Nest Site Selection and Predation of *Chrysemys picta* and *Chelydra serpentine*

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Abstract

I evaluated which physical habitat variables of nesting painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentine*) could be used to form a predictive model of presence, density, and depredation (using discriminant and multiple regression analysis). Nests along gravel roads (n=359) were measured for the following variables: soil type, type of nearest body of water, slope and aspect of the nest, as well as the distance to the nearest body of water, patch of wooded area, and the nearest turtle nest. The distance to the nearest body of water and light intensity were significantly associated with the presence or absence of painted turtle nests. Soil type, distance to the nearest body of water, aspect, and light intensity were all found to be driving variables in determining the presence or absence of snapping turtle nest sites. The multiple regression model for painted nests showed only slope and soil moisture, and snapping turtle nests showed that the type of adjacent body of water, distance to the nearest body of water, and soil moisture were significant in determining the number of nests across sites. The slope of the site, the aspect, soil moisture, and light intensity were all determined to be driving factors in predicting depredation of painted turtle nests. Only soil type was considered a driving factor in predicting snapper depredation. Light intensity was a common variable in predicting painted turtle presence and depredation, as was soil type for snappers. However, it is unlikely that there are nesting adaptations to avoid nest predation. It is important to understand depredation and nest destruction rates, both by predators and anthropological causes, because of turtle's long lifespan and easily disturbed life tables.

Introduction

Although there is a general knowledge of conditions female snapping turtles (*Chelydra serpentine*) and painted turtles (*Chrysemys picta*) select to nest in, there is little research studying habitat and other ecological characteristics that affect the success of offspring. The physical factors involved in nest selection play an important role in the fitness, survivability, and phenotype of the hatchlings (Weisrock and Janzen 2000, Packard et al. 1999). Furthermore, because turtles do not tend to their nests or raise young, nest site selection is the only manner in which parental care is shown (Hughes and Brooks 2000). A series of detailed observations concerning popular nesting and highest predation conditions would be useful in determining what combination of conditions result in the highest fitness.

Physical Factors of Nest Site Selection

In order to asses the conditions of preferred nesting sites, I need to establish an understanding of the factors involved in the development of hatchlings. Both painted and snappers are temperature sex determined (TSD) species, meaning that hatchling sex is determined by incubation temperature (Wilhoft et al. 1983). Sun light exposure, largely regulated by the amount of over hanging vegetation, determines incubation temperature, which is critical both to hatchling survivability and sex (Wilhoft et al. 1983, Kolbe and Janzen 2002, Congdon et al. 1987). Temperature also depends on other physical variables such as aspect and soil moisture, which can induce freezing and destroy over-wintering painted hatchlings. Previous studies have shown preference among painted turtles for southwestern aspects and dry (less than 15% saturation) soil (Hughes and Brooks 2000, Costanzoa et al. 2000). At the same time, hatchlings in wetter conditions have shown to consume more egg yolk and therefore have greater fitness (Packard et al. 1999). Because nesting is a dangerous and expensive process, turtles should also show a distinct preference for potential nesting areas located closer to the safety of their home body of water. Studies by Congdon and Gatten (1989) concluded that painted turtles spent on average 1.5h constructing the nest. Furthermore, the nesting process proved to be highly anaerobic, producing 3.7 times more lactate than resting status. Compounding the danger is the fact than many nesting painted turtles spend the night on land and return to their home habitat in the morning (Rowe et al. 2005), extending the period in which the turtle is vulnerable to predators, possibly necessitating the need for adjacent vegetative shelter.

Physical Factors of Predation

The most significant form of egg mortality is depredation (Hamilton et al. 2002, Christens and Bider 1987), averaging 70% in long term studies and occurring primarily in the first 24h of nesting (Congdon et al. 1987, Robinson and Bider 1988, Tinkle et al. 1981). Because many known predators of freshwater turtle nests have been observed on the property being researched, including Coyotes (*Canis latrans*), Gray Foxes (*Urocyon cinereoargenteus*), Fishers (*Martes pennanti*), Minks (*Mustela vison*), and Raccoons (*Procyon lotor*), the potential predation rate is high (Marchand and Litvaitis 2002). Previous research concerning freshwater turtle nest predation has conflicting conclusions of the importance of many physical characteristics of nesting turtles on predation rates. For example, studies have concluded that proximity to a major body of water both increases (Marchand and Litvaitis 2004, Marchand et al. 2002, Temple 1987) or has no effect on depredation (Congdon et al. 1987, Robinson and Bider 1988, Rowe et al. 2005).

