and thermoregulation behavior (Schwarzkopf and Brooks 1987, Packard and Packard 1988a, Packard 1991, Kolbe and Janzen 2001, 2002). Nest site selection thus affects hatchling phenotype and fitness (Doody 1995, Hughes and Brooks 2006).

Microhabitat conditions at nest sites are one of the least understood areas of turtle ecology in South Dakota and are an important factor in the conservation of turtles. Microhabitat characteristics including soil type, soil moisture, distance from water, exposure to sunlight and vegetative cover (Packard 1999, Kolbe and Janzen 2001, 2002) are important factors for nest site selection (Wood and Bjorndal 2000). Nesting habitat influences incubation, how successful hatchlings will be at reaching the water, and probability of depredation (Kolbe and Janzen 2001).

G. pseudogeographica and *Apalone* sp. prefer sandy substrates (void of much vegetation) for nesting, typically choosing the highest areas on sandbars to construct nests (Plummer 1976b). However, when areas free of vegetation are not available, nesting *Apalone* sp. females have been known to crawl through dense vegetation to reach

open areas for nesting (Fitch and Plummer 1977b, Plummer 1976b, Ernst et al. 1994, Doody 1995, Riley et al 2005).

Vegetative cover is a variable presumably assessed by female turtles when selecting nest sites (Janzen 1994). Vegetation around a nest affects nest/incubation temperature. Nests closer to vegetation are cooler than those in open sand (Vogt and Bull 1984, Wilson 1998, Kolbe and Janzen 2002). For example, snapping turtle (*Chelydra serpentina*) nests in Illinois that were located in grassy patches had a mean temperature 2ºC lower then those nests located in open sand (Kolbe and Janzen 2002). Vegetation close to the nest site of *Apalone* sp. can be harmful because even though they possess genotypic sex determination, they require a relatively high temperature for development (Vogt 1980, Ewert and Nelson 1991). If the incubation temperature is too low, eggs will develop slowly (affecting chance of survival after hatching) or may not develop at all (Janzen 1993). In Louisiana, both *A. mutica* and *A. spinifera* chose areas with no shading during daylight hours as nest locations more than 90% of the time (Doody 1995). Nests from the same *A. mutica* and *A. spinifera* population in Louisiana that were located in shaded areas experienced longer incubation times (Doody 1995).

G. pseudogeographica females prefer open sandy habitat, but will nest in open sandy patches in vegetation. *G. pseudogeographica* have temperature-dependent sex determination and vegetation close to nest sites lowers temperature and alters sex ratios (Vogt and Bull 1982, Ewert and Nelson 1991, Janzen 1993). Deviating from a 1:1 sex ratio in hatchlings causes bias that can affect population dynamics (Kolbe and Janzen

2002). Therefore, incubation temperature requirements can have profound influence on turtle population demographics.

Vegetation surrounding the nest site also influences hatchling survival by determining their path to the water. Hatchlings from nests in areas with little to no vegetation and lower slopes have an advantage in reaching the water over those from nests that are in vegetation or on steep slopes (Kolbe and Janzen 2001, 2002).

Nesting females may further affect incubation temperatures by altering the depth of the nest (Burger 1977, Doody 1995, Bodie and Smith 1996). The amount of exposure the nest receives from the sun has the greatest effect on nest temperature. However, the depth of nest and subsequently location of eggs in the nest can affect incubation of eggs (Morjan 2003).

Substrate moisture can influence the incubation success of turtles with flexible-shelled eggs such as *G. pseudogeographica*. Eggs incubated in cool, moist microclimates produce embryos that are larger at hatching then those in warmer, dry conditions (Packard et al. 1987, Cagle et al. 1993). Large hatchlings may have a greater chance of survival than smaller hatchlings (Janzen 1993, Janzen et al. 1995). *Apalone* sp. have rigid-shelled eggs which are not as susceptible to water loss during incubation. Therefore, mass of hatchlings is not usually affected (Packard et al. 1981). However, incubation temperature does affect body size of hatchlings and incubation length (Janzen 1993).

The location of a nest on a sandbar is an important factor in nest and hatchling success. When a nest is located far from water, hatchlings are forced to travel farther to

reach water. This lengthier travel increases the risk of predation, desiccation, and causes an increase in energy expenditure (Congdon et al. 1983). Female *Apalone* sp. have been shown to select nest sites on sandbars that are close to water (Fitch and Plummer 1977b, Plummer 1976b). However, distance from water may be related to the height of the nest above water level because higher areas are less likely to flood. Selecting height above water rather than distance from water may have evolved as a response to the frequent flooding of river systems during oviposition. Doody (1995) found that female *Apalone* sp. selected sandbars of higher elevation for nesting and suggested that height above water is more important than distance from water since it was the only variable contributing to nest survivorship.

Apalone sp. tend to nest during the day and the process lasts approximately an hour (Doody 1995). *A. spinifera* in Ontario spend a good deal of time on the sandbar testing the sand and digging test holes when selecting a nest site (Bolton and Brooks 2007). *Apalone* sp. are vigorous diggers throwing sand several meters in the air while excavating a cavity (Plummer 1976b, Daigle et al. 2002, Bolton and Brooks 2007). Nesting activity tends to increase on days after rainfall events (Bolton and Brooks 2007). In Louisiana, *Apalone* sp. rarely nested on overcast or rainy days (Doody 1995).

Nest site characteristics

Apalone sp. have a relatively short incubation period compared to other turtles (Janzen 1993). This short period could be advantageous, allowing more time for hatchings to prepare for hibernation and reducing the chances of having the nest flooded.

Incubation length is greatly influenced by temperature; as temperature decreases, the number of days to hatching increases exponentially (Janzen 1993). Incubation temperature is probably more important than moisture for *Apalone* sp. hatchlings (Janzen 1993). *Apalone* sp. hatchling size also seems to differ greatly between clutches, suggesting that a genetic difference among individuals also plays a role in determining hatchling size (Janzen 1993).

The minimum incubation temperature for *Apalone* sp. eggs is 26ºC. However, incubation temperatures rarely fall below 26ºC in bare sand, so a tolerance to high incubation temperatures is more likely than a low tolerance (Janzen 1993). *A. mutica* turtles only use approximately 25% of the yolk lipids in the egg for embryo development. The remaining 75% is stored by the hatchling in yolk reserves for post-hatching survival until the individual can obtain enough energy through foraging (Kraemer and Bennett 1981, Congdon and Gibbons 1990, Fischer et al. 1991, Nagle et al. 2003).

G. pseudogeographica eggs are considered to have a flexible shell. During incubation, flexible-shelled eggs absorb or lose water depending on the hydric conditions of the substrate (Packard and Packard 1988b). However, there is little difference in nest or hatchling success between nests in moist substrates to those in dry substrates (Janzen et al. 1995).

Hatchling emergence

Emergence of turtle hatchlings from the nest cavity begins in mid-August and lasts through September (Plummer 1976b). There is debate as to whether *G.*

pseudogeographica in its northern range overwinters in the nest cavity. A Mississippi River population of *G. pseudogeographica* in Wisconsin showed no evidence of nest site overwintering (Vogt 1980). Hatchlings of many species emerge synchronously at sunset and dispersal from the nest is synchronous (Anderson 1958, Whitherington et al. 1990, Gyuris 1993). Doody (1995) reported *Apalone* sp. hatchling emergence was spread over several days. It is beneficial for hatchlings to leave the nest at sunset because sand temperatures are decreasing and predators may not yet be active. Once hatchlings reach the surface, they maintain a brisk pace towards water although some hatchlings go the opposite direction of the water and eventually die from desiccation or predation (Anderson 1958, Plummer 1976b, Plummer 2007). Many turtle populations are characterized by high mortality during the first year of life (Kolbe and Janzen 2001). Factors contributing to this high mortality are hatchling size (Gibbons and Semlitsch 1982, Iverson 1991) and predation (Kolbe and Janzen 2001, Plummer 2007).

Hatchlings have a relatively short amount of time to grow and obtain resources needed for survival before hibernation. Those that hatch in August have time to grow, while those hatching in late September have little time to grow before hibernation. This factor may affect over winter survival and success the following year (Plummer 1976b).

Depredation

Depredation is a leading cause of egg mortality and in some cases is responsible for 100% of nest failures (Congdon et al. 1987, Horne et al. 2003, Marchand and Litvaitis 2004). Known turtle nest predators include coyotes (*Canis latrans*), red fox (*Vulpes*

vulpes), mink (*Neovison vison*), skunks (*Mephitis mephitis*), opossums (*Didelphis virginiana*) and raccoon (*Procyon lotor*) are known to depredate nests in other areas (Marchand and Litvaitis 2004). Timken (1968) noted several areas along the Missouri River in South Dakota that had high depredation rates and recorded a beach with over 100 nests destroyed in one night. Factors that lead to high nest depredation are the number of generalist predators as well as high turtle nest densities. As appropriate nesting sites decline, turtles are forced to nest in higher densities making it easier for predators to locate and depredate nests (Marchand and Litvaitis 2004). The effects of predators should be considered when trying to stabilize or restore declining turtle populations (Marchand and Litvaitis 2004).

Man-made sandbars

Water levels on the Missouri River are controlled by the U.S. Army Corps of Engineers (USACE) to meet agricultural, electrical and navigational needs (USACE 2004). Water flows in the Missouri National Recreation River (MNRR) stretch of the Missouri River are controlled by discharge out of Gavins Point Dam and Fort Randall Dam, which has a great effect on the acreage of sandbars that are available as nesting habitat. The controlled release of water erodes sandbars; however, it rarely creates new ones or scours off vegetation. Thus, the erosion rate of sandbars is higher than the creation of sandbars in this reach of river (USACE 2004). Chanalization, impoundment, and flow regulations have also caused a reduction in the number of sandbars in the river (Bodie 2001).

In an effort to increase sandbar habitat for piping plover (*Charadrius melodus*) and least tern (*Sternula antillarum*) nesting habitat, the USACE has begun to build sandbars by mechanical means. A 2004 environmental assessment noted that turtles would benefit from the creation of sandbars. During a study conducted in 2003 (South Dakota Game, Fish & Parks, unpublished data), three *Apalone* sp. nests were located in the area of the proposed sandbars at RM 770 (Doug Backlund; personal communication, USACE 2004).

South Dakota riverine turtle demographics

Timken's (1968) study of South Dakota turtles produced the only known data on turtle nesting in South Dakota. He first found a nesting female *A. mutica* on 20 June, 1967. Between 24 June and 3 July of the same year he located freshly destroyed turtle nests. Peak nesting seemed to occur between 25 June and 5 July each year of the study, but Timken (1968) believed the season most likely began before then.

In South Dakota, male *A. mutica* are sexually mature when they reach a carapace length of 12 cm. Females are sexually mature when they reach 21cm in carapace length. *A. spinifera* males are sexually mature when they reach a carapace length of 13 cm and females are sexually mature at a carapace length of 29 cm. In both *Apalone* sp., testes of males start increasing in size in mid-June. Large females have a higher reproductive potential because they have more ovarian follicles and the potential to lay two clutches a year.

G. pseudogeographica males are sexually mature at 9-10 cm plastron length. Male testes increase in size from June until August. Females are sexually mature at plastron lengths of 18-19 cm. Large females had greater numbers of ovarian follicles (over 8 mm) and therefore increased reproductive potential over smaller females (Timken 1968). Females with a plastron length over 21cm also have the potential to lay two clutches a year. No female *G. pseudogeographica* with oviductal eggs were captured after June 30th. In early June, there was a steady decrease in the number of female *G. pseudogeographica* with large follicles with the sharpest decline occurring from mid June to mid July. An increase in number of follicles began in August (Timken 1968).

Timken (1968) reported that of the eight intact *A. mutica* nests located, all were in moist substrate. However, no measurements of the nest cavity were recorded. Timken (1968) also noted that all nests were located in large, bare, sandy areas free of vegetation, and that many nesting areas were inaccessible by females because of eroded banks. However, in areas where females could access the nesting beach, several nests were located. Nests were located as close as 3.04 m from the water and up to 91.44 m from water. The majority of the nests were found 15.24 m to 45.72 m from shore.

Justification of study

When efforts are being made to stabilize and manage declining populations of turtles, nesting habitat should be protected (Kolbe and Janzen 2002, Marchand and Litvaitis 2004). Timken (1968) speculated that even though there were a high number of adult females in the population, reproductive rates might be low as a result of few ideal

nesting areas and high depredations rates, which may lead to decreases in the population. Since Timken's study (1968) the available nesting sites for South Dakota's riverine turtles has continued to decrease. *G. pseudogeographica* has been listed as state threatened and both *Apalone* sp. have been listed as species of concern. In order to increase and adequately manage the turtle population along the Missouri River in South Dakota it is thus important to locate key areas of nesting habitat. Therefore, the three objectives of this study were:

1) To locate specific nesting areas for *A. spinifera*, *A. mutic*a and *G. pseudogeographica*.
2) To determine the characteristics of the nesting habitat of these species including soil type, distance from water, exposure to sunlight and vegetative cover.
3) To compare habitats being used by these species as nesting habitats to areas not being utilized for nesting.

Methods

Study area

The Missouri River is the longest river in the United States (4090 km) and drains approximately 17% of the North American continent (Galat et al. 1996). The river originates in Montana and flows into the Mississippi River at St. Louis, Missouri. Previous to human intervention, the Missouri River was known for being a wide, shallow, dynamic river that was difficult to navigate due to fallen trees and large sandbars that changed yearly. The river also flooded annually creating large sandbars and clearing others of vegetation (USACE 2004). The Flood Control Act of 1944 authorized the construction of six dams in the northern four states that the river runs through (one in Montana, one in North Dakota and four in South Dakota) for flood control, bank stabilization, navigation and irrigation. With the completion of the dams, annual flooding regimes were prevented which reduced the flooding and meandering that created sandbars and scoured other sandbars free of vegetation (USFWS 2000, USACE 2004). Today, the flow regime on the river is dictated by USACE. Water flow on the river is low from October to April, with a planned spring rise if water is available in May. Water flow is also increase to its greatest amount for downstream river navigation in July after piping plovers and least terns have fledged. However, there are daily increase and decrease in water flow based on navigation, electrical, irrigation and reservoir needs.

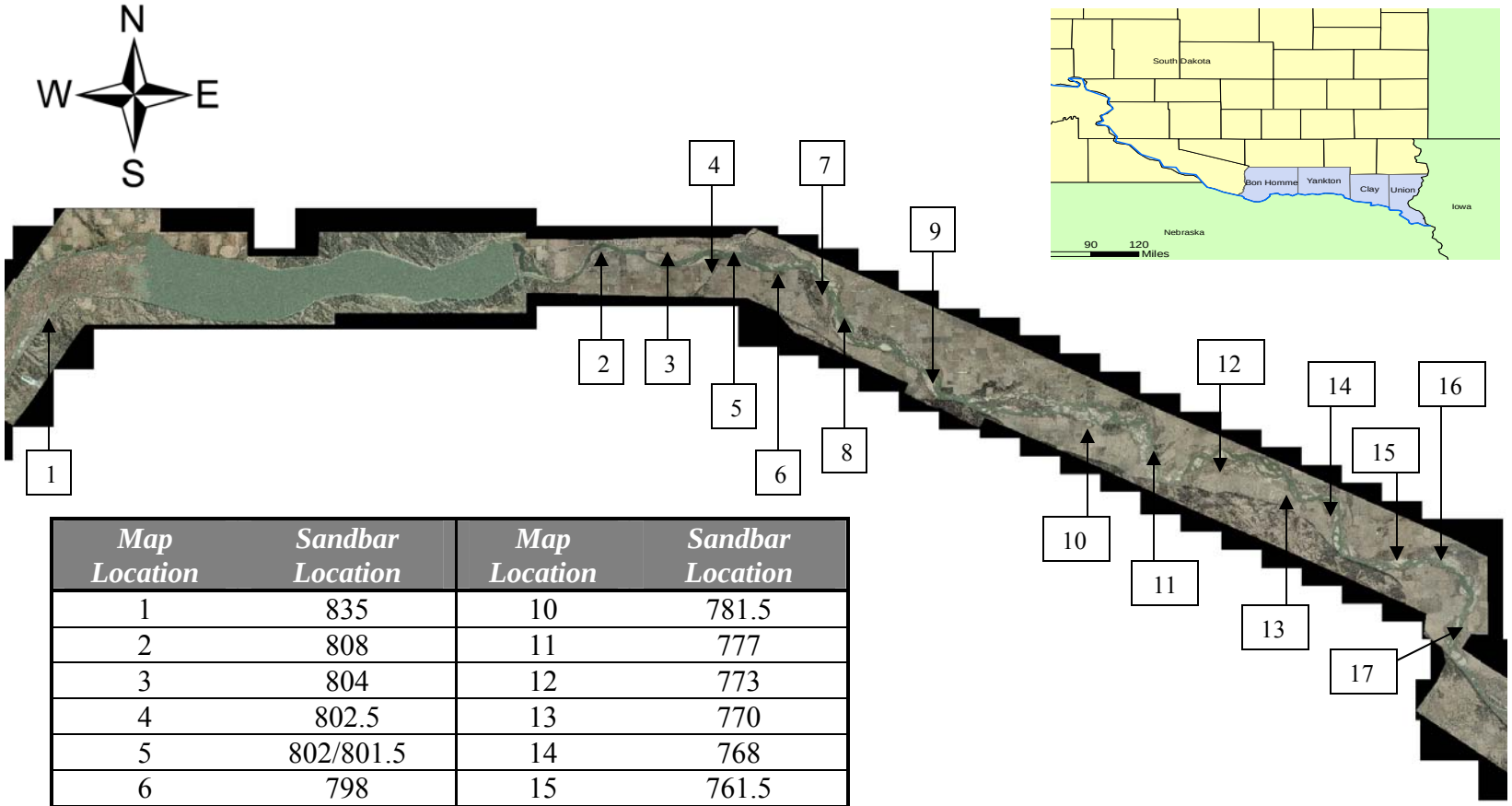
Along the portion of the MNRR that made up the study site, the gradient of the river is mostly level and sandbars are composed of Norway loamy fine sand (Cooley 2003). Average summer air temperature is 23.3ºC with an average high of 30.6ºC. The average winter temperature is -6.1ºC with an average low of -12.2ºC. Annual

precipitation is 63.5 cm with the majority of that falling between April and September. Snowfall averages 76.2 cm a year. Annual mean humidity is 60% (USACE 2004).

In 1978, 59 miles of the river from Gavins Point Dam to Ponca State Park in Nebraska were designated as the MNRR (USACE 2004). In 1991, an additional 39 mile stretch of river from Fort Randall Dam to Niobrara, Nebraska was added. These two stretches are the only remaining stretches of river that are considered free flowing and unchannelized. The lower 59 mile stretch of river supports approximately 44 species of plants and animals that are listed as federal and state endangered, threatened, or species of concern (USACE 2004).