There is also conflicting evidence over whether close proximity to wooded areas (and habitat fringes other than shorelines) increases (Wilhoft et al. 1979, Temple 1987) or decreases depredation (Marchand and Litvaitis 2004). Studies have ultimately concluded that nests in clusters (within close proximity to each other) are likely to have a higher rate of depredation (Marchand and Litvaitis 2004, Robinson and Bider 1988, Marchand et al. 2002). Furthermore, because snapping turtles have a high propensity to return to the same grounds every nesting season, it is likely that predators will frequent these locations more often (Kynast 2008, Robinson and Bider 1988). Nesting turtles may also prefer obscured coverage provided by overhanging vegetation in order to avoid predation, but at the same time must allow enough sunlight to stabilize incubation temperatures.

Predation is a consequence of nest location relative to the foraging activities of predators (Marchand and Litvaitis 2003). Where the driving physical variables of nest site selection and predation coincide, predator prey interactions can be inferred. By analyzing what physical variables follow the same trends for nest site selection and depredation, I can determine areas in which snapping and painted turtle survivorship is compromised. On the contrary, if nest selection seems to avoid the important factors of predation, a form of nest survival technique could be inferred. Previous studies by Robinson and Bider (1988) have shown that snapping turtles do not nest in areas of the highest survivorship, however, it has been suggested by Hamilton et al. (2002) that turtles may exhibit nesting behavior adapted to predation. Determining the predator prey interaction aids in understanding the population dynamics of snapper and painted turtle populations.

METHODS

Variables

To determine nest site selection and nesting success in painted and snapping turtles, I measured a variety of abiotic factors that characterize nest site location. Variables quantified included: the soil type, type of nearest body of water, slope and aspect of the nest, as well as the distance to the nearest body of water, patch of wooded area, and the nearest turtle nest were all recorded (Table 1). Soil was categorized as either gravel, sand, or grass. Each category was given a relative grain size value of 10, 5, or 1 respectively. The nearest body of water was categorized as either a lake, creek/stream or pond. Distances to the body of water, wooded area, and nearest nests were measured from the center of the sample nest to the edge of each parameter outlined above. Wooded areas were defined as substantial vegetation that could provide shelter for either a turtle or a mammalian predator, usually consisting of a cluster of trees. The nest itself was characterized by two factors, the species that made the nest (either painted or snapper) and whether it had been depredated by a predator. In order to help with data collection, nests were clustered into sites based on geographical location. Site size followed no specific regulations, but rather was based on nest clustering (mean nest number per site =15, n_{sites}=24). All sites consisted of a stretch of road usually 30-40 meters long and 10-20 meters wide. Each site was further characterized by two factors, soil moisture and light intensity. Soil moisture was measured with an HB-2 Kelway Soil Acidity and Moisture Tester and taken only when precipitation did not exceed 2cm in 24 hours. Light intensity was measured with a LI-COR LI-1000 Data Logger and taken only during clear skies and between the hours of 1100 and 1400. For most sites, only one soil moisture and light intensity reading was taken and applied to all nests located within that site. However, sites that showed heterogeneous differences in either variable, caused by different draining patterns or shade coverage, had multiple readings taken. GPS coordinates were also taken for each site location (Map 1). For an experimental control, the same measurements were taken for 15 randomly selected sites in which no turtle nests were found. Unlike previous studies of turtle nest depredation, this experiment is purely observational and does not implement any artificial nest or variable manipulations. All sites are on or along low traffic gravel roads.

Predicting the Presence/Absence of Nests Among Sites

The data for the control sites, in which no nests were found, were used to calculate the probability of turtle nest absence. The averages of each variable were calculated for sites ($n_{\text{total sites}}$=39) and assed using a discriminant function analysis (using MYSTAT 12; SPSS Chicago, IL), with the presence of each species acting as the grouping variable and the mean of each physical variable as the predictors. The results were predictive models for the presence and absence of both species of turtle (a total of 4 models).

Predicting Numbers of Nests Within Sites

Multiple regression analyses were run on the individual nest site data (n_{nests}=359), excluding sites specifically chosen to lack nests. For these analyses, the raw values of the physical parameters were used to assess nest density (the number per site). Stepwise procedures were employed using MYSTAT 12.

Predicting Depredation of Individual Nests

The whole collection of raw data, excluding the control sites chosen specifically without turtle nests, was divided by species and run through two discriminant function analyses (using MYSTAT 12), with depredation as the grouping variable and the measured physical variables as the predictors. The results were predictive models for the occurrence or absence of predation of nests for each species of turtle (a total of 4 models).

RESULTS

Predicting the Presence/Absence of Nests Among Sites

A discriminant functions analysis using backward stepwise elimination revealed distinct physical variables that predict the presence and absence of painted and snapper nests. The distance to the nearest body of water and light intensity were significantly associated with the presence of painted turtle nests (Figures 1 and 2). The predictive models derived from these factors (Figure 1) provide an overall 85% accuracy (95% for the presence of nests; 71% for the absence of nests). Soil type, distance to the nearest body of water, aspect, and light intensity were all found to be driving factors in determining the presence or absence of snapping turtle nest sites (Figures 3 through 6). The models derived from these factors (Figure 3) provide an overall 85% accuracy (94% for the presence of nests; 76% for the absence of nests).

Predicting Numbers of Nests Within sites

Multiple regression analyses (using both forward and backward elimination methods) were used to establish the dependent relationship of the number of nests present among sites with the measured variables. The multiple regression model for painted nests showed only slope and soil moisture to be of significant importance in determining the number of nests present (F= 4.351, p= 0.026, df=2,21, R^2=0.293). The multiple regression model for snapping turtle nests showed that the type of adjacent body of water, distance to the nearest body of water, and soil moisture were significant in determining the number of nests across sites (F= 3.8, p= 0.026, df=3,20, R^2= 0.363).

Predicting Depredation of Individual Nests

Discriminant analysis (using backward elimination methods) was also used to determine the factors associated with nest depredation for both painted and snapper nests. The slope of the site, the aspect, soil moisture, and light intensity were all determined to be driving factors in predicting depredation of painted turtle nests (Figures 7 through 10). The models derived from these factors (Figure 7) predict depredation with an overall accuracy of 77% (51% for intact/unharmed nests; 87% for depreyed nests). Only soil type was considered a predicting factor in the model created to predict depredation of snapping turtle nests (Figure 11). The models derived from these factors (Figure 11) tested with an overall accuracy of only 63% (35% for intact/unharmed nests; 92% for depreyed nests). Total depredation reached 69.6%.

DISCUSSION

Models of Presence and Absence

The models derived from the discriminant analysis for the presence and absence of painted and snapping turtles is considerably accurate (85% for both). Distance from the water and light intensity were considered driving variables in both models, showing the importance these factors play in overall turtle nesting behavior. Sites closer to the water provide the security of close shelter in the event of danger as well as less time spent on land. Both turtle species are clearly not physically adapted for easy terrestrial movement, so lessening the amount of time spent on land would be a determining factor in whether a turtle nests in a potential site. Light cover is equally as important to nesting turtles because of the vital role it has in developing embryos. Both species are TSD species and need enough sunlight to ensure the survival of the nest.

The predictive model of snapping turtle presence also included soil type and aspect as driving factors in presence. Previous studies have not shown snappers to have a preference for a specific substrate. However, since all observations in this experiment took place along roads, substrate dispersion cannot be considered random and could be correlated to other physical factors. For example, grass was almost always located along the side of the roads, which made it closer to forests fringes and reduced the amount of light. Although aspect was not statistically significant for painted turtle nests, snapping turtles showed a preference for an aspect average of 162° (Figure 5), a southeastern orientation. Even though studies by Hughes and Brooks (2006), which predicted a preference for southwestern aspects, specifically studied painted turtles, because both species are TSD, it is understandable that snapping turtles would show preference for a similar aspect. Because both species of turtle have similar nesting needs, it is logical that they have similar driving factors. The fact that snapping turtles have additional driving factors (soil type and aspect) could be the result of unobserved differences in nesting behavioral patterns or physiology.

Models of Site Densities

The regression analysis used to predict nesting densities for both species of turtle depended on a larger range of driving variables. Slope was considered a significant factor in painted clustering. There were no previous studies found assessing slope as a determinant in painted or snapper nesting, so I only have speculation of its importance determined in this experiment. Slope facing a southern aspect will increase direct sun exposure during the summer months. Although aspect was not considered a determining factor, this concept of greater direct sunlight could be responsible for slope's importance in clustering. Soil moisture could also encourage nest clusters by providing ideal digging conditions (either soft or hard), or reflect distances to water or soil type (with wetter conditions closer to shorelines and on sandy or grassy substrates). Furthermore, slope could affect soil moisture by altering draining patters, causing it to be a factor in painted nest clustering.

Snapping turtle nest clustering was also influenced by moisture and showed a similar means to painted turtle for nest presence (mean $\text{moisture}_{\text{snapper}}$=0.14, mean $\text{moisture}_{\text{painted}}$=0.15). Once again distance to water was determined to be a driving factor for snapper nests, proving that there is significant importance in how far a turtle will travel for ideal nesting grounds. Finally, water type was a significant factor in determining snapper clustering. The significance is most likely the result of snapping turtle habitat preference. Because snapping turtles prefer some habitat variables over others, it is very likely that they prefer certain types of bodies of water. If this is the case, because most snapping turtles do not travel far from their home bodies of water to nest (mean distance to $water_{sanpper}$=23.6 m), there should be clusters surrounding preferred snapper habitats. Without taking physical characteristics of the body of water itself, including turbidity, pH, vegetation, and substrate characteristics, I cannot draw any further conclusions (Froese 1978). Such observations could be included in future studies.