Surveys

I surveyed for turtle nests starting on 22 May 2006 from river mile (RM) 880 to RM 753 and 14 May 2007 from RM 835 to RM 753 (Figure 1). Surveys continued until no new nests were located (Oldfield and Moriarty 1994, Bodie and Semlitsch 2000, Christiansen and Parmelee 2003, Riley et al. 2005). Nests were located by walking (from the shoreline to the vegetation line or in areas of bare sand) along sandbars and suitable shoreline looking for predated nests, tracks and scrapes, or by actually seeing turtles nesting (Kolbe and Janzen 2002, Christiansen and Parmelee 2003, Horne et al. 2003, Morjan 2003, Bolton and Brooks 2007). A recent nest site is often obvious because the sand is disturbed. Once a nest was located, I marked it using a Garmin 76Cx global positioning unit (GPS) unit so I could return to the nest for monitoring throughout the



Map Location	Sandbar Location	Map Location	Sandbar Location
1	835	10	781.5
2	808	11	777
3	804	12	773
4	802.5	13	770
5	802/801.5	14	768
6	798	15	761.5
7	796.6	16	756.5
8	795	17	755
9	788		

Figure 1. Study area and sandbar locations in South Dakota (where surveys for turtle nest were conducted) in 2006 and 2007. Counties in blue on the insert state map are where the river surveyed lies in South Dakota.

field season. For each nest, I recorded data on incubation period, nest success, and depredation rates were recorded.

Excavations

I excavated nests to identify the turtle species as evidenced by egg characteristics and to record physical characteristics of the nest. Identification of eggs was made to the species for *G. pseudogeographica*. However, because the shape and size of *A. spinifera* and *A. mutica* are similar, identification was made only to genus. I was careful to maintain egg orientation and location in the nest cavity to avoid terminating embryonic development (Bolton and Brooks 2007). Nest measurements taken included egg size (using calipers), number of eggs, depth and width of nest (cm), temperature of substrate, and straight line distance from water (100 m tape). After nest characteristics were measured, the nest was reconstructed and covered (Congdon et al. 1983, Bodie and Smith 1996, Kolbe and Janzen 2001, Christiansen and Parmelee 2003, Horne et al. 2003, Morjan 2003). Bank slope was measured during the 2007 field season using a clinometer to determine if there was any correlation between distance traveled on a sandbar and the slope of the sandbar.

Habitat

To determine habitat variables the nesting females were selecting for at the on-site and off-site landscape level, I measured aspects of vegetation, substrate, and debris to determine habitat at the nest site. Vegetation variables measured were land cover class,

percent terrestrial herbaceous cover, percent woody vegetation cover, woody stem number, mean vegetation height (m) and maximum vegetation height (m). Substrate characteristics measured were percent silt, percent sand, percent small pebble, percent gravel, percent cobble, and percent boulder. Debris measured was percent leaf litter cover, percent wrack (debris < 2 cm in length) and percent large debris (debris > 2cm in length) (Sherfy et al. 2008). Percent exposure to sunlight during daylight was determined by a visual estimation based on the amount of vegetation surrounding the nest site.

To measure variables I used a 1m x 1m quadrat was placed around the nest with the nest site located at the center (Figure 2). The center of a quadrat was also placed in the four cardinal directions at a distance of three meters (on-site level) from the nest site (Sherfy et al. 2008). I further compared the known nest sites to randomly chosen points (off-site level) within the same habitat to determine characteristics nesting females were selecting for (Wilson 1998, Kolbe and Janzen 2002), and to determine the difference between occupied and unoccupied nest sites. The random point was selected by spinning a pen for a direction and rolling dice for number of meters away from the nest site so that random points were located within the area accessible to nesting females.

Land cover class was determined for the entire quadrat. Land cover class was composed of seven different habitat compositions that can be found on sandbars (Table 1; Sherfy et al. 2008). A modified Daubenmire classification (Daubenmire 1968) was used to measure all variables except woody stem count and vegetation height. The Daubenmire classification was composed of seven classes using a percent cover range.

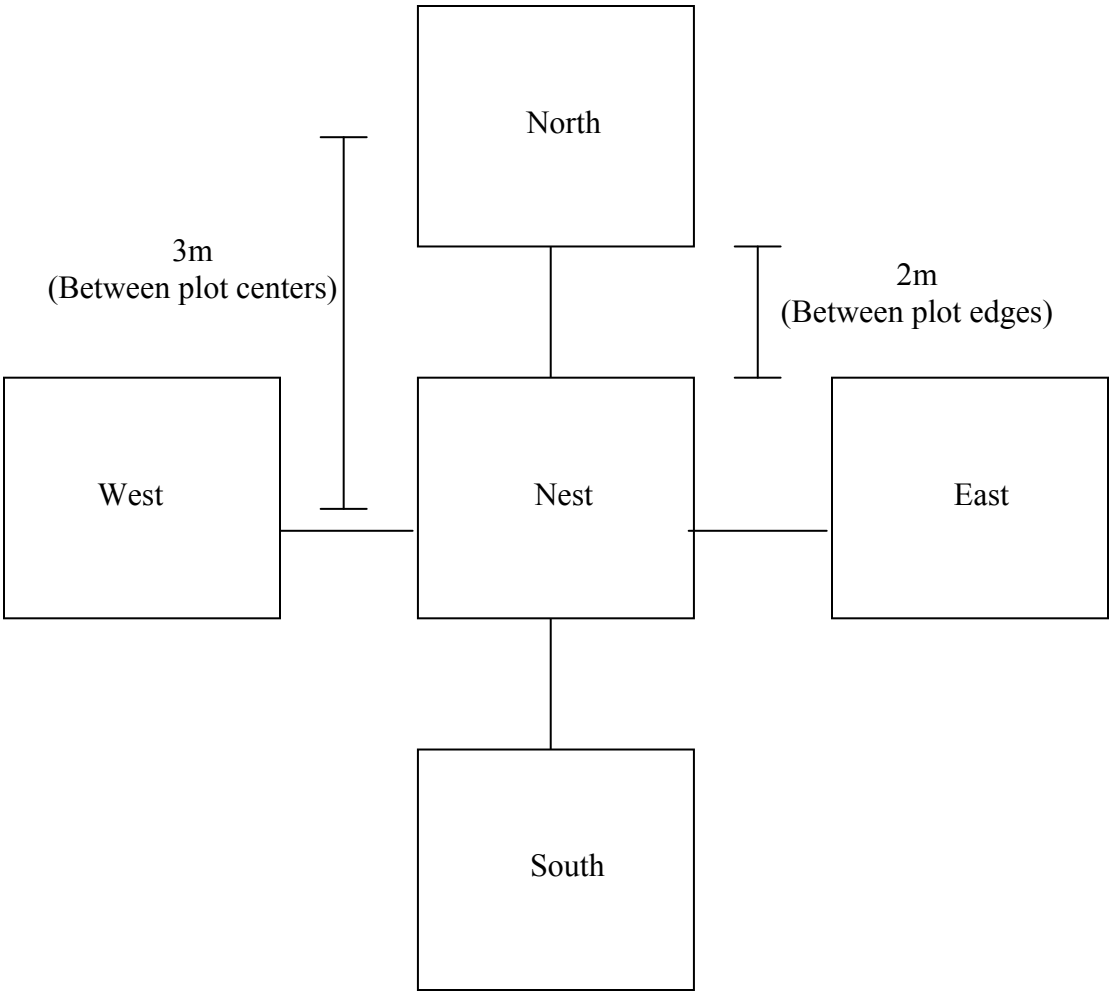


Figure 2. The 1m x 1m quardrat used to assess vegetation at turtle nest sites in 2007. The nest site was located at the center of the quardrat and the center of a quadrat was also place in the four cardinal directions at a distance is three meters from the nest site (Sherfy at al. 2008).

Table 1. Land cover classes used to compare habitat compositions near turtle nests found on sandbars along the Missouri National Recreational River (Sherfy et al. 2008).

Class	Cover type	Description
1	Dry sand	Sand substrate with no obvious moisture of vegetation
2	Wet sand	Areas of moist sand with little of no vegetation
3	Sparsely vegetated	Mostly sand substrate with 30-50% vegetation
4	Mixed vegetation	Areas with >50% vegetation with interspersed visible substrate
5	Wetland	Water areas with green vegetation present
6	Submerged sand	Submerged substrate visible through water
7	Water	Areas of water with no visible substrate

The midpoint of the percent cover range class was used for statistical analysis (Table 2). Woody stem number was the direct count of woody plants in the quadrat and vegetation height was measured using a height range which the midpoint was used for statistical analysis (Table 3) (Sherfy et al. 2008).

Statistical analysis

Nest site characteristics and habitat characteristics were described and analyzed using basic statistical analyses, and were performed on only the characteristics that had measurable variables (> zero) using SYSTAT 12 (SYSTAT 2007). Two sample t –tests were used to: (1) compare intact nests to predated nests to determine if distance from water or any habitat characteristics played a role in whether the nest was depredated or not, (2) to determine if there was a difference between the straight line distances to water from nest sites between *Apalone* sp. and *G. pseudogeographica*, (3) to determine if there was a difference between the clutch sizes of the penultimate week and last week of nesting season for both *Apalone* sp. and *G. pseudogeographica*, and (4) to determine if there was a difference in vegetation around nests that hatched out compared to nests that were laid the same week and had not hatched to determine if vegetation had any effect on incubation length (SYSTAT 2007). Upper and lower quartiles were used to determine the upper limits of the straight line distance to water for both *Apalone* sp. and *G. pseudogeographica* using SYSTAT 12 (SYSTAT 2007).

Table 2. Classification used to measure vegetation variables along the Missouri National Recreation River (Daubenmire 1968). The midpoint of the percent cover range class was used for statistical analysis (Sherfy et al. 2008).

Class	% Cover range	Midpoint %
0	0	0
1	>0 - 5	2.5
2	6- 15	10
3	16- 30	23
4	31- 45	38
5	46 - 70	58
6	7 - 100	85

Table 3. Classes used to measure height of vegetation near turtle nests found on sandbars along the Missouri National Recreational River. The midpoint was used for statistical analysis (Sherfy et al. 2008).

Class	Height (m)	Midpoint (m)
0	0	0
1	>0 - 0.5	0.25
2	0.5 – 1.0	0.75
3	>1.0	1.0

Variables collected at the nest site and the cardinal directions (three meters from the nest site) were compared to determine the selection process at the microhabitat level. Variables collected at the nest site and the paired random points were compared to assess nest site selection at the off-site level. A matched-pair stepwise logistic regression was used to construct the models for both *Apalone* sp. and *G. pseudogeographica*, because it is more powerful when comparing paired independent variables than a standard logistic regression (Compton et al. 2002).

In order to determine which of the habitat variables should be included in the matched-pair stepwise logistic regression, a Wilcoxon signed rank test with an $\alpha = 0.05$, with Bonferroni adjustment to maintain experiment-wide alpha, was used to compare each variable at the nest site to the variables at the cardinal directions (averaged together) and each variable at the nest site to the variables from the paired random point using SYSTAT 12 (SYSTAT 2007). If a significant difference was found, that variable was then used in the matched-pair stepwise logistic regression.

Spatial Analysis

I recorded the location of the 102 *Apalone* sp. nests on the beach at RM 804.5 using Garmin 76Cx a hand-held GPS unit with 3-5 meter accuracy. I analyzed the nest location as a point pattern to determine if the distribution of the nests was random, clustered, or uniform. I used point pattern analysis to determine if the number of points (*Apalone* sp. nests) within a circular window of radius r was similar to the number of points in a circular window of radius r under complete spatial randomness (CSR) model.

If the number of points in the circular window of radius r is larger than the number of points in the circular window of radius r under CSR, it can be concluded that there was a clustered pattern. This relation is expressed in the formula of Ripley's K statistic (Ripley 1981). In order to see the departure from CSR in a clearer way, I transformed Ripley's K statistic to a Lhat statistic which equals zero under CSR and is greater than zero for a clustered distribution (suggestion attraction between points) and is less then zero for a uniform (repulsion) distribution.

To determine the significance of the attraction or repulsion, I compared the results from the observed points to a null model (*Apalone* sp. nests are randomly distributed on the nesting beach at RM 804.5). I used the minimum and maximum geographic coordinates (the minimum and maximum of x, y coordinates) to define the boundary of the nesting beach on RM 804.5. I used 999 Monte Carlo simulations of the same number of nest sites from RM 804.5 to generate confidence envelopes with 5% and 95% quantiles as the confidence bounds. I then calculated the Lhat statistic for a range of values of r. If the observed statistic (RM 804.5) fell inside the confidence envelope calculated from the Monte Carlo simulation, then there is a 90% confidence that the nests follow a CRS model (nests are randomly distributed). If the observed statistic falls above the confidence enveloped, I assumed clustered distribution and if the statistic fell below the confidence envelope I assumed distribution was regular. I ran the point pattern analysis using the spatstat package in the statistical software R, version 2.6.2 (R Development Core Team 2008).

Results

Number of nests located

I found 16 intact *Apalone* sp. turtle nests and five depredated *Apalone* sp. turtle nests during 2006 surveys. I located four intact *G. pseudogeographica* nests and one depredated *G. pseudogeographica* nest during the 2006 nesting season. In 2007, I found 29 intact *Apalone* sp. nest and 175 depredated *Apalone* sp. nests. In 2007, I located 13 intact *G. pseudogeographica* nests and an additional nine *G. pseudogeographica* nests were found depredated. A total of 230.5 hours were spent searching sandbars resulting in a detection rate of one nest every 5.5 hours. Approximately 116 hours were spent searching on man-made sandbars resulting in one nest located every six hours and approximately 114.5 hours were spent searching natural sandbars resulting in one nest located every 5 hours.

Length of nesting season

In 2006, *G. pseudogeographica* and *A. mutica* were first observed nesting on 6 June. The last *G. pseudogeographica* and *Apalone* sp. nests were located on 23 June. All nests were located on the 59 mile stretch of MNRR from RM 811 to RM 753.

The first *Apalone* sp. nest of the 2007 season was located on 29 May and the last nest was located on 28 June (31 days) (Figure 3). All *Apalone* sp. nests were located on the 59 mile stretch of river from RM 811 to RM 753. I also observed *Apalone* sp. staging off the man made sand bars located in Lewis and Clark lake on15 June.

In 2007, the first *G. pseudogeographica* nest was located on 28 May and the last nest was found on 2 July (36 days) (Figure 3). All *G. pseudogeographica* nests except one were located on the 59 mile stretch from RM 811 to RM 753. One *G. pseudogeographica* turtle nest was located on a flooded sandbar at RM 835. The nest was excavated for identification purposes and the number and size of eggs was recorded. No other data was recorded.

Estimated number of nests

I determined an estimate of the number of *Apalone* sp. nests in the 59 mile stretch of the MNRR using the ratio (Burger 1977, Tinkle et al. 1981, and Doody 1995):

$$\frac{\text{number of nest discovered then depredated}}{\text{number of nests discovered intact}} = \frac{\text{number of nest located depredated}}{\text{number of undiscovered nests intact}}$$

The estimated number of nest was calculated as follows:

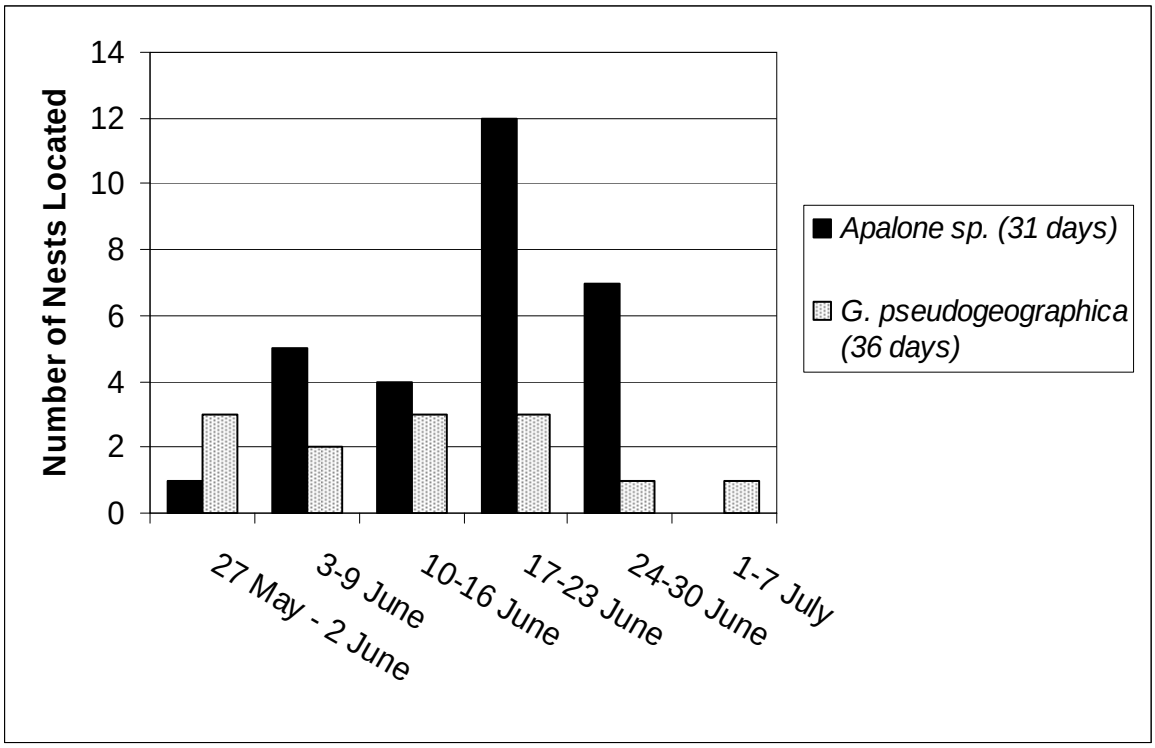
Estimated total number of nests = number of intact nests + number of destroyed nests

Therefore,

$$\frac{12}{30} = \frac{175}{\text{number of undiscovered nests intact}}$$

Number of undiscovered nests intact = 437.5

Figure 3. Length of nesting season and number of nests per week for *Apalone* sp. and *G. pseudogeographica* during the 2007 nesting season along the Missouri National Recreation River from RM 835 to RM 753.



Using this estimate, there were approximately 468 *Apalone* sp. nests located on sandbars along the 59 mile stretch of the MNRR. Assuming that both species of *Apalone* were found in equal proportion (Doody 1995), approximately 4 nests/mile/species were found. Total number of nests for *G. pseudogeographica* turtles could not be estimated using this equation because of the small sample size.

Nest cavity characteristics

The mean number of eggs in an *Apalone* sp. clutch was 15 $\pm$ 0.533 (S.E.) (Figure 4) and mean egg diameter was 23.97 mm $\pm$ 0.046 (S.E.). The mean depth to the top egg (nest depth) was 9.085 cm $\pm$ 0.404 (S.E.) (Table 4). The mean number of eggs in a *G. pseudogeographica* nest was 11 $\pm$ 0.526 (S.E.) (Figure 5). Mean *G. pseudogeographica* egg width was 23.16 mm $\pm$0 .111 (S.E.) and mean length was 34.42 mm $\pm$ 0.210 (S.E.). The mean depth to the top egg (nest depth) was 9.95 cm $\pm$ 0.483 (S.E.) (Table 5).

The mean number of eggs per clutch for both *Apalone* sp. and *G. pseudogeographica* decreased as nesting season progressed until the last week when there was an increase in the number of eggs (Figure 6 and 7). There was no difference in mean clutch size between the penultimate week and last week of nesting for *Apalone* sp. ($p = 0.149$ $t = -1.512$, $df = 16.95$). For *G. pseudogeographica* a two sample t – test could not be conducted due to insufficient data.

Figure 4. Distribution of clutch size for *Apalone* sp. nests during 2006 and 2007 along the 59 mile stretch of the Missouri National Recreation River.

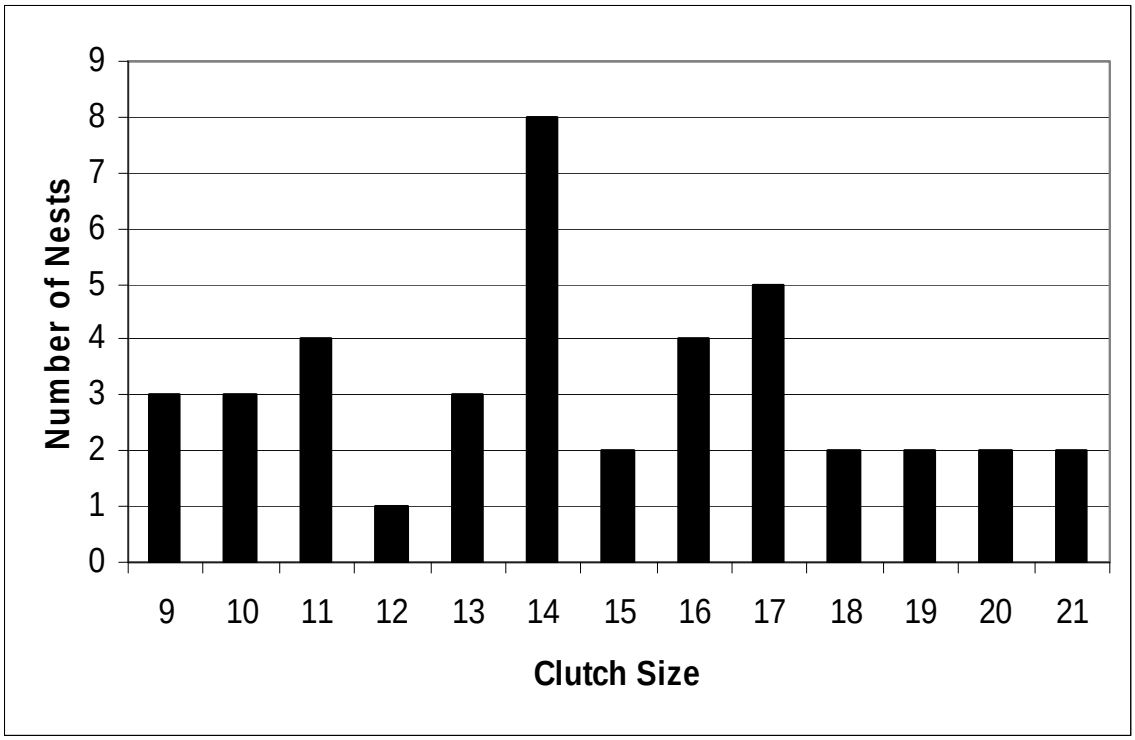


Table 4. Nest site characteristics for *Apalone* sp. during 2006 and 2007 along the 59 mile stretch of the Missouri National Recreation River.

	Number of Eggs in Nest (N=41)	Egg Diameter (mm) (N=599)	Depth to Top Egg (cm) (N=41)	Distance to Water (m) (N=41)
Minimum	9	19.5	4.5	10.06
Maximum	21	26.75	15.6	175.05
Mean	15	23.97	9.085	61.27
Standard error of mean	0.533	0.046	0.404	7.123

Figure 5. Distribution of clutch size for *G. pseudogeographica* nests during 2006 and 2007 along the 59 mile stretch of the Missouri National Recreation River.

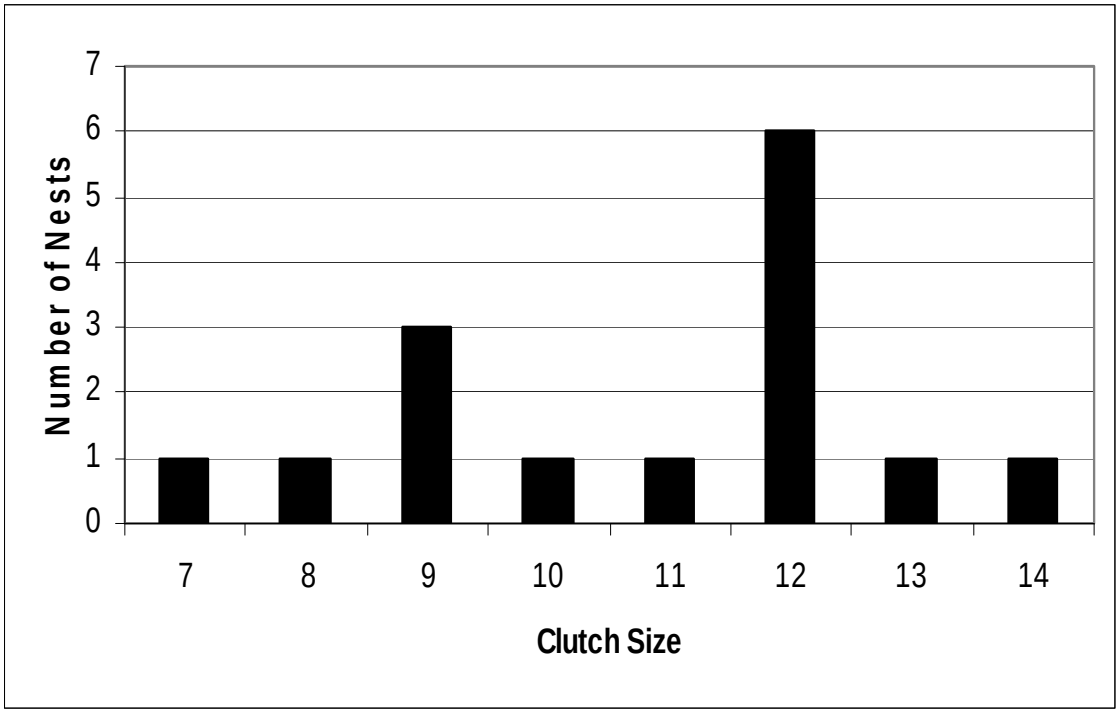


Table 5. Nest site characteristics for *G. pseudogeographica* during 2006 and 2007 along the 59 mile stretch of the Missouri National Recreation River.

	Number of Eggs in Nest (N=15)	Egg Width (mm) (N=161)	Egg Length (mm) (N=161)	Depth to top egg (cm) (N=14)	Distance to Water (m) (N=15)
Minimum	7.0	19.60	26.60	7.00	17.10
Maximum	14.0	25.80	39.60	12.90	115.80
Mean	11	23.16	34.42	9.95	54.25
Standard error of mean	0.536	0.111	0.210	0.483	8.768

Figure 6. Mean number of *Apalone* sp. eggs per clutch per week during the 2007 nesting season along the 59 mile stretch of the Missouri National Recreation River.

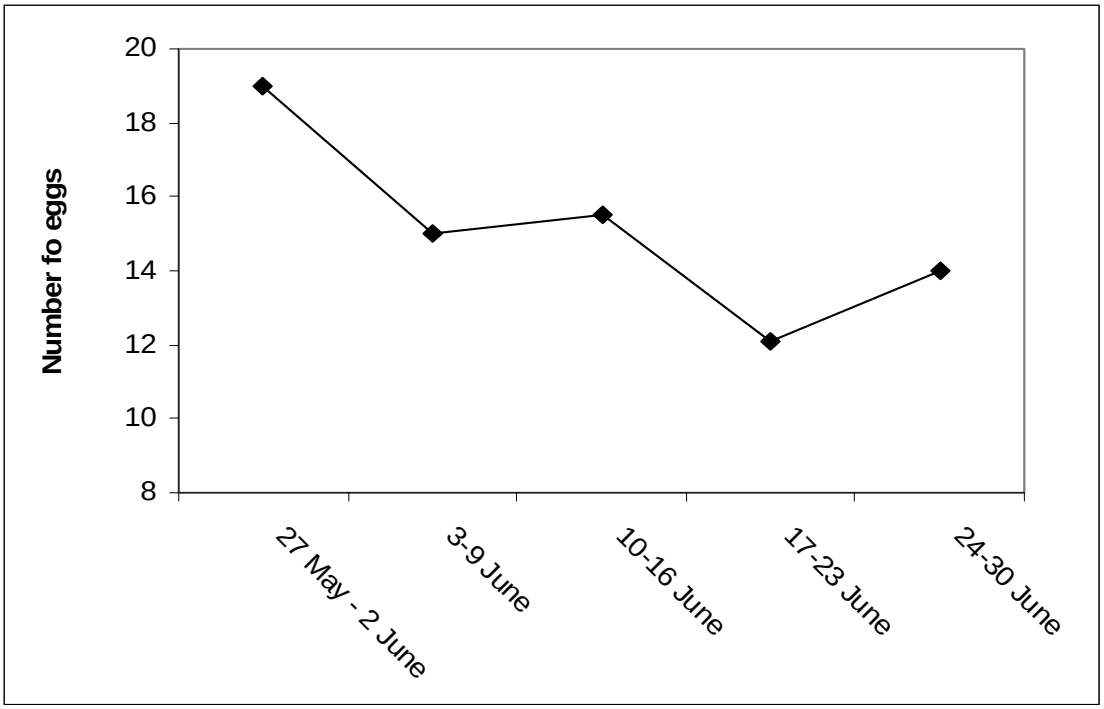
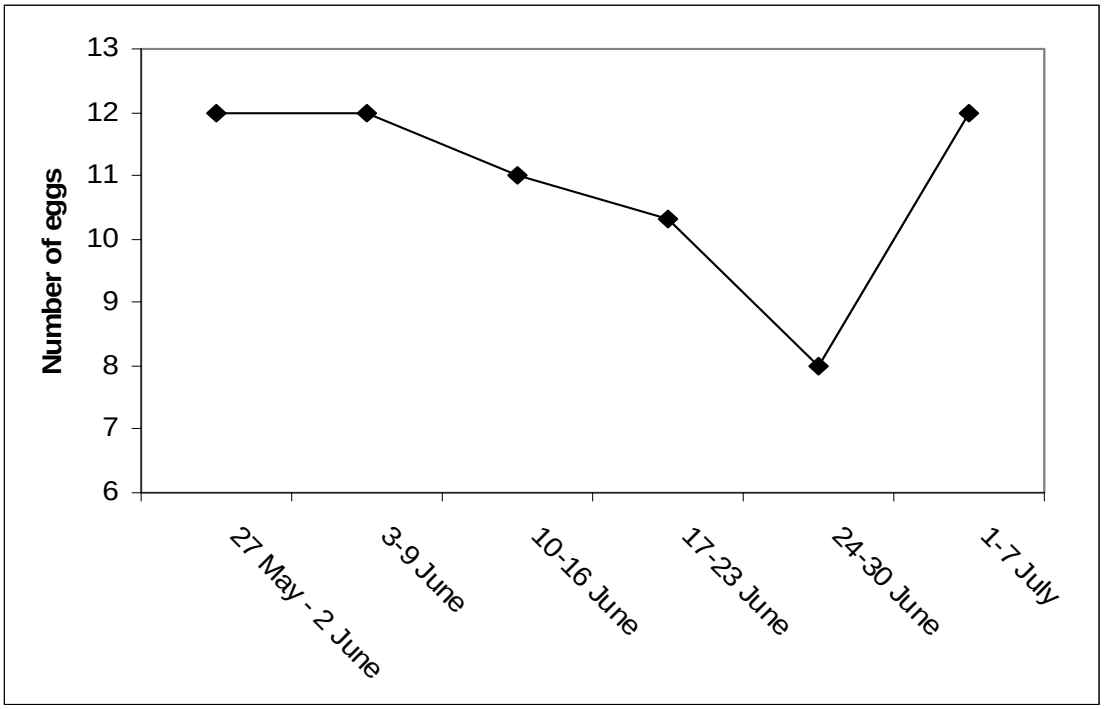


Figure 7. Mean number of *G. pseudogeographica* eggs per clutch per week during the 2007 nesting season along the Missouri National Recreation River from RM 835 to RM 755.



Distance traveled from water to nest site

The mean straight line distance to water traveled by nesting *Apalone* sp. was 61.27 m $\pm$ 7.123 (S.E.M.) (Figure 8). Of the distances traveled by nesting *Apalone* sp., 75.6% were less than 89 m (the forth quartile of movements). However, on man-made sandbars 60% of the distances traveled were greater than 89 m. The mean straight line distance to water traveled by nesting *G. pseudogeographica* was 54.24 m $\pm$ 8.768 (S.E.M.) (Figure 9). Of the distances traveled by nesting *G. pseudogeographica*, 73.3% were less than 83.54 m (the fourth quartile of movements). However, on man-made sandbars 50% of the distances traveled were greater than 83.54 m. There was no difference in the straight line distance from nest to water between *Apalone* sp. and *G. pseudogeographica* ($p = 0.552$, $t = 0.601$, $df = 36.47$).

Average slope on man-made sandbars was 2.79 (n= 5) and the average slope of natural sand bars was 10.97 (n=13). There was a difference between slopes of man-made sandbars and natural sandbars ($p = 0.003$, $t = -3.699$, $df = 13.35$). When the mean slope of a sandbar was compared to the mean straight line distance from nest to water on the same sandbar *Apalone* sp. had a R^2 value of 0.1487 (n = 13) (Figure 10) and *G. pseudogeographica* had an R^2 value of 0.2471 (n = 7) (Figure 11).

Figure 8. Distribution of the straight line distance (m) from nest site to water for *Apalone* sp. in 2006 and 2007 along the 59 mile stretch of the Missouri National Recreation River.

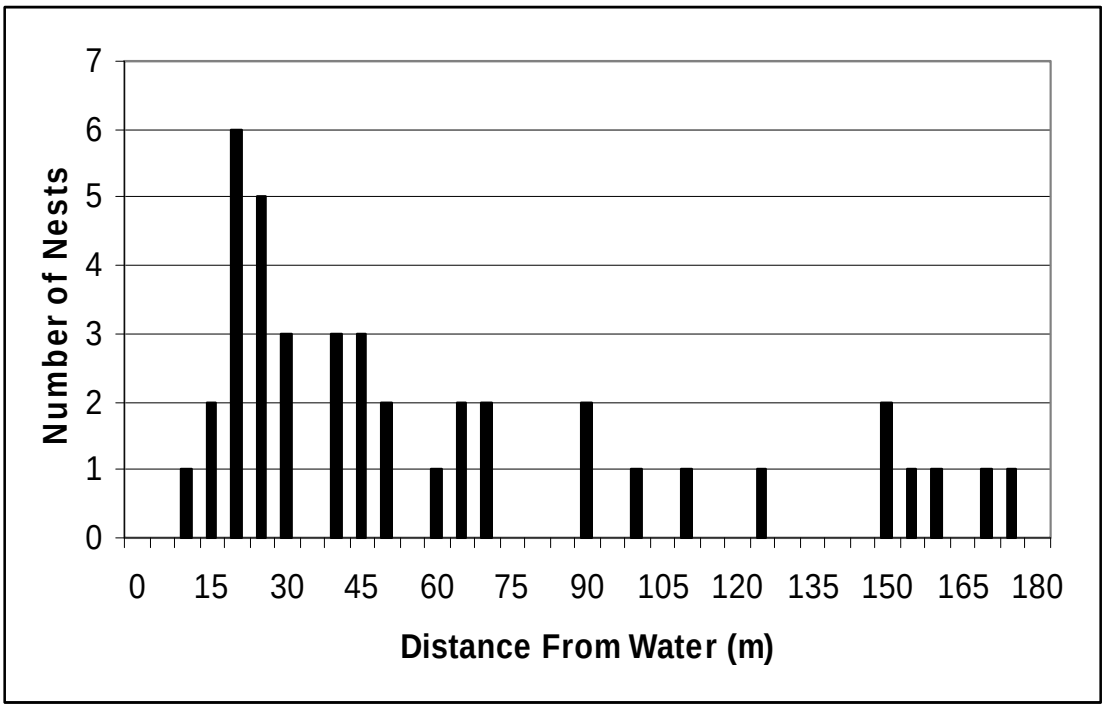


Figure 9. Distribution of the straight line distance (m) from nest site to water for *G. pseudogeographica* nests in 2006 and 2007 along the 59 mile stretch of the Missouri National Recreation River.

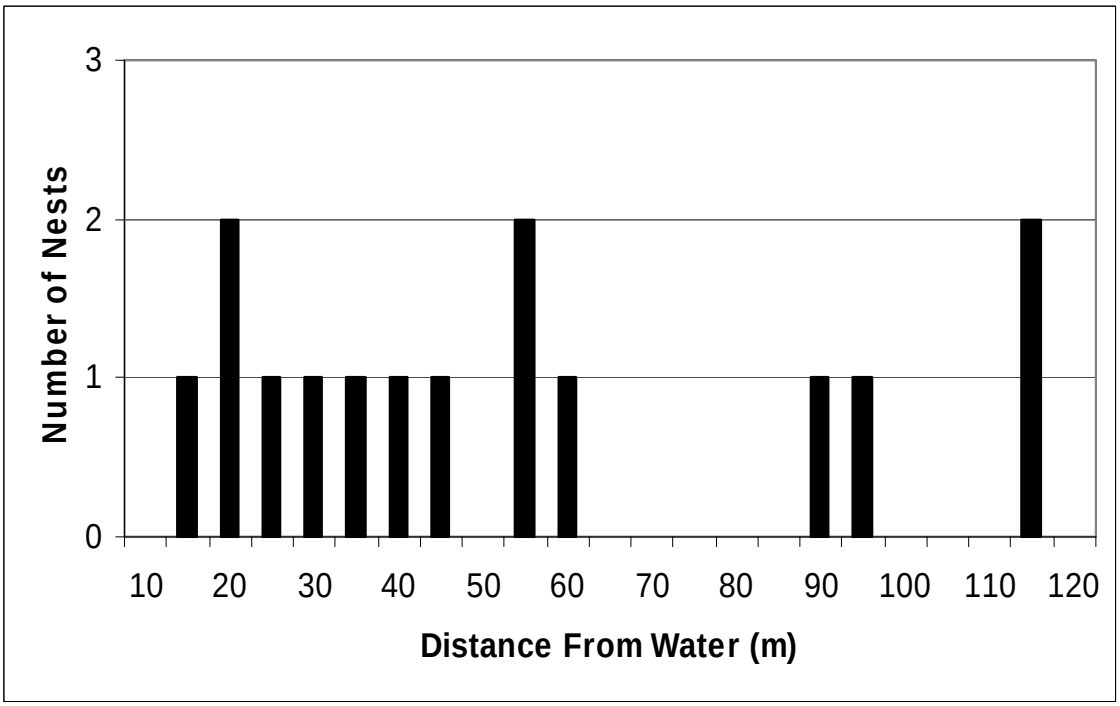


Figure 10. Linear regression of average distances (m) traveled per sandbar by nesting *Apalone* sp. versus average slope for sandbars that were used for nesting in 2007.