Models of Depredation

The predictive models created by the discriminant analysis of depredation are less accurate than the predictive models of presence and absence (77% for painted and 63% for snappers. Models showed slope, aspect, moisture, and light intensity as determining factors in painted turtle depredation. Although visual cues are suspected to be predators' primary mode of detecting nests (Wilhoft et al. 1979), olfactory sensing could also be an effective mode of detection. Nesting turtles empty their cloacal bladder to soften the soil and aid in digging (Mahmoud 1968). The scent left by this action as well as the scent of the eggs themselves could cue predators to the presence of a nest (Bowen and Janzen 2005). Increased soil moisture (Figure 9) could likely aid in maintaining the scent of nests and allowing easier detection. Similarly, higher slope could aid in visual sighting because nests on a more vertical plane would be easier to spot from farther away at ground level. Finally, light is likely a result of less surrounding and overhanging vegetation. Nests with greater light exposure are most likely located in clearings without close vegetation to visually hide nests from predators, resulting in higher rates of predation for nests with higher light exposure (figure 10).

Only soil type was a significant factor in snapping turtle predation. Depreyed nests had an average soil grain size close to the size of gravel (mean=9.4, Figure 11).

Because most gravel nesting sites were located directly on roads, predation could be related to roads themselves. Although all nests sampled in this experiment were either located directly on roads or close to them, predators could follow roads and more readily detect nests lying on them.

Coinciding Physical Variables

For the predictive models of painted turtles, only light intensity was determined to be a significant driving factor in determining both presence and predation. High light exposure is necessary for embryo development and nest survival, but is also most likely the result of cleared vegetation, aiding in visual detection by predators. Because there is no way to avoid the necessity of light, there are most likely no adaptations possible to avoid this form of visual detection. Studies performed on genetically sex determined (GSD) species of turtles showed less concern for nest microhabitat and greater concern for predation (Spencer and Thompson 2003). Because the local species of turtles require this extra variable, they are limited in their potential nesting sites and therefore must continue to nest in cleared areas with high light exposure, despite the risks of nest depredation. Although other variables were statistically significant in depredation models, these variables were not considered driving variables in nest selection of painted turtles. Moisture and slope were both factors in the regression clustering models as well as depredation models. Although this experiment did not find distances to adjacent nests to factor into predation rates, previous studies have shown clustering to increase overall predation (Marchand and Litvaitis 2004), so it is likely that factors that induce clustering would also contribute to higher predation rates. Moisture most likely plays a significant role in olfactory detection by predators, however, slope and aspect have not shown to be significant factors in previous studies. Although slope could result in easier visual detection, its inclusion in the depredation model could also be the result of the lower overall accuracy of the models.

The only factor considered significant in snapper depredation model is also included in the snapper's model of presence. Mean soil grain size for snapper presence (mean=7.5) is closer to the mean of grain size for intact snapper nests ($\text{mean}_{\text{intact}}$=7.9, $\text{mean}_{\text{depreyed}}$=9.4, Figure 11). This could be an indication of snappers choosing to nest on soil types that reduce the amount of depredation, which would contradict a previous study by Robinson and Bider (1988) that showed no difference in depredation given soil substrate. No factors coincided among clustering models and depredation models. Because of the low level of overall accuracy for snapping turtle depredation, there could be other significant variables not included in the model.

Conclusion

Because of the importance of many of the physical variables involved in nesting, nest site location is in most circumstances nonnegotiable. Specific characteristics are required for nest and embryo fitness, so there are no choices but these locations, even if it may involve higher rates of depredation. Further studies concerning depredation should focus on a predator down approach rather than a nest up approach, as is the style of this and most other experiments syudying turtle nest depredation. These studies should address the nutritional value of eggs as well as other potential food sources in regards to Macarthur and Pianka's optimal foraging theory (1966) and their effects on predator densities (Hamilton 2002). Understanding the consequences of nest depredation and overall turtle health is also important in understanding the population dynamics of both species of turtles. Because turtles are long living vertebrates and their life tables can be easily altered, it is necessary to understand population decreases due to predation rates and nest failure (Gibbons 1968, Tinkle et al. 1981, Congdon et al. 1987). Further long term studies could correlate yearly depredation rates with species histograms. Furthermore, studies should include other physical variables that could decrease nest survivability or alter sex ratios, such as changes in drainage patterns, surrounding habitat, or climate (Kolbe and Janzen 2002). Special attention needs to focus on changes caused by human activity for a full assessment of the risks posed to painted and snapping turtle populations.

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Tables, Graphs, and Maps

Table 1: Physical variables measured or qualified during field observations and used in statistical analysis.