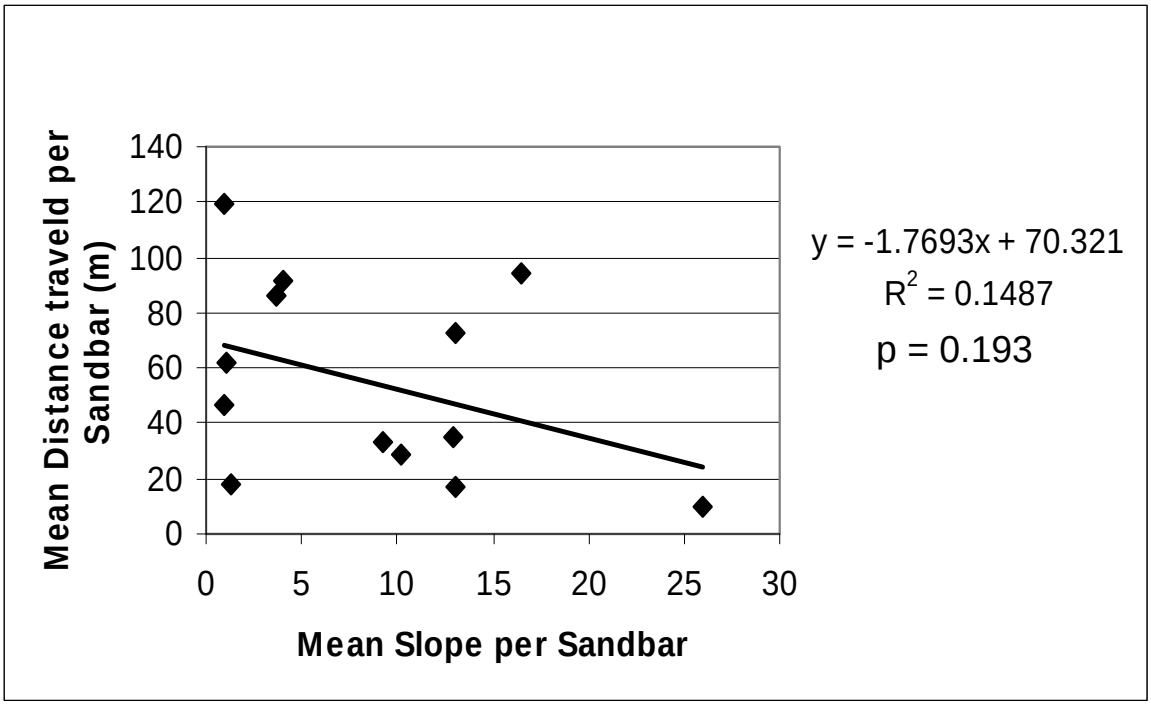
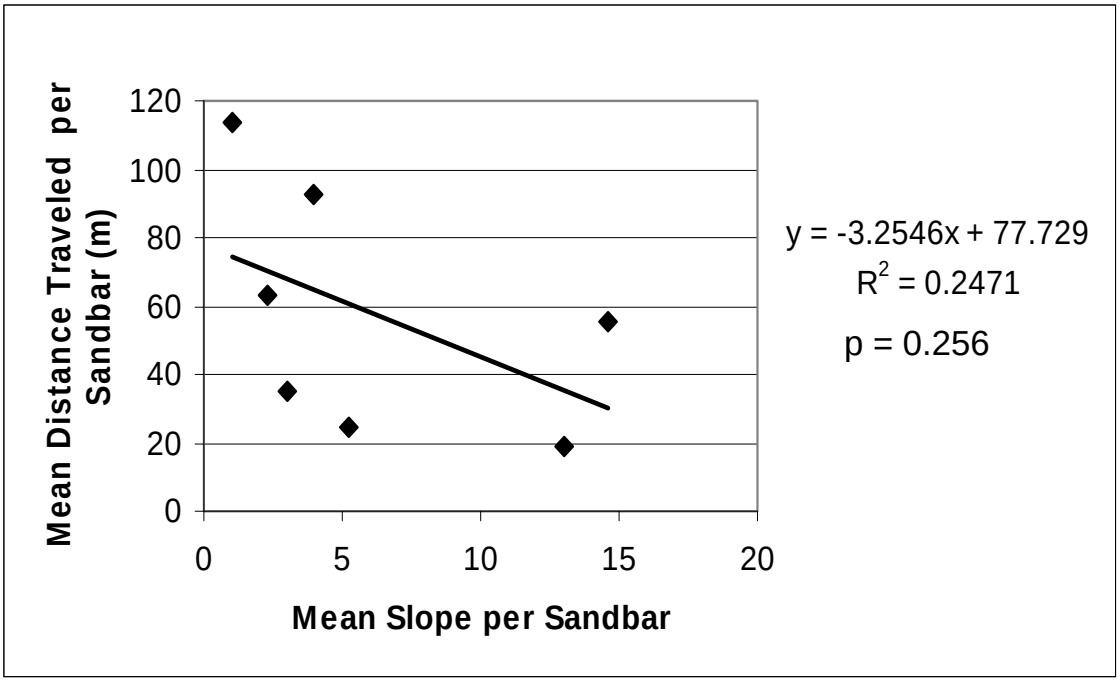


Figure 11. Linear regression of average distances (m) traveled per sandbar by nesting *G. pseudogeographica* versus average slope for sandbars used for nesting in 2007.



Nest mortality

Depredation

I located 184 depredated nests (175 *Apalone* sp. and nine *G. pseudogeographica*) during surveys in 2006 and 2007. In 2007, the predation rate of nest that were located intact and then depredated was 36%. There was no depredation of nests on the man-made sandbars. There was no difference in the straight line distance to the water between depredated and intact nests (all species combined) ($p = 0.909$, $t = 0.115$, $df = 40$). Habitat characteristics at the nest site had no effect on nest depredation rates of located nests (Table 6 and 7).

Flooding

One *G. pseudogeographica* nest was lost to flooding during surveys. In 2007 the Niobrara River briefly flooded causing water levels to rise where the Niobrara River enters the Missouri River. The sandbar (RM 835) was submerged and subsequently the nest was flooded.

Table 6. T-test of habitat characteristics around the nest site between depredated (n=15) and intact nest (n=27) in 2007 along the 59 mile stretch of the Missouri National Recreation River *.

	P - value
Terrestrial herbaceous cover	0.194
Woody vegetation cover	--
Woody stem number	--
Mean vegetation height	0.259
Maximum vegetation height	0.259
Silt	--
Sand	0.072
Small pebble	0.176
Gravel	--
Cobble	--
Boulder	--
Leaf litter cover	0.675
Wrack (debris < 2 cm)	--
Large debris (debris > 2cm)	0.301

* P-values with – in the column had insufficient data for a t-test to be conducted.

Table 7. Mean and standard error of the mean (S.E.) of habitat characteristics around the nest site between predated and intact nest in 2007 along the 59 mile stretch of the Missouri National Recreation River.

		Located Intact Nests	Located Depredated Nests
Terrestrial herbaceous cover	Mean	4.944	1.500
	S.E.	2.501	0.681
Woody vegetation cover	Mean	0.556	0.00
	S.E.	0.385	0.00
Woody stem number	Mean	0.296	000
	S.E.	0.225	0.00
Mean vegetation height	Mean	0.130	0.083
	S.E.	0.024	0.031
Maximum vegetation height	Mean	0.130	0.083
	S.E.	0.024	0.031
Silt	Mean	2.148	0.00
	S.E.	2.148	0.00
Sand	Mean	83.00	76.00
	S.E.	1.387	3.402
Small pebble	Mean	0.370	2.700
	S.E.	0.370	1.601
Gavel	Mean	0.093	0.00
	S.E.	0.093	0.00
Cobble	Mean	0.00	0.00
	S.E.	0.00	0.00
Boulder	Mean	0.00	0.00
	S.E.	0.00	0.00
Leaf Litter Cover	Mean	0.093	0.167
	S.E.	0.093	0.167
Wrack (debris < 2 cm)	Mean	0.093	0.00
	S.E.	0.093	0.00
Large debris (debris > 2cm)	Mean	0.185	0.500
	S.E.	0.128	0.267

Incubation length

Three *Apalone* sp. nests hatched before surveys were completed in 2007. All hatched nests were located on 10 August. Nest #4 was located on the 29 May, and therefore had an estimated incubation length of 74 days. Nest 7 and 8 were located on the 5 June and therefore had an estimated incubation of 67 days. Nest 8 contained one egg that experienced late term mortality (well developed embryo). Based on the three incubation lengths, an estimate incubation length for *Apalone* sp. turtles was 70-71 days.

When comparing the vegetation around nests laid the same week that hatched versus nests that had not hatched, nests 4, 7 and 8 had no measurable vegetation at the nest site while nests 5 and 9 both had measurable vegetation at the nest site. Mean terrestrial herbaceous vegetation cover was 20.25%, mean vegetation height was 0.25 cm and max vegetation height was 0.25 cm for the latter two nests.

Nest site selection

Sandbar

I found *Apalone* sp. and *G. pseudogeographica* nesting only on sandbars. Fifteen sandbars in the lower reach of the MNRR and one sandbar in the stretch above Gavins Point Dam were used as nesting beaches. Three sandbars were man-made islands, 10 were natural island sandbars and three were natural sandbars attached to the bank. Of the 16 sandbars that were used for nesting, five (31%) were used by both *Apalone* sp. and *G. pseudogeographica*, nine (56%) were used by only *Apalone* sp., and three (13%) were

used only by *G. pseudogeographica*. Seven sandbars were used in both 2006 and in 2007 while nine were used only in 2007.

Of the 14 sandbars used by nesting *Apalone* sp., five were used in both 2006 and 2007. *G. pseudogeographica* used seven different sandbars and returned to two of those during 2006 and 2007 surveys. However, there was only one sandbar, RM 761.5, where both *Apalone* sp. and *G. pseudogeographica* returned to nest in both years.

Twenty one nests were located on the man-made sandbars. Of these, 13 were *Apalone* sp. and eight were *G. pseudogeographica* nests. Fifteen of the nests located on man-made sandbars were found on 761.5. Thirty-nine nests were located on natural island and bank sandbars (31 *Apalone* sp., and eight *G. pseudogeographica*).

Man-made vs. natural sandbars

There was no difference between any of the nest site habitat characteristics for man-made and natural sandbars.

Habitat characteristics

For *Apalone* sp., three of the 29 nests were found in cover class 3 (sparsely vegetated). The remaining 26 of the 29 nests were found in cover class 1 (dry sand). For *G. pseudogeographica,* one nest was located in cover class 6 (submerged sand), one nest was located in cover class 4 (mixed vegetation), four nests were located in cover class 3 (sparsely vegetated) and seven nests were located in cover class 1 (dry sand).

The mean terrestrial herbaceous vegetation cover for *Apalone* sp. was 2.26% ± 1.332 (S.E.) and the mean woody vegetation cover was 0.086% ± 0.086 (S.E.). The mean woody stem number was 0.034 ± 0.034 (S.E.). The mean vegetation height was 0.086 m ± 0.022 (S.E.) and mean maximum height was 0.086 m ± 0.022 (S.E.). For the substrate characteristics measured only sand, small pebble, and gravel measurements had data that could be used for analysis. For *Apalone* sp., the mean percent substrate that was composed of sand was 79.41 ± 2.067 (S.E.), small pebble was 1.74 ± 0.901 (S.E.), and gravel was 0.086 ± 0.086 (S.E.). Only large debris had data that could be used for data analysis. The mean large debris percent cover was 0.35% ± 0.163 (S.E.). All *Apalone* sp. nests were located in 100% sunny sites. A comparison of the means of habitat variables at the nest sites, on-site and off-site for *Apalone* sp. show a difference in the habitats (Table 8).

The mean terrestrial herbaceous vegetation cover for *G. pseudogeographica* was 7.32% ± 5.140 (S.E.) and the mean woody vegetation cover was 1.14% ± 0.915 (S.E.). The mean woody stem number was 0.64 ± 0.544 (S.E.). The mean vegetation height was 0.182 m ± 0.035 (S.E.) and mean maximum height was 0.182 m ± 0.035 (S.E.). For the substrate characteristics measured, only sand measurements had data that could be used for analysis. For *G. pseudogeographica* the mean percent substrate that was composed of sand was 85.00 ± 0.00 (S.E.). For the debris characteristic measured, percent leaf cover, percent wrack and percent large debris had data that could be used for data analysis. The mean percent leaf cover was 0.227 ± 0.227

Table 8. Mean and standard error of mean (S.E.) of habitat characteristics around the nest site, on-site and off-site for *Apalone* sp. in 2007 along the 59 mile stretch of the Missouri National Recreation River.

		Nest site	On-site	Off-site
Terrestrial Herbaceous cover	Mean	2.259	3.970	9.707
	S.E.	1.332	1.866	4.206
Woody vegetation cover	Mean	0.086	2.431	1.655
	S.E.	0.086	1.129	0.850
Woody stem number	Mean	0.034	0.491	1.138
	S.E.	0.034	0.176	0.762
Mean vegetation height	Mean	0.086	0.164	0.207
	S.E.	0.022	0.028	0.051
Max vegetation height	Mean	0.086	0.183	0.233
	S.E.	0.022	0.034	0.059
Sand	Mean	79.414	81.276	79.897
	S.E.	2.067	1.759	2.511
Small pebble	Mean	1.741	1.569	1.759
	S.E.	0.901	0.904	1.099
Gravel	Mean	0.086	0.00	0.00
	S.E.	0.086	0.00	0.00
Leaf Litter Cover	Mean	0.00	0.237	0.345
	S.E.	0.00	0.079	0.163
Wrack (debris < 2 cm)	Mean	0.00	0.539	0.268
	S.E.	0.00	0.119	0.149
Large debris (debris > 2 cm)	Mean	0.345	0.388	0.431
	S.E.	0.163	0.171	0.178

(S.E.), percent wrack cover was 0.227 ± 0.227 (S.E.), and percent large debris cover was 0.227 ± 0.227 (S.E.). All nests were located in 100% sunny areas. A comparison of the means of the habitat variables at the nest sites, on-sites and off-sites for *G. pseudogeographica* show a difference in habitats (Table 9).

Habitat model

G. pseudogeographica nest site variables showed no difference between the nest site and the average of the cardinal directions or between the nest site and the random point. Therefore, I was unable to construct a nest site selection model for *G. pseudogeographica* to determine which variables were being used or at what scale selection is occurring.

For *Apalone* sp., at the on-site level (nest site compared to average of cardinal directions) the Wilcoxon signed rank test calculated differences between habitat variables terrestrial herbaceous vegetation ($p = 0.008$), woody vegetation ($p = 0.005$), woody vegetation stem number ($p = 0.019$), mean vegetation height ($p = 0.010$), max vegetation height ($p = 0.005$) and leaf debris ($p = 0.009$). Even though there were differences between on-site habitat characteristics, none of the characteristics were incorporated into a significant model.

At the on-site level (nest site compared to random point) the Wilcoxon signed rank test calculated differences between terrestrial herbaceous vegetation ($p = 0.046$), woody vegetation ($p = 0.008$), woody vegetation stem number ($p = 0.020$), mean

Table 9. Mean and standard error of mean (S.E.) of habitat characteristics around the nest site, on-site and off-site for *G. pseudogeographica* in 2007 along the 59 mile stretch of the Missouri National Recreation River.

		Nest site	On-site	Off-site
Terrestrial Herbaceous cover	Mean	7.318	5.852	5.955
	S.E.	5.140	2.524	5.216
Woody vegetation cover	Mean	1.136	1.784	3.682
	S.E.	0.915	0.948	3.439
Woody stem number	Mean	0.636	0.727	1.545
	S.E.	0.544	0.420	1.448
Mean vegetation height	Mean	0.182	0.199	0.159
	S.E.	0.035	0.54	0.070
Max vegetation height	Mean	0.182	0.205	0.136
	S.E.	0.035	0.060	0.070
Sand	Mean	85.00	85.00	85.00
	S.E.	0.00	0.00	0.00
Leaf Litter Cover	Mean	0.227	0.227	0.00
	S.E.	0.227	0.227	0.00
Wrack (debris < 2 cm)	Mean	0.227	0.398	0.455
	S.E.	0.227	0.194	0.305
Large debris (debris > 2 cm)	Mean	0.227	0.170	0.455
	S.E.	0.227	0.088	0.305

vegetation height ($p = 0.032$), max vegetation height ($p = 0.025$) and leaf debris ($p = 0.046$) variables and were used in a matched-pair stepwise logistic regression. The final calculated model included max vegetation height and leaf debris ($p = 0.007$, McFadden $Rho^2 = 0.123$).

Spatial analysis

The density of the *Apalone* sp. nests on the sandbar at RM 804.5 is shown to increase towards the center of the sandbar where little vegetation is located (Figure 12). The Lhat statistic of the point pattern analysis of the predated *Apalone* sp. nests at RM 804.5 falls above the generated confidence envelopes (Figures 13). This suggests that the nests were clustered in the defined area and that nest site selection occurred.

Figure 12. Density of *Apalone* sp. nests (number of nests per meter) on sandbar RM 804.5 (area defined by minimum and maximum latitude and minimum and maximum longitude were used to define the boundary of the area).

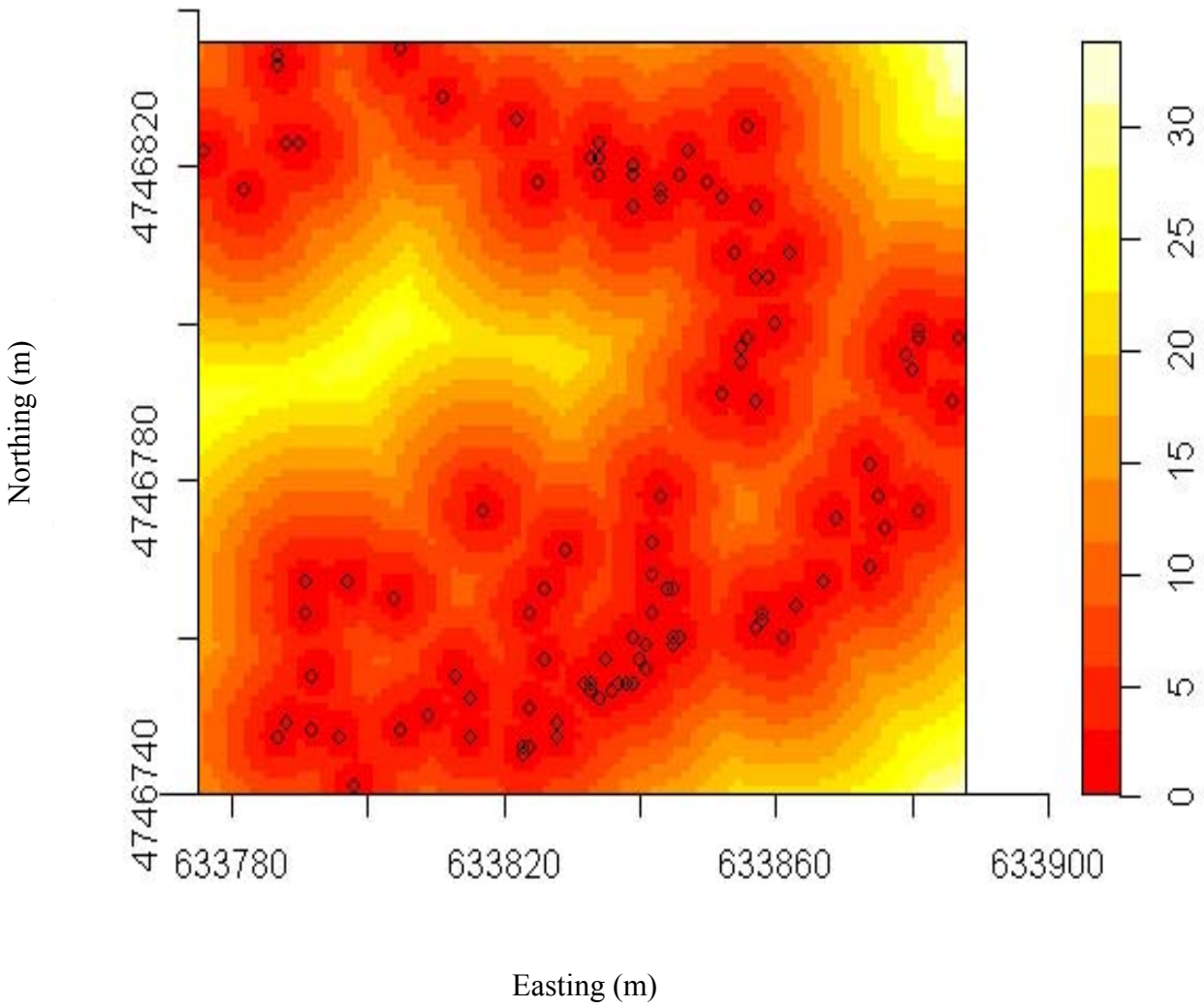
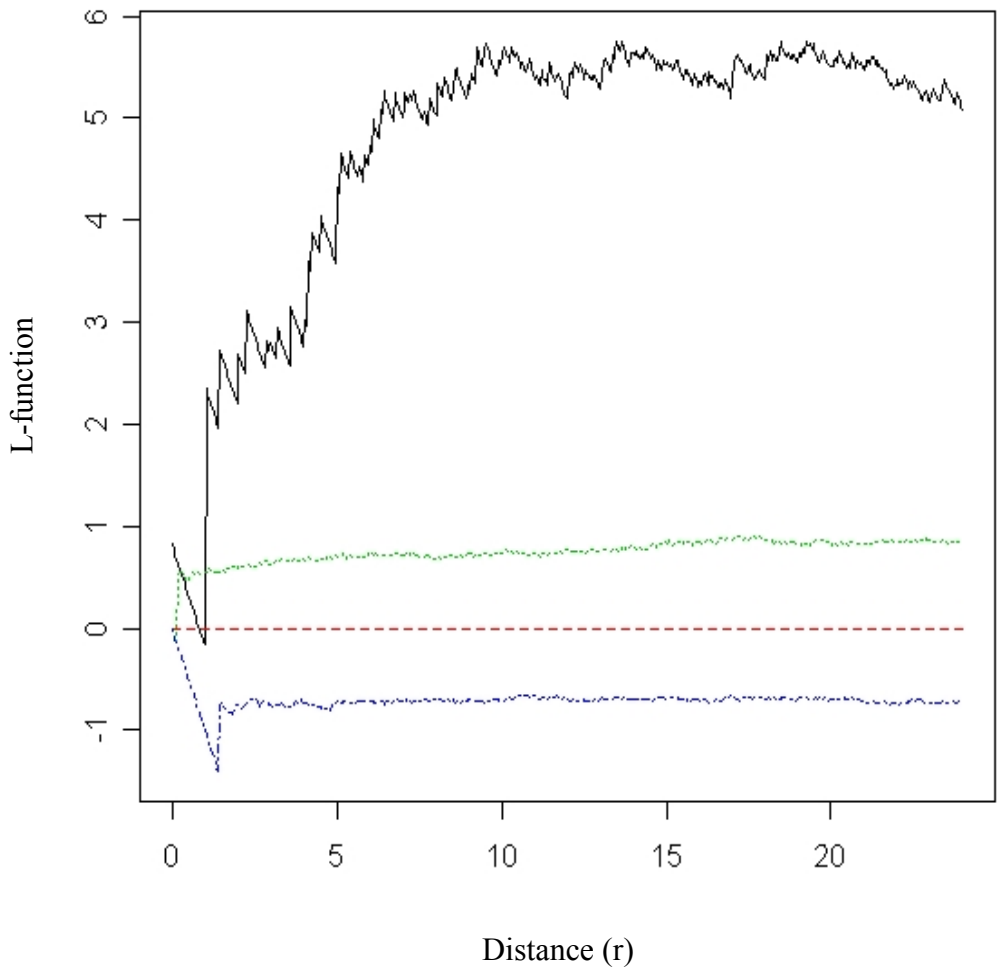


Figure 13. Univariate Ripley's Lhat statistic (black line) for depredated *Apalone* sp. nests, with 90% confidence envelopes (blue and green lines) generated from 999 simulations under a null model of complete spatial randomness (CSR).



Discussion

Length of nesting season

The length of the nesting season for both *Apalone* sp. (31 days) and *G. pseudogeographica* (36 days) along the lower stretch of the MNRR was similar to other populations found at similar latitudes (Fitch and Plummer 1977b, Plummer 1976a,b, Robinson and Murphy 1978, Vogt 1980, Ernst et al. 1994, Graham and Graham 1997, Johnson 2000, Riley et al. 2005, Bolton and Brooks 2005). The peak nesting period was late in the season. This suggests that small females, who take longer to gather the resources need to produce a clutch, are producing their first clutch towards the end of the season and large females are laying a second clutch (Plummer 1977).

Number of nests located

I found that *G. pseudogeographica* and at least one species of *Apalone* are nesting along this stretch of the Missouri River. I could not determine if both *Apalone* sp. were represented because the eggs are so similar in shape and size. However, both species have been trapped along this stretch of river (A. Gregor, personal communication), so it is likely that both species nests were represented.

If nests from both species of *Apalone* sp. were located in equal numbers, then approximately 23 nests of each species were found (Doody 1995). Which may account for the difference between the number of *Apalone* sp. nests located versus the number of *G. pseudogeographica* nests located. However, *G. pseudogeographica* are thought to be more numerous along this stretch of river (A. Gregor, University of South Dakota, pers.

commun.) and therefore, I expected to find a greater number of *G. pseudogeographica* nests. Based on the nest site habitat characteristics from this study, *G. pseudogeographica* may have a higher tolerance for vegetation around the nest site and as a result nests may be located in vegetated areas. Since survey efforts focused on open sandy areas, I may have under represented nests located in vegetated areas. Vogt and Bull (1984) found in their study that *G. pseudogeographica* nested in both open sandy areas and areas with some vegetation. *G. pseudogeographica* have TSD and nest located among vegetation are cooler and tend to be all male. Tolerance for nesting in habitats with varying vegetation ensures a sex ratio close to 1:1 in the population.

Estimated number of nests

I estimated 438 *Apalone* sp. nests along the 59 mile stretch of the MNRR (8 nests/mile of the river). An estimate for the number of *G. pseudogeographica* nests located along the 59 miles stretch of river could not be calculated because so few depredated nests were located.

Nest cavity characteristics

Apalone sp. and *G. pseudogeographica* nest site characteristics were similar to populations in neighboring states (Timken 1968, Fitch and Plummer 1977b, Plummer 1976b, Vogt 1980, Doody 1995, Graham and Graham 1997, De Solla et al. 2003, Bolton and Brooks 2005, Riley et al. 2005). The mean number of eggs per clutch for both *Apalone* sp. and *G. pseudogeographica* decreased as the nesting season progressed until

the last week when there was an increase in the mean number of eggs per clutch. This increase may be due to large females laying a second clutch as well as to smaller females who need longer to gather the resources needed to lay their first clutch of eggs. However, there was no difference in mean clutch size between the penultimate week and last week of nesting for *Apalone* sp.

Distance traveled to nesting sites

The mean straight line distance from nest to water is not a clear representation of the distance traveled by nesting females because it is not the actual movement made by the turtle. The straight line distance measured is actually the shortest distance from the nest to the water. I found that turtles were willing to move great distances (up to 175 m) to nest sites. Distances traveled by turtles on this stretch of the MNRR are greater than distances found in other populations. Movements typically range from 5–150 m for *G. pseudogeographica* and 10-100 m for *Apalone* sp. (Timken 1968, Fitch and Plummer 1977b, Plummer 1976b, Vogt 1980, Doody 1995, Graham and Graham 1997, De Solla et al. 2003, Bolton and Brooks 2005, Riley et al. 2005). These data suggest that turtles may have to travel great distances to find suitable nesting habitat in the study area. The majority of long range movements were found on man-made sandbars for both *G. pseudogeographica* and *Apalone* sp. This finding may be attributed to the larger size of man-made sandbars in comparison to the natural sandbars, since movement is most like based on the size and slop of sandbars. However, some of the longest distances (> 100 meters) were found on natural sandbars.

Doody (1995) suggested that turtles select for height above water rather than distance from water for nests. It is possible that turtles are moving farther on the man-made islands because they have a very low slope and therefore low profile on the river. I found little correlation between distance moved by the turtles and slope of the sandbar. However, there is a difference between the mean slope of man-made sandbars and natural sand bars. This low correlation may be a result of the small number of nests located on natural sandbars and that it could not be determined exactly where nesting females exited the water on the way to nesting sites. The relationship between the distance moved and slope of the sandbar may have been detected if I could have determined what the actual slope used by the nesting female was and the actual distance traveled by each nesting female.

Nest mortality

Depredation

The depredation rate (36%) of intact nests in 2007 was relatively low when compared to other turtle populations of similar species where predation ranges from 40-100 % (Fitch and Plummer 1977b, Burger 1977, Congdon et al. 1983, 1987, 1994, Hughes and Brooks 2006). The low depredation rate may have been due to the fact that the majority of natural sandbars are islands and predators may have a difficult time accessing them. I was unable to determine which animals were depredating the nests. However, coyotes (*Canis latrans*), red fox (*Vulpes vulpes*), mink (*Neovison vison*),

skunks (*Mephitis mephitis*), opossums (*Didelphis virginiana*) and raccoon (*Procyon lotor*) are known to depredate nests in other areas (Marchand and Litvaitis 2004).

Intact nests were depredated within a week of being laid. However, it was likely that depredation took place within 24-48 hours after excavation. Vogt (1980) found that 90% of nest depredation on a population of *G. pseudogeographica* occurred within the first 24 hours after laying and that after 48 hours the nest was not likely to be disturbed by predators. Congdon et al. (1983) reported a depredation rate of 54% on nests in the first 24 hours for Blanding's turtles (*Emydoidea blandingii*), and the number of nests predated after oviposition in a population of snapping turtles (*Chelydra serpentina*) in the Ottawa River peaked at four days after nest construction then steadily decreased (Robinson and Bider 1988).

Although depredation was not a major factor of nest mortality in most areas, it may be in areas where preferred nesting areas are not available. On the sandbar at RM 804.5, the depredation rate of nests was close to 100%. This nesting beach is isolated and the only available habitat along this stretch of river that can be used for nesting. It is likely that turtles are nesting in high densities at this site making it easier for predators to locate and depredate nests (Burger 1977, Kolbe and Janzen 2002).

All depredated nests were located on natural sandbars. There are several factors that may account for the lack of depredation on the man-made sandbars. Man-made sandbars are relatively new to the system, having been constructed between 2004 and 2005. Predators may simply be unaware that the sandbars exist or because of the lack of vegetation on man-made sandbars that can be used as cover and/or habitat are both

reasons that predators may not be utilizing these areas. It is possible that man-made sandbars are further from shore, making predator access more difficult.

Habitat on the man-made sandbars was also composed of ideal nest site characteristics which are large, vegetation free areas. Doody (1995) found relatively low depredation of intact nests (7% *A. mutica* and 8% *A. spinifera*) and suggested it might be the result of an abundance of suitable nesting area at his study site in comparison to other studies. Burger (1977) and Temple (1986) found that nests of *Malaclemys terrapin* that were located closer to vegetation had high depredation rates because predators could use the vegetation as cover.

Flooding

The only other recorded cause of nest mortality during this study was one flooded *G. pseudogeographica* nest in 2007. Water levels on the Missouri River are controlled by dams and flood events are rare. However, after a rainfall event in northern Nebraska, a flooded Niobrara River emptied into the Missouri River above Lewis and Clark Lake. The resulting increase in the water levels caused the submergence of a sandbar and at least one nest to be inundated. Flooding could potentially be a cause for nest mortality along any stretch of the Missouri River because the rivers that drain into the Missouri are not regulated with dams.

Incubation length

Excavating turtle nests for the purpose of handling eggs has been criticized because it can jeopardize the survival of embryos by jarring, rotating, or damaging eggs, and increasing depredation by leaving human scent around nests (Samson et al. 2007). However, I found no negative effects to embryonic development and it is likely that the gain in knowledge from handling eggs outweighs the risk of embryo mortality (Samson et al. 2007).

Nest success was relatively high with only one late term mortality (i.e. well developed embryo in egg) for *Apalone* sp. The estimated incubation length of 70-71 days is the same as incubation lengths in neighboring populations (Ernst et al. 1994). Although it cannot be determined which *Apalone* sp. laid the clutches, no difference in incubation period was found between spiny and smooth softshells in Louisiana (Doody 1995) so it is likely incubation lengths are the same for both *Apalone* sp. in this population as well.

Nests that hatched had no measurable vegetation, while the nests that did not hatch had vegetation surrounding the nest. *Apalone* sp. do not have temperature-dependant sex determination (TSD) (Janzen and Paukstis 1991), however, they have a high temperature tolerance (up to 36°C) and the higher the temperature is in the nest cavity the quicker development will be. It is possible that temperatures in nests without surrounding vegetation were higher, and the embryos were able to develop and hatch quicker.

Nest site selection

Sandbar

Apalone sp. and *G. pseudogeographica* nested exclusively on sandbars, and nests were found on all three man made sandbars with the exception of RM 754.5, which was inaccessible because of cut banks. Although return rate to the sandbars for nesting was low, both *Apalone* sp. and *G. pseudogeographica* returned to nest on sandbars in subsequent years. The low re-use of sandbars by turtles between years may be a result of not detecting turtle nests during surveys not the result of turtles not returning to sandbars in subsequent years.

Apalone sp. nested on the majority of the sandbars while *G. pseudogeographica* appeared to be more selective. This difference might be due to the habitats utilized by adult turtles. *G. pseudogeographica* turtles prefer slower current and vegetated areas, like oxbows, as opposed to the fast flowing main channel of the river like *Apalone* sp. Six of seven sandbars used by *G. pseudogeographica* were located near oxbows or had a slow moving secondary channel on one side of the island.

Man-made vs. natural sandbars

Thirty five percent of nests were located on man-made sandbars. However, man-made islands account for only 19% of islands available for nesting. There was no difference in the habitat characteristics between the man-made sandbars and natural sandbars. There is, however, a difference in the slope between sandbar types. A possible

reason for the high proportion of nests located on man-made sandbars may be because they are located in a preferred habitat for adult turtles. There is also a lack of natural sandbars and nesting beaches along the stretches of river where the man-made sandbars are located. Nesting females may have no other option then to use the beaches on the man-made sandbars.

Of the 21 nests located on the man-made sandbars, 15 were found on the sandbar at RM761.5. There are at least two possible explanations as to why the majority of nests on man-made sandbars were located on the sandbar at RM 761.5. The sandbar at RM 761.5 is located in a stretch of the river with ideal adult habitat and because of its profile. The man-made sandbar at RM 770 has a very low profile and the sand is wet most of the nesting season, there by preventing turtles from nesting. The man-made sandbar at RM 755 has cut banks along the side by an oxbow with a healthy population of turtles, and gradual slope along the side that faces a fast flowing stretch of the Missouri River.

Habitat characteristics

Apalone sp. and *G. pseudogeographica* in South Dakota nest in habitat similar to other populations in North America (Ernst et al. 1994). Little variation occurs in the cover class habitat type used by *Apalone* sp. with most nests (90%) located in dry sand cover types. *G. pseudogeographica* nest sites were located in a more diverse group of habitats and 38% of nests were located in habitats with vegetation. This difference may explain why so few nests were located in comparison to *Apalone* sp., since survey efforts

were concentrated in areas with bare sand and sparse vegetation. *G. pseudogeographica* has TSD, so nesting in areas with some vegetation may ensure lower temperature in the nest cavity and a sex ratio of hatchlings close to 1:1.

Little terrestrial herbaceous vegetation and woody vegetation was found surrounding *Apalone* sp. nest sites. The composition of the substrate that nests were laid in was also mostly sand with no overhead shade. Had the midpoints of the Daubenmire ranges not been used for analysis, the percent sand composing the substrate would have been closer to 100% since the majority of the sandbars along this stretch of river are composed of fine sand (particles > 2 mm). However, *Apalone* sp. have been known to nest on gravel sandbars, so in areas where sand composition may be a little coarser it is not unusual to find nests (Johnson 2000). *Apalone* sp. also appeared to avoid any debris around the nest site.

G. pseudogeographica had more terrestrial herbaceous vegetation and woody vegetation around nest sites including a tolerance for higher vegetation. However, it is unlikely that vegetation caused enough shading to alter the temperature in the nests I observed (a result of my search protocol). However, as discussed earlier, *G. pseudogeographica* is known to nest in areas with greater amounts of vegetation where temperature would be lowered in the nest cavity (an evolutionary response to ensure a sex ratio close to 1:1). *G. pseudogeographica* nest sites were located solely in sand substrates. Had the midpoints of the Daubenmire ranges not been used in analysis the percent competition of the substrate would have been 100% sand. Debris was also more common surrounding the nest site with leaf cover, wrack and large debris recorded.

However, the percent coverage was very low, and it is unlikely that there would be any effect on incubation temperature.

Habitat model

Apalone sp.

Turtles may have several habitat characteristic thresholds that need to be met in order for a nest site to be selected for nesting, *Apalone* sp. may select specific nest sites within nesting areas based on habitat qualities (Wood and Bjorndal 2000, Bolton and Brooks 2007). The analysis of habitat characteristics from my study support this idea because differences were seen between the nest site and the measurements taken three meters surrounding the nest site (on-site landscape level). However, when the variables were used to construct a model, there was no significance found. Even though there were differences in the means of variables, the differences were not large enough to construct a selection model. Therefore, it may be beneficial in future studies to use a smaller on-site level scale and smaller quadrats.

At the off-site level, the difference in the variables was large enough to construct a selection model. Nest-site selection was occurring and turtles selected for areas without vegetation and leaf debris. This information supports the view that *Apalone* sp. prefer bare sand for nesting. However, if the random nest site selection process was truly random, it is possible that several of the random sites could have been used as nest sites, making it difficult to see a difference between areas used as nest sites and areas not

utilized for nesting (Hughes and Brooks 2006). It is likely that this holds true in this study and this would explains the low McFadden's Rho.

G. pseudogeographica

I could not construct a model because there were no differences in the means of the variables between the nest sites and at either the on-site or off-site levels were found. However, nest site selection may still be occurring. It is possible that I was looking in the wrong habitat. Due to the size of the survey area and the short nesting season of turtles in South Dakota, in an attempt to maximize the number of nests located, surveys were only conducted in areas of bare sand and along the vegetation line because *Apalone* sp. and *G. pseudogeographica* are thought to nest in bare sand (Timken 1968, Fitch and Plummer 1976b, Plummer 1976b, Vogt 1980, Doody 1995, Graham and Graham 1997, De Solla et al. 2003, Bolton and Brooks 2005, Riley et al. 2005). However, when the habitat characteristics surrounding the nest sites of *G. pseudogeographica* were examined, females were using sites with vegetation.

Spatial Analysis

The point pattern analysis suggested that *Apalone* sp. nests on the beach at RM 804.5 were clustered, which may explain the 100% depredation rate. When turtles nest in high density, they face a greater risk of depredation (Kolbe and Janzen 2002, Marchland and Litvaitis 2004). The nests on this beach were clustered exclusively in bare open sand, supporting the theory that *Apalone* sp. select this habitat for nest sites. Other

populations of *Apalone* sp. are reported to have nests clusters in specific areas on nesting beaches (Plummer 1976, Bolton and Brooks 2007). Since this beach is the only nesting area in approximately 8 kilometers of river, it demonstrates the importance of providing appropriate nesting sites along the entire stretch of the MNRR.