Measured Physical Variable	Unit of Measurement
GPS Coordinates	Universal Transverse Mercator (UTM)
Soil Type	Gravel (10), Sand (5), Grass (1)
Closest Body of Water Type	Lake, Creek/Stream, or Pond
Species of Nest	Snapping Turtle or Painted Turtle
Depredation	Yes or No
Distance to Nearest Patch of Wooded Area	Meters (m)
Distance to the Nearest Body of Water	Meters (m)
Distance to the Most Adjacent Nest	Meters (m)
Slope of Ground	Degrees Declination (°)
Aspect of the Slope	Directional Degrees (°)
Soil Moisture	Percent Relative Saturation
Light Intensity	µmol s^{-1} m^{-2} per µA

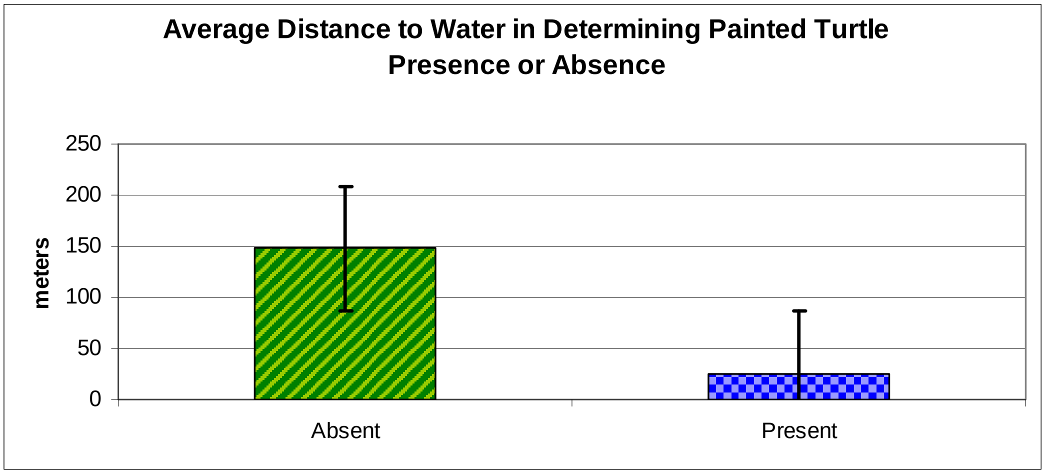

Figure 1: Averages of the distance to the nearest body of water in the presence and absence of painted turtle nests.
Present= -5.22 + 0.01(distance to water) + 0.005(light)
Absent= -4.67 + 0.029(distance to water) + 0.003(light)

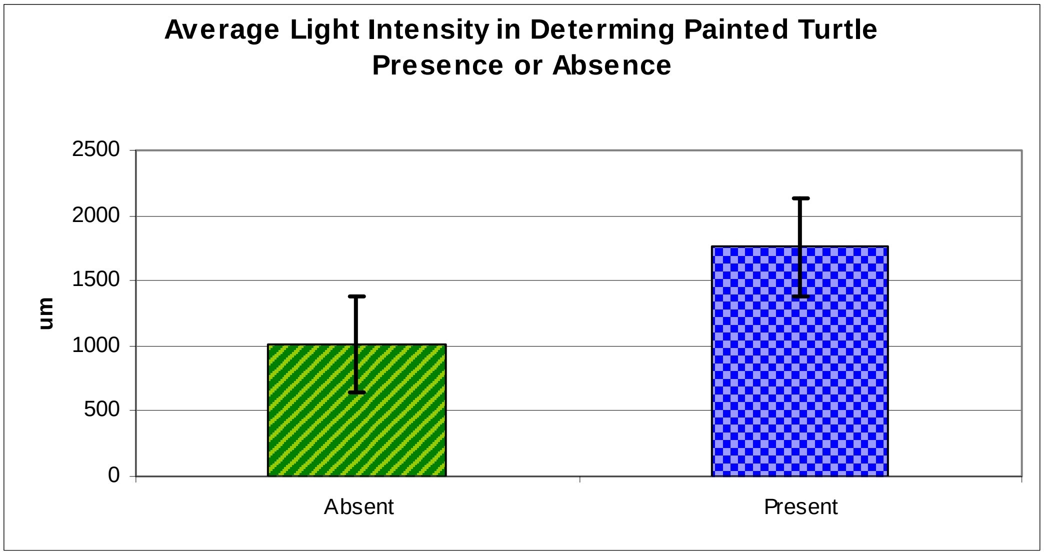

Figure 2: Averages of the intensity of light shining on the ground in the presence and absence of painted turtle nests.