Management Implications

Introduction

Turtles are long lived animals and present a unique challenge to conservationists. Bolton and Brooks (2007) suggest that because turtles are long lived it may appear that populations are doing well. Turtle evolutionary response to changes is also very slow, so adapting to a rapidly changing environment is not always easily accomplished (Crouse et al. 1987, Congdon et al. 1994). If little or no recruitment occurs in a population, drastic decreases can result when the older individuals start to die. Therefore, when changes are made to nesting habitat, a decrease in the population may not be observed for many years after the alteration because adults continue to survive regardless of the lack of recruitment into the population and an inability to adapt.

Anthropogenic disturbances during egg laying and incubation are a serious conservation concern because mortality of eggs is high without the added pressure of humans (Congdon et al. 1983, 1987). When *Apalone* sp. are disturbed during nesting, they have been known to leave eggs uncovered, exposing them to certain termination (Bolton and Brooks 2007). I have observed this behavior along the MNRR for both *Apalone* sp. and *G. pseudogeographica*. Eggs and nest cavities can also be easily trampled when walked over by people (Bolton and Brooks 2007), which occurs frequently in the MNRR population because of least tern (*Sternula antillarum*) and piping plover (*Charadrius melodus*) surveys. I would recommend that when researchers happen upon a nesting female or a freshly constructed nest that they remain as far from the turtle as possible and avoid walking over nests.

Depredation

Horne et al. (2003) suggests that populations of turtles are declining as a result of low recruitment and abnormally low reproductive frequency. His model predicted that the number of eggs a nesting yellow blotched map turtle (*G. flavimaculata*) would need to lay in order to replace herself if depredation was 90% was 153 eggs. This depredation means a female would need to survive through 55 nesting seasons, which is far longer than the average life span of these turtles (Horne et al. 2003).

Although depredation rates are low and not apparently an immediate concern for the MNRR population, situations such as those at RM 804.5 are likely to increase as appropriate nesting sites are reduced (Kolbe and Janzen 2002). The nesting beach at RM 804.5 is the only nesting beach in an 8 km stretch of the river, and it is located on a large forested island. This situation creates high turtle nest densities near high predator populations, resulting in high depredation rates. Marchand and Litvaitis (2004) suggest removal of predators and/or caging nests as ways to limit depredation. However, they point out the removal of predators is not an effective long-term solution because of other methodological problems, such as the number of predators may be too numerous for trapping to be effective. The difficulty with caging nests is that there is a high labor requirement. I do not recommend trapping or caging nests along the MNRR. The most effective solution for limiting the effects of depredation on this stretch of the MNRR would be to ensure that there is plenty of available habitat throughout the entire length of the MNRR.

Habitat management

When attempting to understand life histories of turtles, it is important to understand nest site selection (Hughes and Brooks 2006, Resetarits 1996). Understanding habitat characteristics that nesting females select for is an important part of conservation. Managers need to better determine which nesting areas are of high importance and how human alterations to habitat can affect nest and hatchling success (Kolbe and Janzen 2002). Therefore, it is important that state and federal managers in South Dakota understand nest site selection when developing management plans for nesting habitat (Bolton and Brooks 2007).

Although *G. pseudogeographica* selected nest sites with some vegetation, I believe too much vegetation on sandbars would be detrimental. This species has TSD and too much vegetation around a nest site could result in a skewed sex ratio or failure to develop. Embryos of *Apalone* sp. benefit from vegetation free sandbars because of a tolerance for high nest temperatures during development (Ewert 1985). Sandbar habitat should provide open areas free of vegetation, and areas with sparse vegetation to meet the needs of imperiled aquatic turtles in the MNRR.

The timing of the nesting season for riverine turtles has adapted to coincide with dropping water levels in rivers as a way to avoid flooding nests and drowning of embryos (Brodie 2001). Nesting a greater distance from water or at higher elevations also limits the risk of a nest flooding (Graham and Graham 1997). Water levels are left low on this stretch of the MNRR during the majority of the nesting season, but can be raised significantly after least tern and piping plover fledge at the end of July. Generally, daily

fluctuations and small water flow increases for downstream navigation should cause no loss of nests. However, I would recommend that major raises (< 5 meters) are limited until mid September as the majority of nest should be hatched out.

Steep banks of sandbars are often inaccessible to nesting females (Barko and Briggler 2006). However, turtles have been known to attempt nesting in banks with a gradients up to 65 degrees (Horne et al. 2003). Doody (1995) also suggested that nesting females select for height above water rather then distance from water for nest sites to limit nest loss to flooding. Along this stretch of the MNRR, greater distances traveled were slightly associated with lower slopes and man-made sandbars. There is also a significant difference between the slopes of man-made sandbars and natural sandbars. Adults and hatchlings are also at risk for depredation and desiccation on the way back to the water. If turtles are selecting for height above water rather than distance from water, this issue could be negated by simply offering greater slopes on the banks of man-made sandbars. Therefore, I would recommend that when man-made sandbars are constructed slopes are increased to at least 10 degrees as that was the average slope of natural sandbars.

The most effective management technique for increasing turtle nesting and nest success is the creation of nesting areas/beaches (artificial or reclaimed) that take into account habitat preferences of the turtle species being managed for (Wilson 1998, Kolbe and Janzen 2002, Marchand and Litvaitis 2004). Therefore, I would recommend increasing the size, availability, and quality of available nesting areas. Quality habitat would include sandbars with steeper slopes, large areas of bare open sand and minimal

vegetation for predator habitat. I would also recommend returning to or simulation of a natural flooding regime. This would ensure sandbar creation along the entire stretch of the MNRR and would allow for the slow growth of vegetation on sandbars that is needed for *G. pseudogeographica* nesting sites. These measures would also likely increase hatchling recruitment and prevent depredation from becoming an issue for the MNRR turtle population (Bolton and Brooks 2007).

Future research recommendations

To better understand the habitat needs of turtles, long term studies are needed to develop sound management plans (Congdon et al. 1987, 1994). Future research needs should include factors that encourage or limit depredation rates, how depredation affects nest success, and how predators affect hatchling recruitment. Although predation is not an immediate concern for the MNRR population, as mentioned previously, when ideal nesting sites decline, depredation may become a significant source of population decline.

I recommend for future nest site selection modeling that a habitat availability assessment should occur at the sandbar level using only sandbars that are accessible to turtles. This way more area could be searched during the nesting season and habitat characteristics being selected for could better assessed, resulting in the construction of significant models. Using smaller quadrats for vegetation assessment would also help researchers determine the difference between site selected for nesting and those that were not with in the same beach. Future studies on *G. pseudogeographica* nest sites should focus on vegetation threshold around the nest sites.

It is also important to determine if there are differences in habitat characteristics between man-made and natural sandbars and if these affect nesting success, incubation length, distance traveled and depredation rates. It would be beneficial to better understand the relationship between the effects of size and slope on the distances traveled to nest sites. Understanding this relationship would provide valuable information on how the shape and size of man made sandbars can provide the most beneficial habitat for least terns, piping plovers and turtle species.

Literature Cited

Anderson, P.K. 1958. The photic responses and water-approach behavior of hatchling turtles. Copeia 1958:211-215.

Bandas, S.J. 2003. Geographic distribution and morphometrics of South Dakota turtles. M.S. Thesis. South Dakota State University, Brookings, South Dakota, USA.

Barko, V.A. and J.T. Briggler. 2006. Midland smooth softshell (apalone mutica) and spiny softshell (apalone apinifera) turtles in the middle Mississippi river Habitat associations, population structure, and implications for conservation. Chelonian conservation and biology 5(2): 225-231.

Bodie, J.R. and K.R. Smith. 1996. A comparison of diel nest temperature and nest site selection for two sympatric species of freshwater turtles. American Midland Naturalist 136(1):181-186.

Bodie, J.R. and R.D. Semlitsch. 2000. Spatial and temporal use of floodplain habitats by lentic and lotic species of aquatic turtles. Oecologia 122:138-146.

Bodie, J.R. 2001. Stream and riparian management for freshwater turtles. Journal of Environmental Management 62:443-455.

Bolton, R.M. and R.J. Brooks. 2005. Nest-site selection and embryo hatch success in Spiny Softshells at Long Point National Wildlife Area. Progress report for Wildlife Preservation Canada. 15 pp.

Bolton, R.M. and R.J. Brooks. 2007. Nest site selection and embryo hatching success in spiny, Blanding's and northern map turtles, and mitigation of mammalian predation and dipteran infestation of turtle nest at [a site in southern Ontario]. Progress report for Wildlife Preservation Canada. 18pp.

Burger, J. 1976. Behavior of hatchling diamondback terrapins (Malaclemys terrapin) in the field. Copeia 4:742-748.

Burger, J. 1977. Determinants of hatchling success in diamondback terrapin, *Malaclemys terrapin*. American Midland Naturalist 97:444-464.

Cagle, F.R. 1954. Observations on the life cycles of painted turtles (Genus Chrysemys). American Midland Naturalist 52(1):225-235.

Cagle, K.D., G.C. Packard, K Miller and M.J. Packard. 1993. Effects of the microclimate in natural nests on development of embryonic painted turtles, *Chysemys picta*. Functional Ecology 7:653-660.

Christiansen, J.L. and J.R. Parmelee. 2003. A key to the eggs and nests of Iowa. Journal of the Iowa Academy of Science 110(3-4):44-59.

Compton, B.W., J.M. Rhymer and M. McMcollough. 2002. Habitat selection by wood turtles (*Clemmys insculpta*): an application of paired logistic regression. Ecology 83(3):833-843.

Congdon, J.D., G.L. Breitenbach, R.C. van Loben Sels, and D.W. Tinkle. 1987. Reproduction and nesting ecology of snapping turtle, *Chelydra serpentine,* in southeastern Michigan, USA.. Herpetologica 43:39-54.

Congdon, J.D., A.E. Dunham and R.C. van Loben Sels. 1994. Demographics of common snapping turtles (*Chelydra serpentine*): implications for conservation and management of long-lived organisms. American Zoology 34:397-408.

Congdon, J.D., and J.W. Gibbons. 1990. Turtle eggs: there ecology and evolution. Pp.109-123. *In* Life history and ecology of the slider turtle (J.W. Gibbons ed.). Smithsonian Institution Press, Washington, DC., 368pp.

Congdon, J.D., D.W. Tinkle, G.L. Breitenbach and R.C. van Loben Sels. 1983. Nesting ecology and hatchling success in the turtle *Emydoidea blandingi*. Herpetologica 39(4):417-429.

Conant, R and J.T. Collins. 1998. Turtles. Pp. 146-199. *In* A field guide to reptiles and amphibians of eastern and central North America. 3rd edition, expanded, Houghton Mifflin Company, New York, NY. pp. xx + 620.

Cooley, K.E. 2003. Soil survey of Clay County, South Dakota. Natural recourses conservation service.

Crouse, D.T., L.B. Crowder and H. Caswell. 1987. A stage-based population model for loggerhead sea turtles and implications for conservation. Ecology 68:1412-1423.

Daigle, C.P. Galois and Y. Chagnon. 2002. Nesting activities of an eastern spiny shoftshell turtle, *Apalone spinifera*. Canadian Field-Naturalist 116(1):104-107.

Daubenmire,R. 1968. Ecology of fire in grasslands. In: Cragg,J.B. ed.Advances in ecological research.Vol.5. New York, NY: Academic Press: 209-266.

De Solla, S.R., M.L. Fletcher and C.A. Bishop. 2003. Relative contributions of organochlorine, parasitism and predation success of eastern spiny softshell turtles (*Apalone spiniferus spiniferus*) from southern Ontario, Canada. Ecotoxicology 12:261-270.

DonnerWright, D.M., M.A. Bozek, J.R. Probst and E.M. Anderson. 1999. Respoorne nses of the turtle assemblage to environmental gradients in the St. Croix River in Minnesota and Wisconsin, U.S.A. Canadian Journal of Zoology 77:989-1000.

Doody, J.S. 1995. Comparative nesting study of two syntopic specie of softshell turtles (Apalone mutica and Apalone spinifera) in southcentral Louisiana. MS Thesis. Louisiana State University.

Ernst, C.H., J.E. Lovich and R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, D.C., 682pp.

Ewert, M.A. 1979. The embryo and its egg: development and natural history. Pp 333-413. In Turtles: perspective and research (M. Harless and M. Morlock, eds.). Wiley, New York. NY, 698pp.

Ewert, M.A. and C.E. Nelson. 1991. Sex determination in turtles: Diverse patterns and possible adaptive values. Copeia 1991:50-69.

Fischer, R.U., F.J. Mazzotti, J.D. Congdon, and R.E. Gatten Jr. 1991. Post-hatching yolf reserves: parental investment in American Alligators from Louisiana. Journal of Herpetology 25:254-256.

Fitch, H.S. and M.V. Plummer. 1975. A preliminary ecological study of the soft-shelled turtle *Trionyx muticus* in the Kansas River. Israel Journal of Zoology 24:28-42.

Frazer, N.B. and J.I. Richardson. 1986. The relationship of clutch size and frequency to body size in loggerhead turtles, Caretta caretta . Journal of Herpetology 20(1):81-84.

Galat, D.L., J.W. Robinson, and L.W. Hesse. 1996. Pp. 49-71. *In* Overview of river-floodplain ecology in the upper Mississippi Basin (D.L. Galat and A.G. Frazier eds.) Science floodplain management into the 21st century (J.A Kelmelis ed.). Vol 3). United States Government Printing Office, Washington, D.C.

Gibbons, J.W. and J.L. Greene. 1990. Reproduction in the slider and other species of turtles. Pp, 124-134. *In* Life history and ecology of the slider turtle (Gibbons J. ed.) Smithsonian Institution press. Washington D.C., pp. 368.

Gibbons, J.W. and R.D. Semlitsch. 1982. Survivorship and longevity of a long-lived vertebrate species: how long do turtles live? Journals of animal ecology 51:523-527.

Gibbons, J.W. and D.W. Tinkle. 1969. Reproductive variation between turtle populations is a single geographic area. Ecology 50:340-341.

Graham, T.E. and Graham, A.A. 1997. Ecology of the eastern spiny softshell, *Apalone spinifera spinirera*, in the Lamoille River, Vermont. Chelonian conservation and biology 2(3):363-369.

Gyuris, E. 1993. Factors that control the emergence of green turtle hatchlings form the nest. Wildlife Research 20:345-353.

Horne, B.D., R.J. Brauman, M.J.C. Moore and R.A. Seigel. 2003. Reproductive and nesting ecology of the yellow-blotched map turtle, *Graptemys flavimaculata*: implications for conservation and management. Copeia 2003(4):729-738.

Hughes, E.J., and R.J. Brooks. 2006. The good mother: does nest-site selection constitute parental investment in turtles? Canadian Journal of Zoology. 84:1545-1554.

Iverson, J.B. 1991. Patters of survivorship in turtles (Order Tesusines). Canadian Journal of Zoology 69:385-391.

Janzen, F.J. 1993. The influence of incubation temperature and family on eggs, embryos, and hatchlings of the smooth softshell turtle (Apalone *mutica*). Physiological Zoology 66(3):349-373.

Janzen, F.J. 1994. Vegetational cover predicts the sex ratio of hatchling turtles in natural nests. Ecology 75(6):1593-1599.

Janzen, F. J., and G. L. Paukstis. 1991. A preliminary test of the adaptive significance of environmental sex determination in reptiles. *Evolution* 45:435-440.

Janzen, F.J., J.C. Ast and G.L. Paukstis. 1995. Influence of the hydric environment and clutch on eggs and embryos of two sympatric map turtle. Functional Ecology 9:913-922.

Johnson, T.R. 2000. The amphibians and reptiles of Missouri. Jefferson City, MO: Missouri Department of Conservation.

Kiesow, A.M. 2006. Reptiles. Pp. 70-72 and 76-82. *In*: A field guide to amphibians and reptiles of South Dakota. South Dakota Game, Fish and Parks. Pierre, SD, pp. viii + 178.

Kolbe, J.J. and F.J. Janzen. 2001. The influence of propagule size and maternal nest-site selection on survival and behavior of neonate turtles. Functional Ecology 15:772-781.

Kolbe, J.J. and F.J. Janzen. 2002. Impact of nest-site selection on nest success and nest temperature in natural and disturbed habitats. Ecology 83(1):269-281.

Kraemer, J.E. and S.H. Bennett. 1981. Utilization of posthatching yolk in Loggerhead Sea Turtles, *Caretta caretta*. Marine Biology 126:406-411.

Marchand, M.N. and J.A. Litvaitis. 2004. Effects of landscape composition, habitat features, and nest disturbance on predation rates of simulated turtle nests. Biological Conservation 117:243-251.

McGaugh, S.E., C.M. Eckerman and F.J. Janzen. 2008. Molecular Phylogeography of *Apalone spinifera* (Testudines: Trionychidae). Zoologica scripta 37:289-304.

Moll, E.O. 1973. Latitudinal and intersubspecific variation in reproduction of the painted turtle, Chrysemys picta. Herpetologica 29:307-318.

Moll E.O. and Moll D. 2000. Conservation of river turtles. Pp 126-155. In: Turtle conservation (Klemend, M.W. Ed.). Washington, DC, Smithsonian Institution Press. Pp. x + 393.

Morjan, C.L. 2003. Variations in nesting patterned affecting nest temperatures in two populations of painted turtles (*Chrysemys picta*) with temperature-dependent sex determination. Behavioral Ecology Sociobiology 53:254-261.

Nagel R.D., M.V. Plummer, J.D. Congdon, and R.U. Fischer. 2003. Parental investment, embryo growth, and hatchling lipid reserves in softshell turtles (*Apalone mutica*) from Arkansas. Herpitologica 59:145-154.

Oldfield, B. and J.J. Moriarty. 1994. Amphibians and reptiles native to Minnesota. University of Minnesota Press, Minneapolis, MN. pp. 237.

Orenstein, R. 2001. Twixt plated decks. Pp. 171-173. *In* Turtles, Tortoises and Terrapins: survivors in armor. 1st ed. Firefly Books, Buffalo, NY, pp. xii + 308.

Packard, G.C. 1991. Physiological and ecological importance of water to embryos of oviparous reptiles. Pp. 213-228. *In* Egg incubation: its effects on embryonic development in birds and reptiles (D.C. Deeming and M.W.J. Ferguson, eds.). Cambridge University Press, New York, NY, pp.464.

Packard, G.C. 1999. Water relations of chelonian eggs and embryos: Is wetter better? American Zoologists 39:289-303.

Packard, G.C. and M.J. Packard. 1988a. Physiological ecology of reptilian eggs and embryos. Pp. 523-605. *In* Biology of the reptilia (C. Gans and R.B. Huey, eds.). Vol.16. Liss, New York, NY, pp.672.

Packard, G.C. and M.J. Packard. 1988b. Water relations of embryonic snapping turtles (*Chelydra serpintina*) exposed to wet of dry environments at different times in incubation. Physiological Zoology 61(2):95-106.

Packard, G.C., T.L. Taigen, M.J. Packard and T.J. Boardman. 1981. Changes in mass of eggs of softshell turtles (*Trionyx Spiniferus*) incubated under hydric conditions simulation those of natural nests. Journal of Zoology, London 193:81-90.

Packard G.C., M J. Packard, K. Miller and T.J. Boardman. 1987. Influence of moisture, temperature and substrate on snapping turtle eggs and embryos. Ecology 68(4):983-993.

Plummer, M.V. 1976a. Activity, habitat and population structure in the turtle, *Trionyx muticus*, Copiea 3:431-440.

Plummer, M.V. 1976b. Some aspects of nesting success in the turtles, Trionyx muticus. Herpetologica 32:353-359.

Plummer M.V. 1977a. Reproduction and growth in the turtle Trionyx muticus, Copeia 1977:440-447.

Plummer, M.V. 1977b. Notes on the courtship and matting behavior of the softshell turtle, Trionyx muticus. Journal of Herpetology 11(1):90-92.

Plummer, M.V. 2007. Nest emergence of smooth softshell turtle (*Apalone mutica*) hatchlings. Herpetological conservation and biology 2(1):61-64.

Porter, K.R. 1972. Reproductive adaptations of reptiles. Pp. 378-389. *In* Herpetology. W. B. Saunders Company, Philadelphia, PA, pp.xii + 524.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing,Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Resetarits, W.J., Jr. 1996. Oviposition site choice and in history evolution. American Zoology 36:205-215.

Riley, C.M., R.V. Anderson and S.E. Jenkins. 2005. Nesting habitat of the softshell turtle, *Trionyx mutica*, below lock and dam 19, upper Mississippi river. Journal of Freshwater Ecology 20(3):513-517.

Ripley, B. D. 1981. *Spatial Statistics.* Wiley, New York, NY, pp. 252.

Robinson, C. and J.R. Bider. 1988. Nesting synchrony – a strategy to decrease predation of snapping turtle (*Chelydra serpintina*) nests. Journal of Herpetology 2(4):470-473.

Robinson, K.M. and G.C. Murphy. 1978. The reproductive cycle of the eastern spiny softshell turtle (Trionyx spiniferus spiniferus). Herpetologica 34:137-140.

Samson, J., Hughes, E.J., Brooks, R.J. 2007. Excavation is a non-deleterious method to obtain fecundity and morphometric data from eggs of freshwater turtles. Chel. Cons. Biol. 5: 263-266.

Schwarzkopf, L. and R.J. Brooks. 1987. Nest-site selection and offspring sex ratio in painted turtles, *Chrysemys picta*. Copiea 1:53-61.

Sherfy, M. H., J. H. Stucker, and M. J. Anteau. In press. Missouri River emergent sandbar habitat monitoring plan: a conceptual framework for adaptive management. USGS Open File Report 2008-1223.

Stukel E.D., D. Backlund, D. Ode, C. Schlueter, L Gigliotti and C. Mehl. 2006. "South Dakota wildlife action plan – the big picture". South Dakota Game, Fish and Parks. 13 April 2009. http://www.sdgfp.info/Wildlife/Diversity/Comp_Plan /planarticle.pdf.

SYSTAT version 12. 2007. SYSTAT Software Inc. Richmond CA.

Temple S.T. 1986. Predation on turtle nests increase near ecological edges. Copiea 1:250-252.

Timken, R.L. 1968. The distribution and ecology of turtles in South Dakota. PhD Dissertation. University of South Dakota, Vermillion, South Dakota, USA.

Tinkle, D.W., J.D. Congdon and P.C. Rosen. 1981. Nesting frequency and success: implications for the demography of painted turtles. Ecology 62:1426-1432.

US Army Corps of Engineers. 2004. Final environmental assessment for the restoration of emergent sandbar habitat complexes as Missouri River miles 790.0, 796.8 and 761.4; Nebraska and South Dakota.

U.S. Fish and Wildlife Service. 2000. Biological opinion on the operation on the Missouri River main stem reservoir system, operation and maintenance of the Missouri River bank stabilization and navigation project, and operation of the Kansas River reservoir system.

Vogt, R.C. 1980. Natural history of the map turtles *Grapytemys psuedogeographica* and *G. Ouachitensis* in Wisconsin. Tulane Studies in Zoology and Botany 22(1):17-48.

Vogt, R.C. and J.J. Bull. 1982. Genetic sex determination in the spiny softshell Trionyx spiniferus (Testudines: Trionychidae). Copeia 1982:699-700.

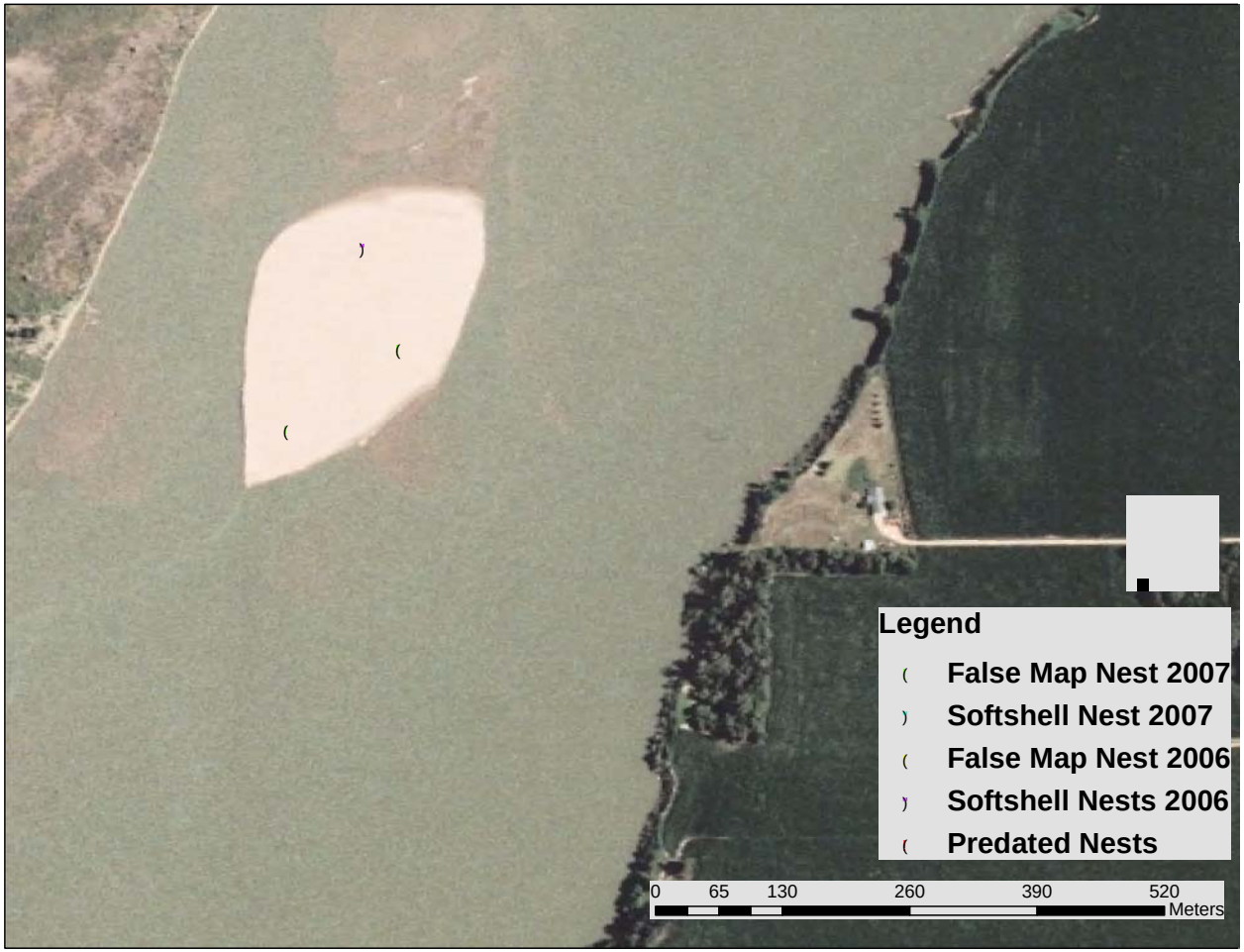
Vogt, R.C. and J.J. Bull. 1984. Ecology of hatchling sex ration in map turtles. Ecology 65:582-587.

Webb, R.G. 1962. North American recent softshell turtles (family Trionchiae). University of Kansas Publications, Museum of Natural History 13:429-611.

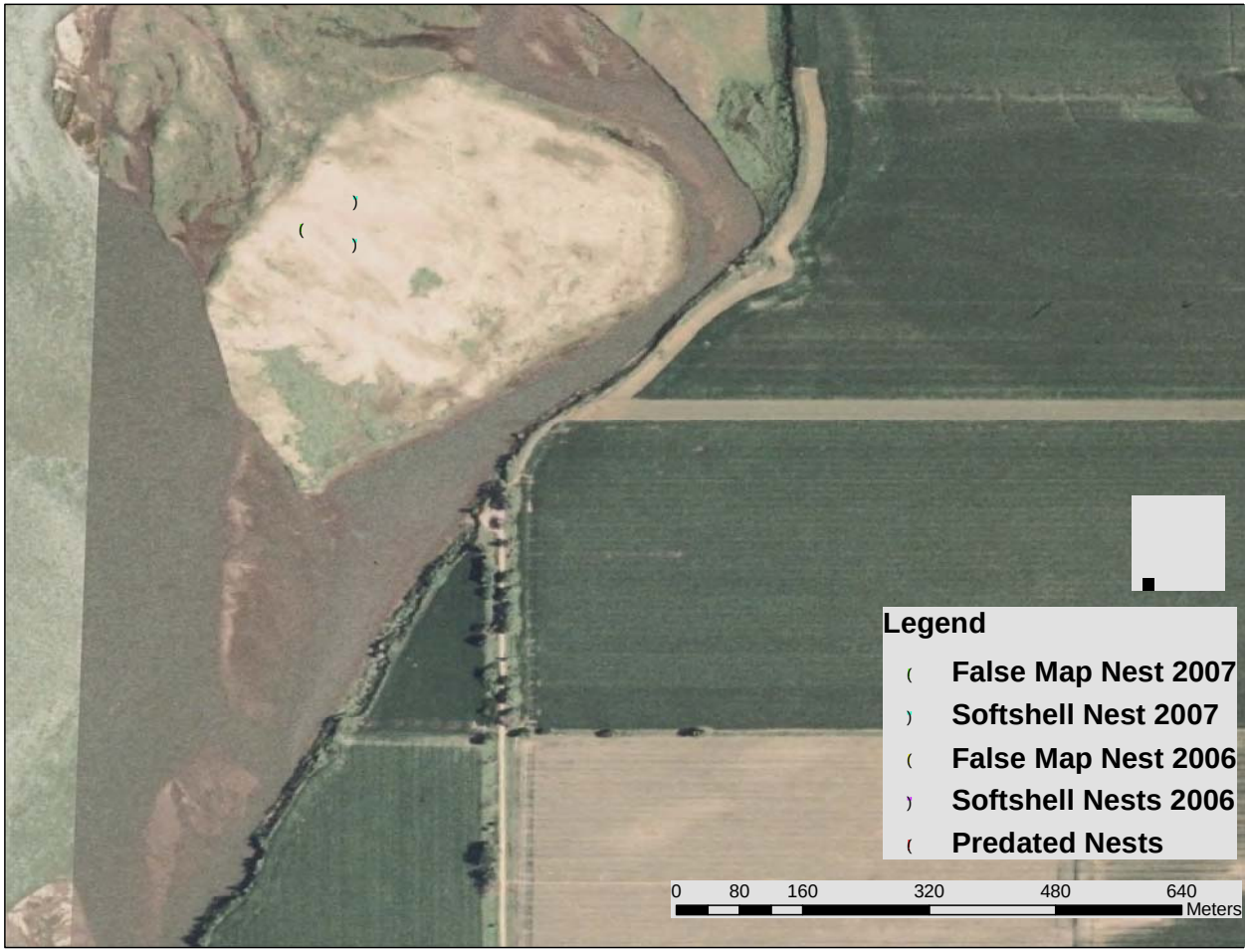
Wilson, D.S. 1998. Nesting ecology of the striped mud turtle (*Kinosternon baurii*) in central Florida. Linnaeus fund research report. Chelonian Conservation and Biology 3(1):142-143.

Witherington, B.E., K.A. Bjorndal and C.M McCade. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. Copiea 1990:1165-1168.

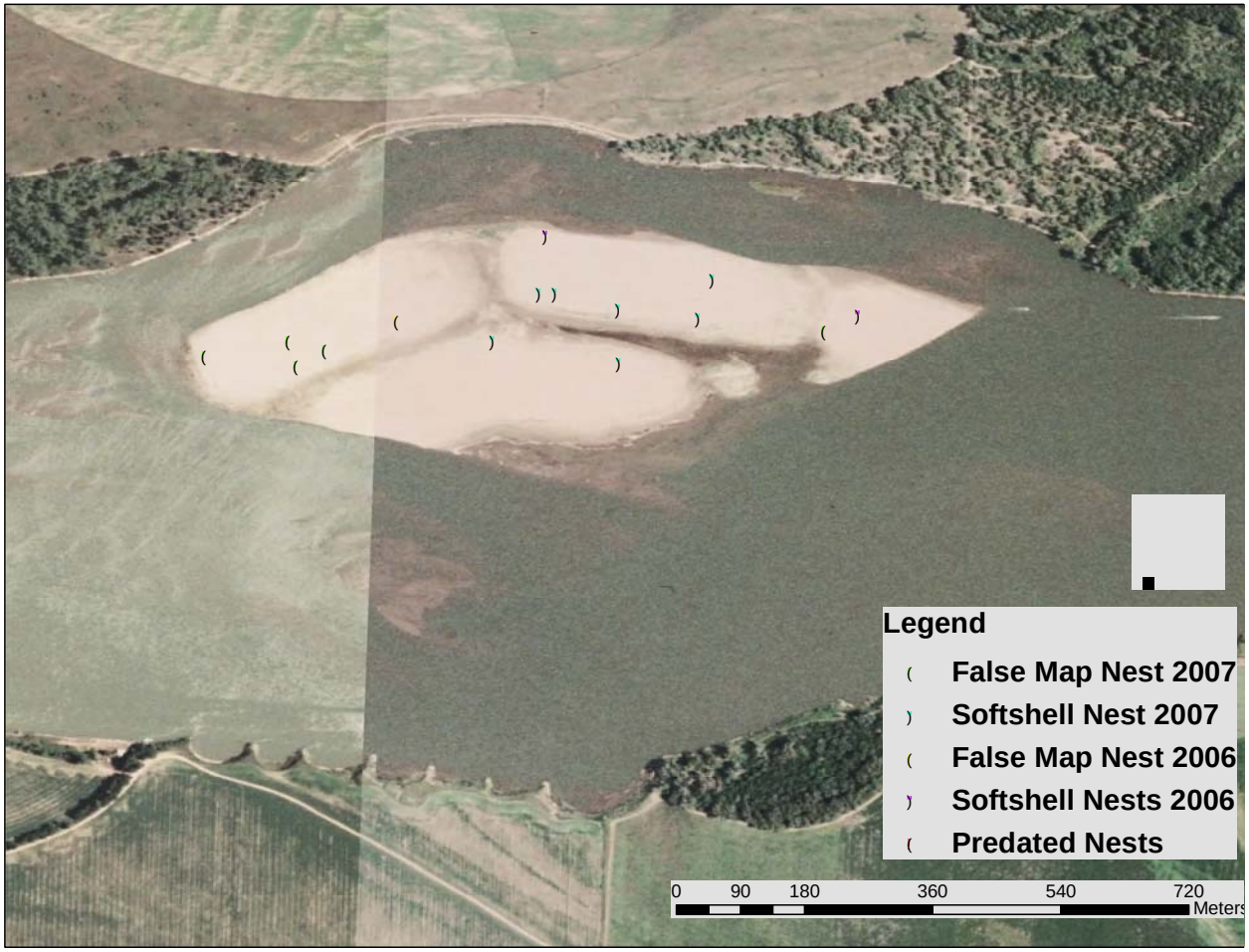
Wood, D.W. and K.A. Bjorndal. 2000. Relation of temperature, moisture, salinity and slope to nest site selection in loggerhead sea turtles. Copeia 2000:119-128.