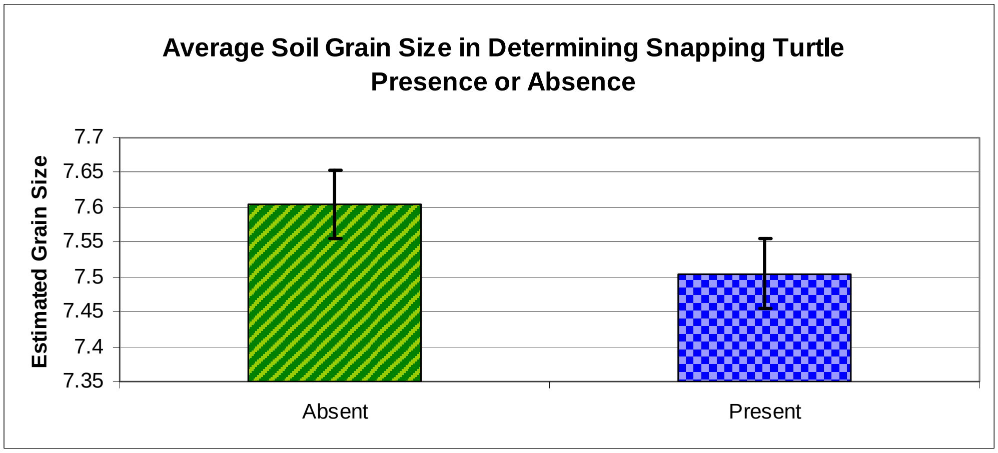

Figure 3: Averages of estimated grain size of soils in the presence and absence of snapper turtle nest.

Present = -12.15+ 1.046(soil size)+ 0.04(distance to water)+ 0.012(aspect) + 0.007(light)

Absent = -11.56 + 1.3(soil size) + 0.05(distance to water) + 0.002(aspect) + 0.051(light)

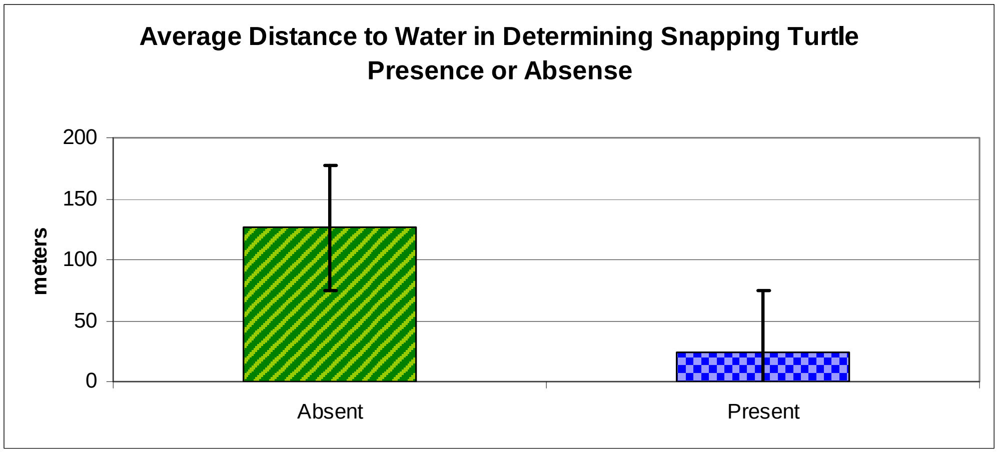

Figure 4: Averages of the distance to the nearest body of water in the presence and absence of snapper turtle nests.

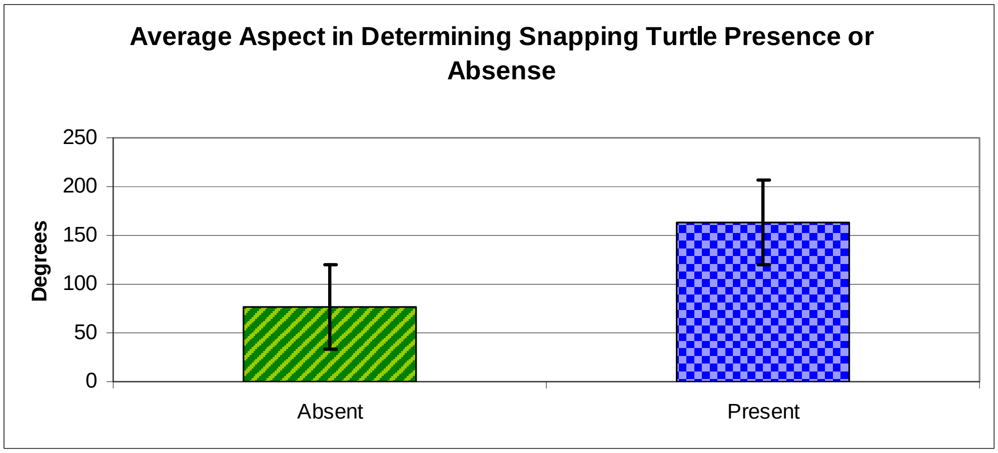

Figure 5: Averages of the aspect of the slope in the presence and absence of snapping turtle nests.

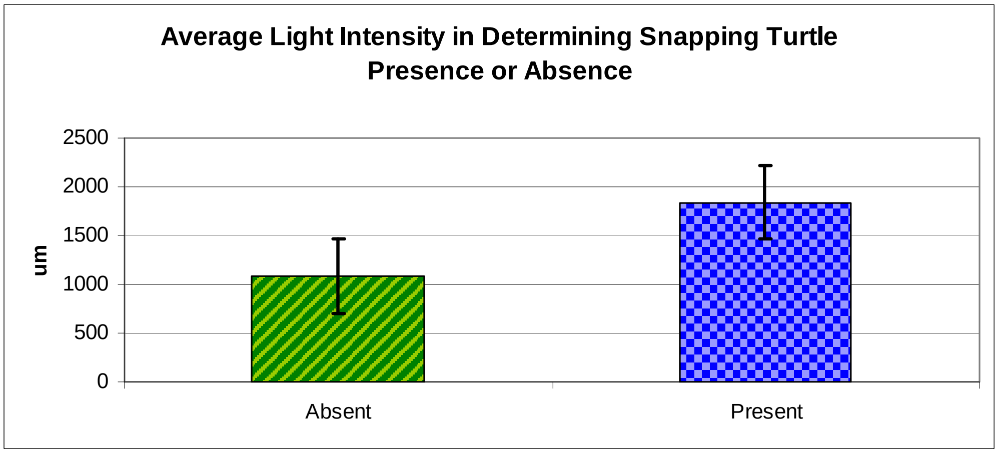

Figure 6: Averages of the intensity of light shining on the ground in the presence and absence of snapper turtle nests.

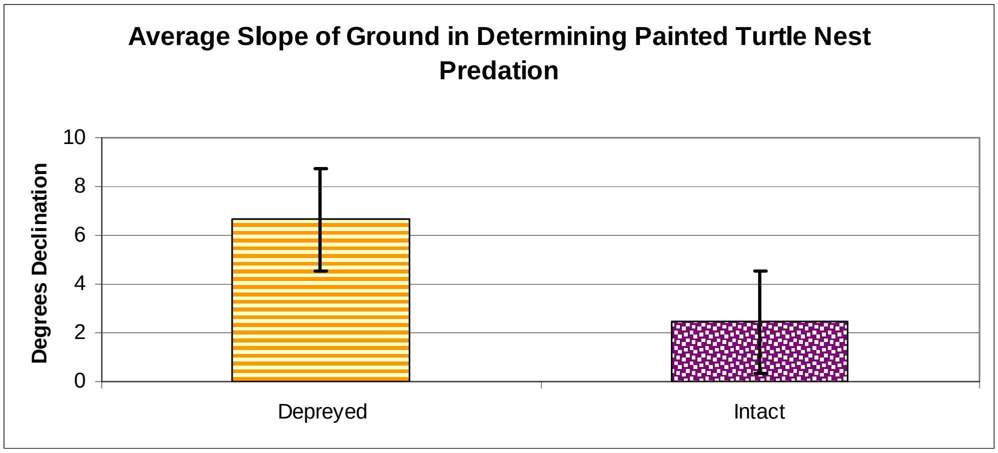

Figure 7: Averages of estimated slope of ground of depreyed and intact painted turtle nests.
Intact= -20.231 + 0.271(slope) + 0.011(aspect) + 26.208(moisture) +0.02(light)
Depreyed= -24.915 + 0.375(slope) + 0.017(aspect) + 34.034(moisture) +0.023(light)

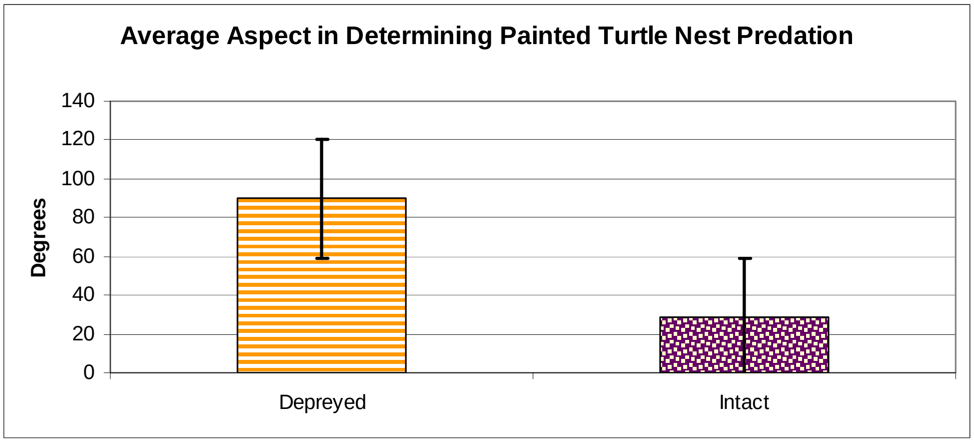

Figure 8: Averages of aspect of slope of depreyed and intact painted turtle nests.