Sandbar at RM 755



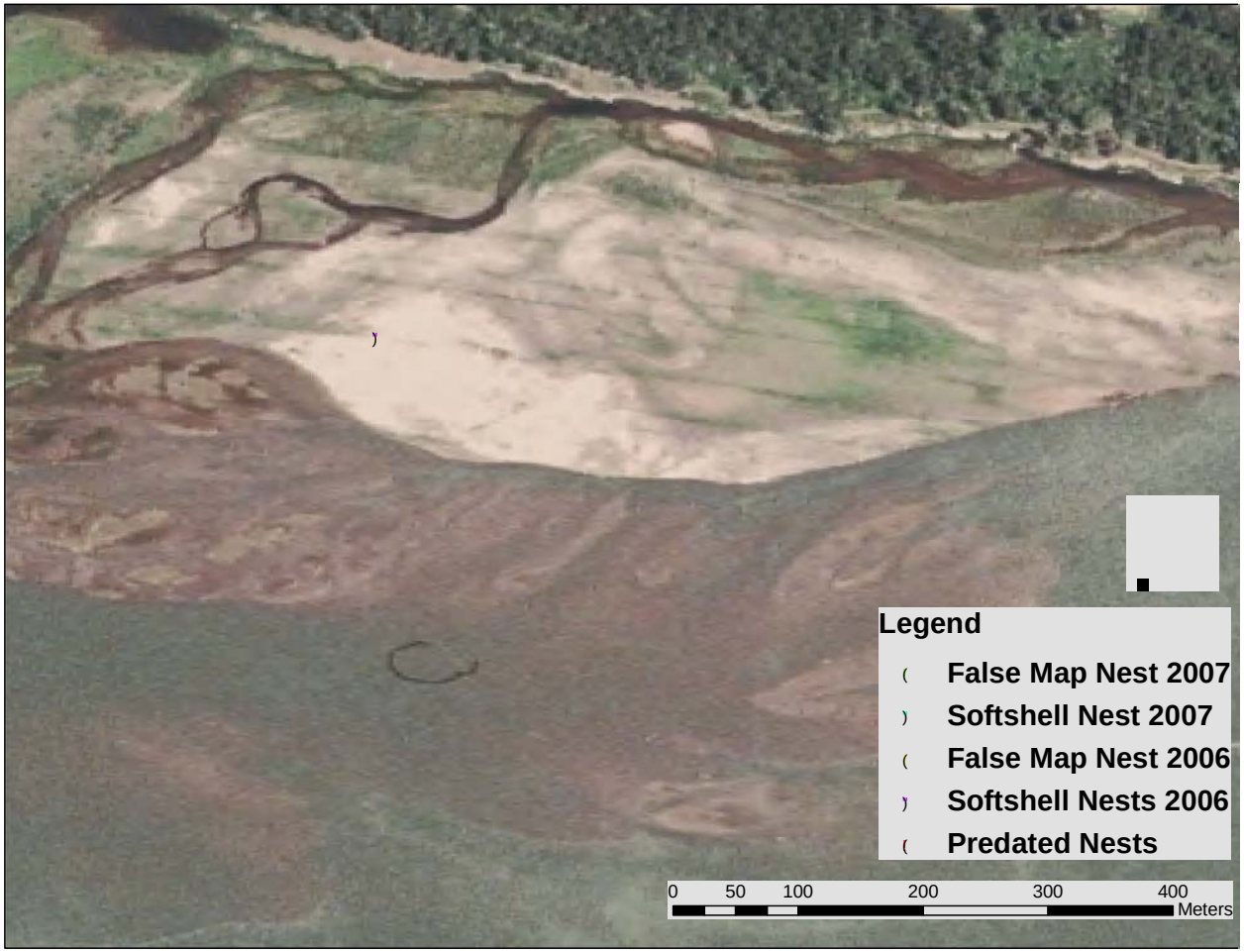
Sandbar at RM 756.5



Sandbar at RM 761.5

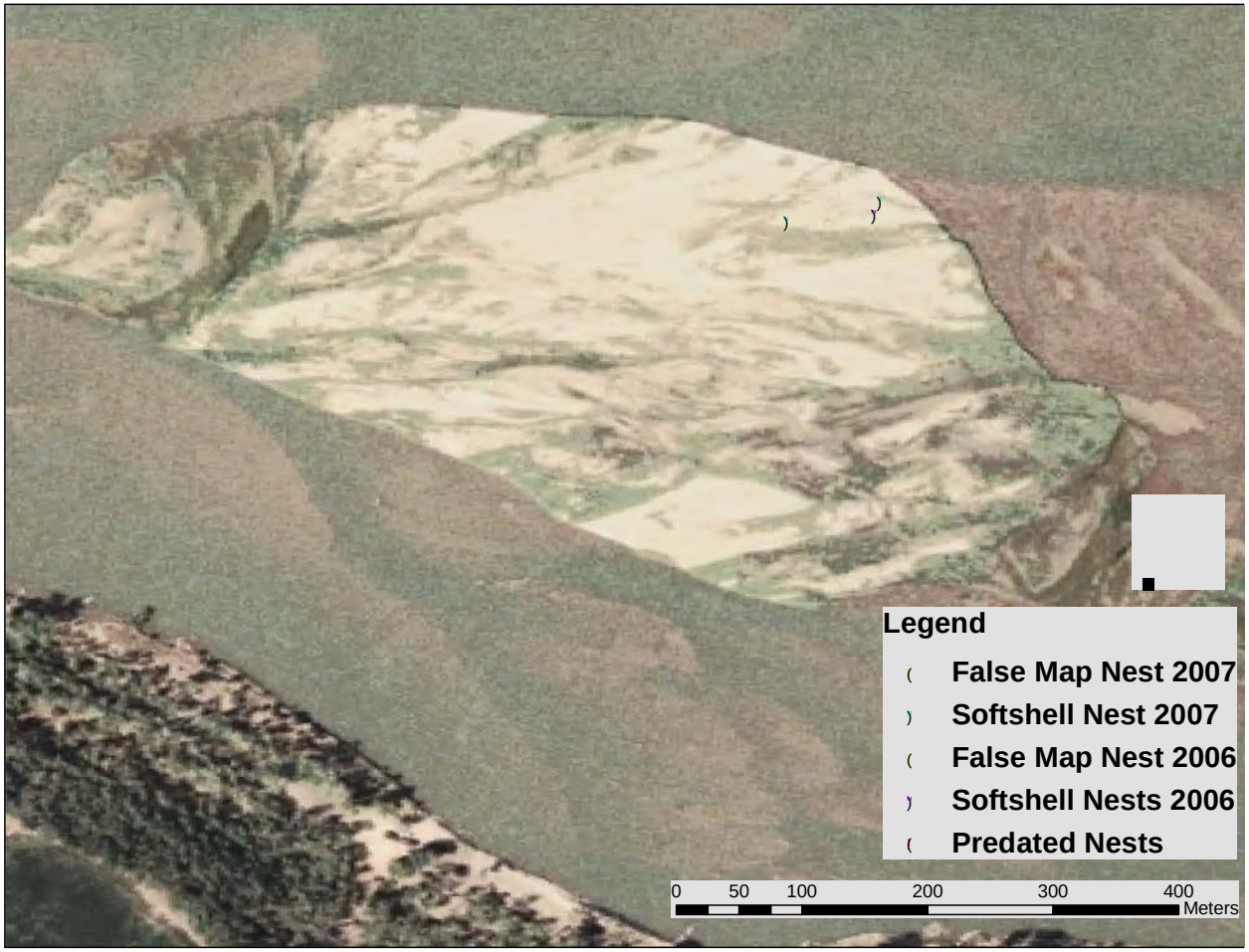
Sandbar at RM 768

Sandbar at RM 770



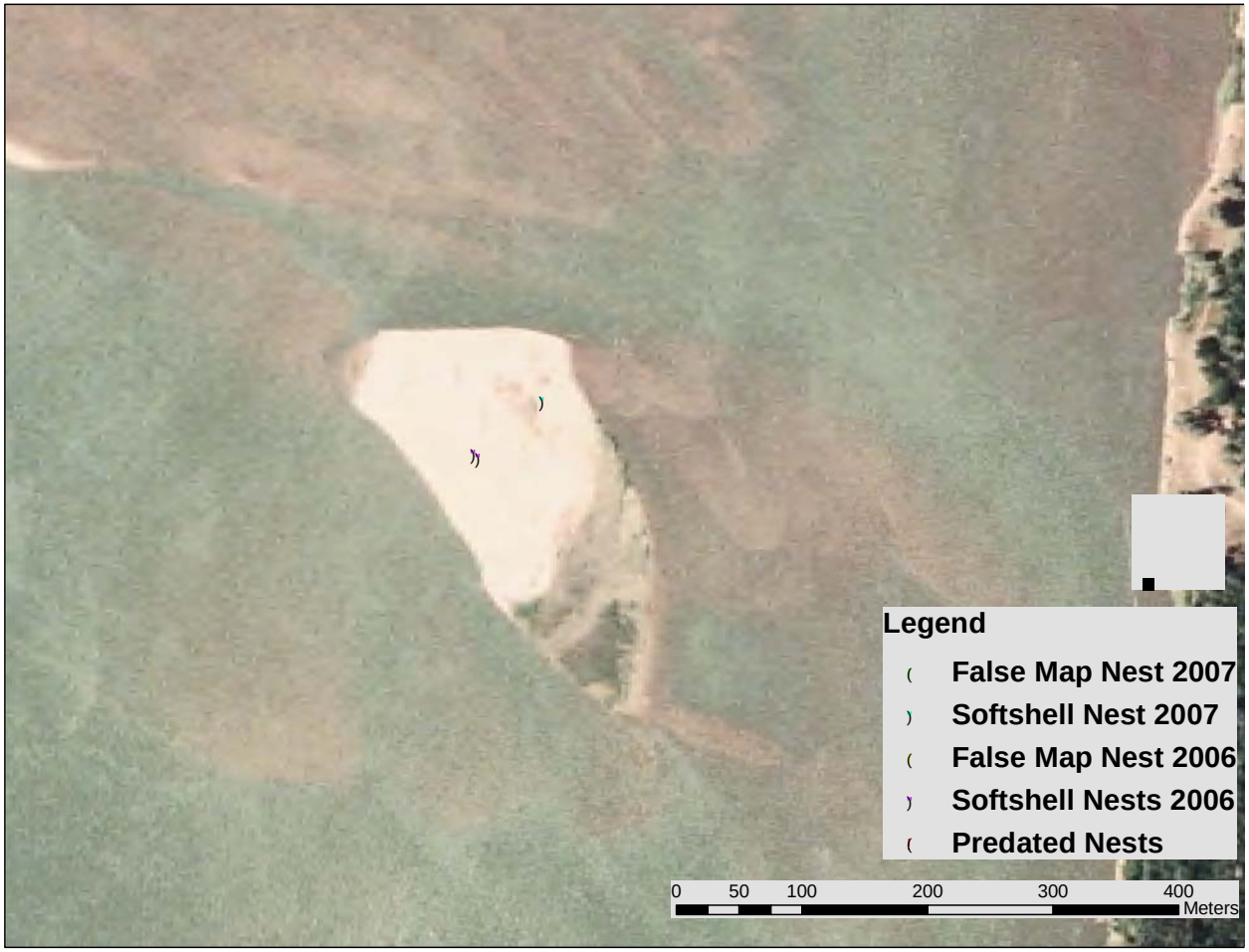
Sandbar at RM 773

Sandbar at RM 777



Sandbar at RM 781.5

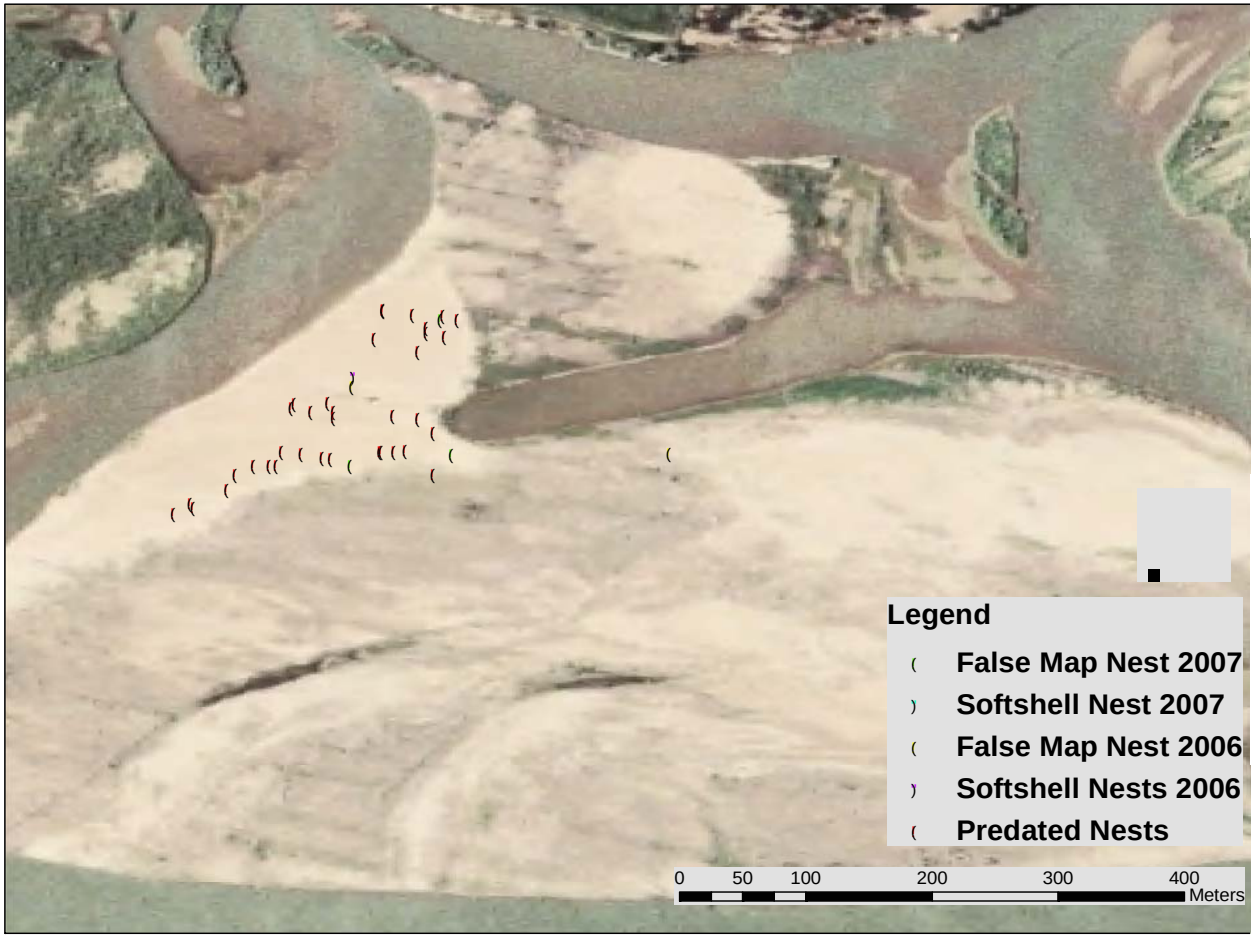
Sandbar at RM 788



Sandbar at RM 795

Sandbar at RM 796.5

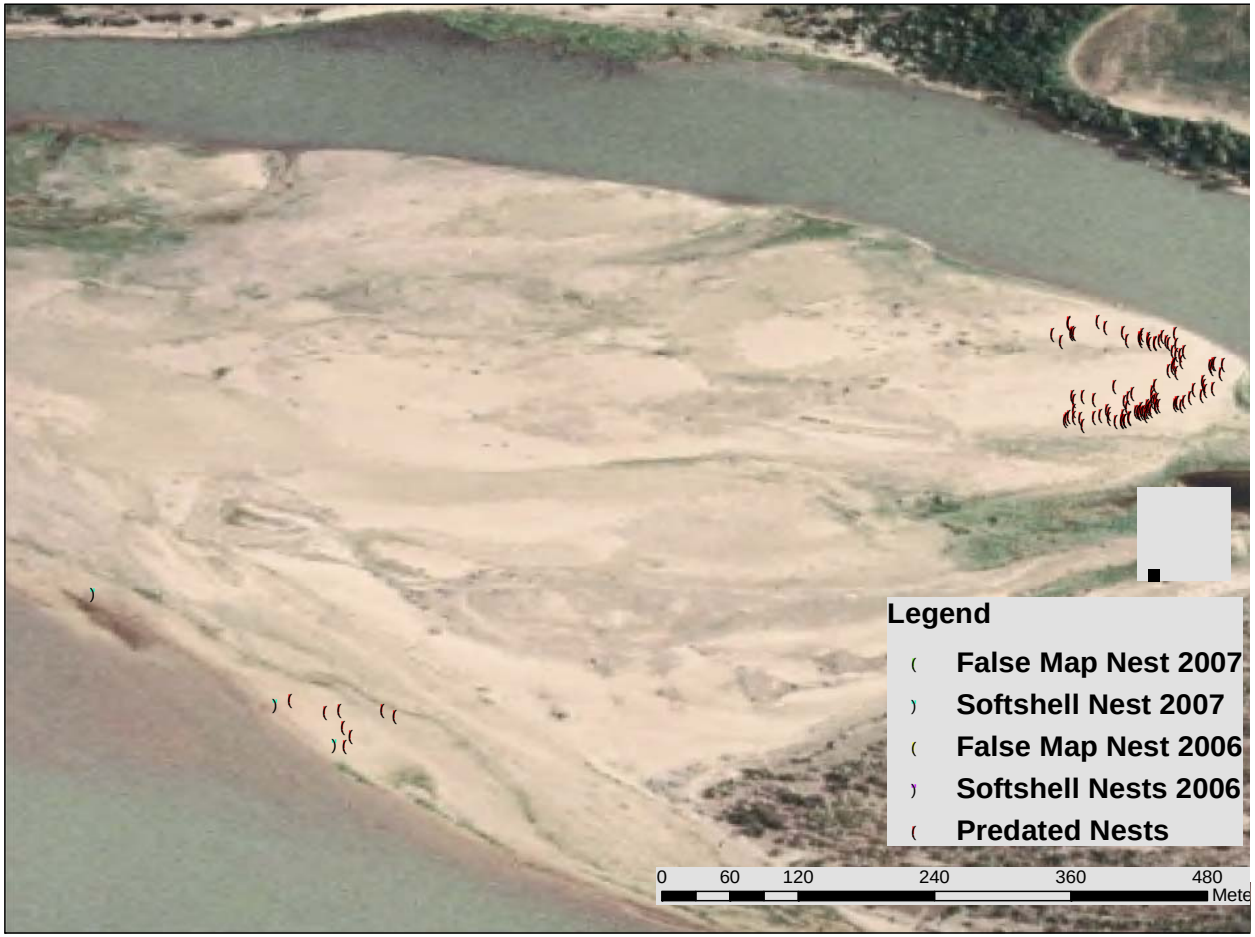
Sandbar at RM 798



Sandbar at RM 801.5

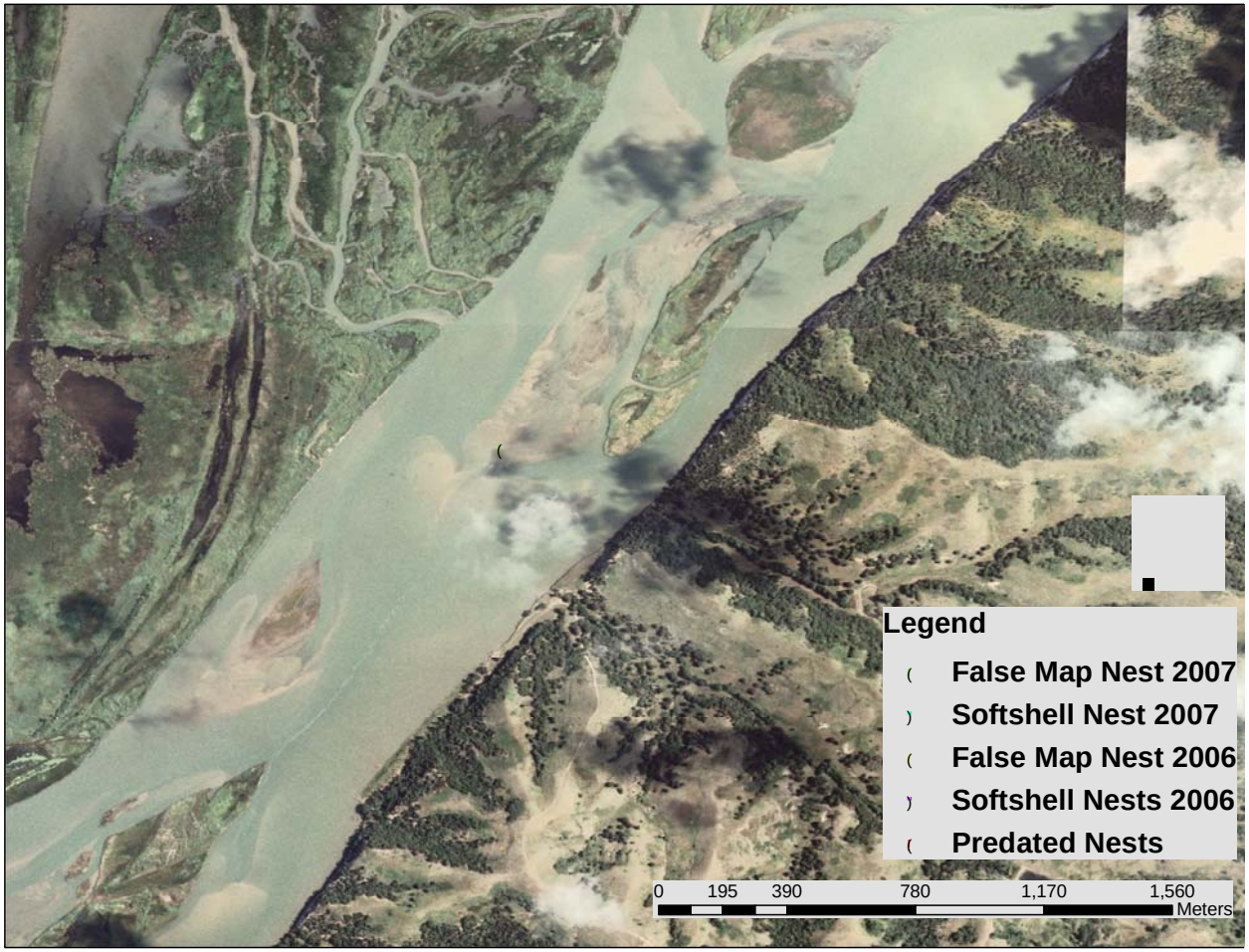
Sandbar at RM 802

Sandbar at RM 802.5



Sandbar at RM 804.5

Sandbar at RM 808



Sandbar at RM 835