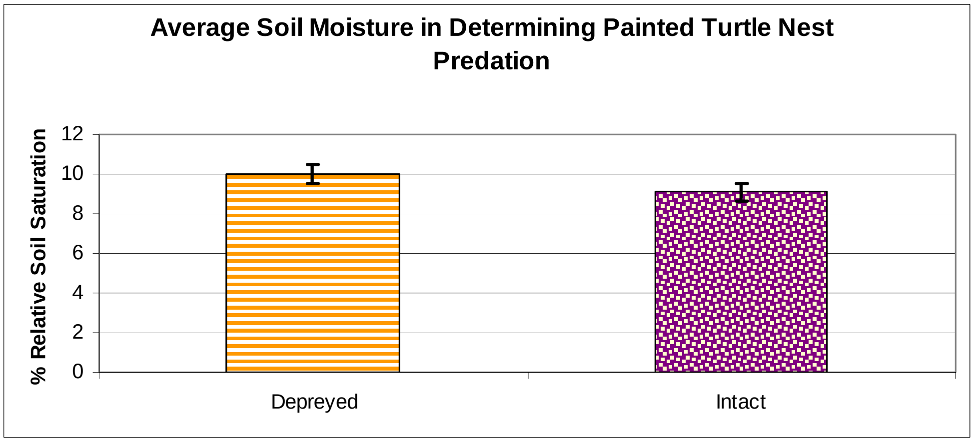

Figure 9: Averages of soil moisture of depreyed and intact painted turtle nests.

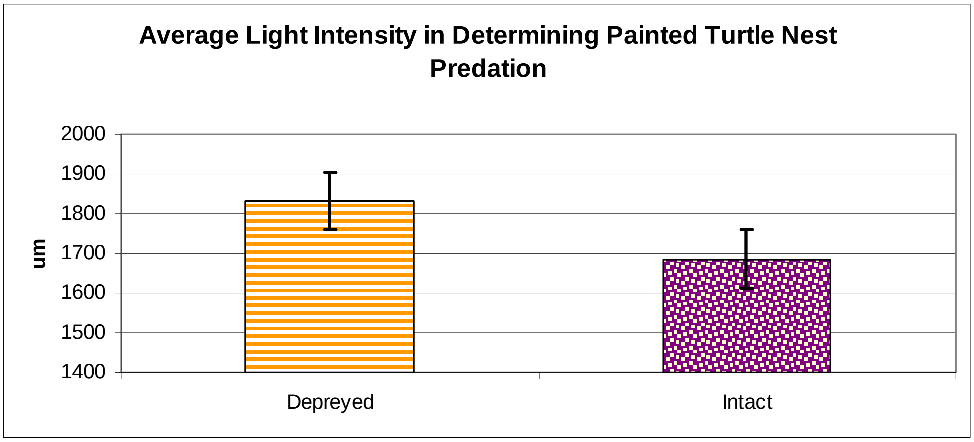

Figure 10: Averages of light intensity of depreyed and intact painted turtle nests.

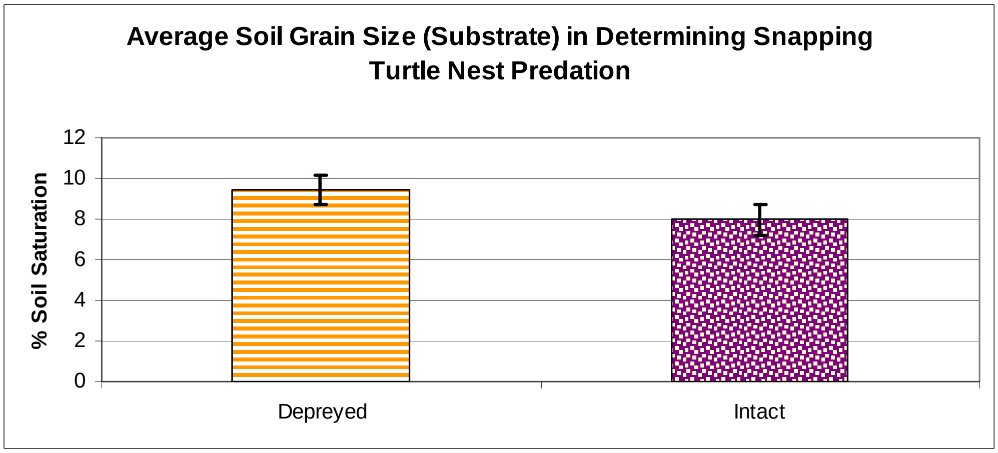

Figure 11: Averages of soil grain size of depreyed and intact snapping turtle nests.
Intact= -5.421 +1.193(soil moisture)
Depreyed = -7.387 + 1.414(soil moisture)

Map 1: The UNDERC property with locations and proportions of nest locations as well as control sites chosen for absence of nests.